WETLAND & STREAM RAPID ASSESSMENTS

Development, Validation, and Application

Edited by John Dorney, Rick Savage, Ralph W. Tiner and Paul Adamus

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Edited by

John Dorney
Moffatt and Nichol, Raleigh, NC, United States

Rick Savage
Carolina Wetlands Association, Raleigh, NC, United States

Ralph W. Tiner
Institute for Wetland & Environmental Education & Research, Leverett, MA, United States

Paul Adamus
Oregon State University, Corvallis, OR, United States

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Chapter 2.2.8

Virginia Wetland Condition Assessment Tool (WetCAT): A Model for Management

Kirk J. Havens*, Carl Hershner*, Tamia Rudnicky*, David Stanhope*, Dan Schatt*, Kory Angstadt*, Michelle Henicheck†, Dave Davis† and Donna M. Bilkovic*

**College of William and Mary, Virginia Institute of Marine Science, Gloucester Point, VA, United States, †Virginia Department of Environmental Quality, Richmond, VA, United States*

Chapter Outline

INTRODUCTION

The Clean Water Act requires that all U.S. waters be periodically assessed, and wetlands are included in this definition of waters. As described elsewhere in this book, a number of wetland assessment methods have been developed over the last two decades (Brinson, 1993; Karr and Chu, 1999; Lopez and Fennessy, 2002; Brooks et al., 2004; Wardrop et al., 2007; Rooney et al., 2012, and this book) requiring various levels of detail in data collection.

One approach assumes that beneficial wetland services do not all operate as a linked set. Instead, individual services (e.g., habitat ecosystem service or water quality ecosystem service) 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 service capacity impairment (SCI) model. Under the SCI model there are typically assessment metrics for each ecosystem 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.

SCI models can differ from other assessment models in several ways. Perhaps the most basic is the description/definition of optimal conditions. Under the SCI model, each wetland ecosystem service can have a set of physical, biological, or chemical conditions that improves the wetland's capacity to perform. For example, conditions that optimize habitat ecosystem services may not be identical to those that are important for water quality ecosystem services. Identification of the optimal set of conditions for each ecosystem 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 calibration and validation are important steps.

SCI models generate several assessments for each wetland. The assessments are specific to ecosystem service (Hemond and Benoit, 1988; Preston and Bedford, 1988). Integrating ecosystem 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 ecosystem service assessments inherently involves relative value. This is a management policy decision that cannot be ecologically based, and so should be very clear if undertaken.

The Virginia Institute of Marine Science, in collaboration with the Virginia Department of Environmental Quality, developed an SCI model—the Wetland Condition Assessment Tool (WetCAT)—that involves a three-part process. This provides for comprehensive wetland condition assessment analysis scalable from the individual wetland to the entire state. In WetCAT, the Level 2 and Level 3 sampling are intended to calibrate and validate the model that is applied to a Level 1 landscape assessment (Wardrop et al., 2013). The condition assessment of all mapped wetlands is conducted using remotely sensed landscape metrics. Surrounding landscape metrics are considered a reliable proxy for wetland condition; Rooney and others (2012)

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suggest that detailed land cover data improves the accuracy of wetland assessments. In this model the three levels of data collection are not designed to operate independently and the goal is to characterize the capacity of the wetland to provide water quality and habitat ecosystem services using remotely sensed data. The underlying models are based on existing research and specify the combination of landscape-level parameters that are most likely to be predictive of these capacities (Larson et al., 1980; Klopatek, 1988; Lee and Gosselink, 1988; Guadagnin and Maltchik, 2007; Rooney et al., 2012; Herlihy et al., in press). The model application produces a score relative to the unstressed capacity of each wetland for each ecosystem service. The scores are then refined and calibrated by site visits to randomly selected wetlands. The relationship between stressors, landscape metrics, and ecosystem services is validated by intensive study of ecological service endpoints.

We present an example of how this approach can be used to assess wetland condition in decision-making from individual wetlands to all units of landscape such as watersheds, local government boundaries, physiographic provinces, or various hydrologic unit codes. We use the results of the methodology to describe the condition, from a habitat and water quality ecosystem service perspective, for a subset of Coastal Plain and Piedmont wetlands of Virginia. This information is useful for status and trends reporting under the Clean Water Act Section 305(b) and can also be used in permitting programs to assess cumulative impacts to wetlands within watersheds and establish mitigation/compensation ratios.

METHODS

In order to develop the assessment model for habitat and water quality ecosystem services, two separate geographic information systems (GIS) analyses were conducted. First, the watershed around each wetland was generated using the U.S. Geological Survey (USGS) National Elevation Dataset (NED). The NWI of the U.S. Fish and Wildlife Service was used as the wetlands frame. A census was conducted of surrounding landscape metrics of all nontidal NWI wetlands ($n = 167{,}004$), which represented approximately 1,640,284 nontidal wetland acres. The NWI and the NED were imported into ESRI ArcGIS software version 9.3.1. Isolated sinks in the NED were assumed to be anomalies and filled. The new NED was used to generate a "flow direction" GRID raster; the flow direction GRID assigns numeric values to individual cells in the GRID raster based on the flow direction in that cell. Each NWI wetland was converted into a GRID format, and the hydrologic tools available in ArcGIS were used with the flow direction GRID to generate a watershed GRID around the wetland. The USGS TIGER/Line roads data and the National Land Cover Database (NLCD) created by the MultiResolution Land Characteristics Consortium (MRLC) were combined with the drainage watersheds created above and the NWI wetlands data. All raster data were converted to vector data and analyses were run in Workstation ArcInfo.

In the second part of the analysis, each wetland was buffered 200 m and combined with the NCLD land cover to determine relationships (Rooney et al., 2012). The NCLD land cover classifications were combined into four types for our analysis: natural, developed, pasture, and row crops (Table 2.2.8.1). Habitat and water quality ecosystem service determination was based upon the union of the drainage watershed and the 200 m buffer (Fig. 2.2.8.1).

Model calibration was conducted on randomly selected wetlands utilizing a suite of anthropogenic stressors. Stressors are considered a good indicator of wetland condition (Crosbie and Chow-Fraser, 1999; Adamus et al., 2001; Otte, 2001; Houlahan and Findlay, 2004; Schlesinger et al., 2008) and were selected after a review of extant

TABLE 2.2.8.1 Combined Landcover Types

Land Cover Type	
Wetland Forest Water Grassland Unconsolidated shoreline	Natural
Pasture	Pasture
Cropland	Cropland
Bare rock/sand, Transition Residential Urban Industrial	Developed

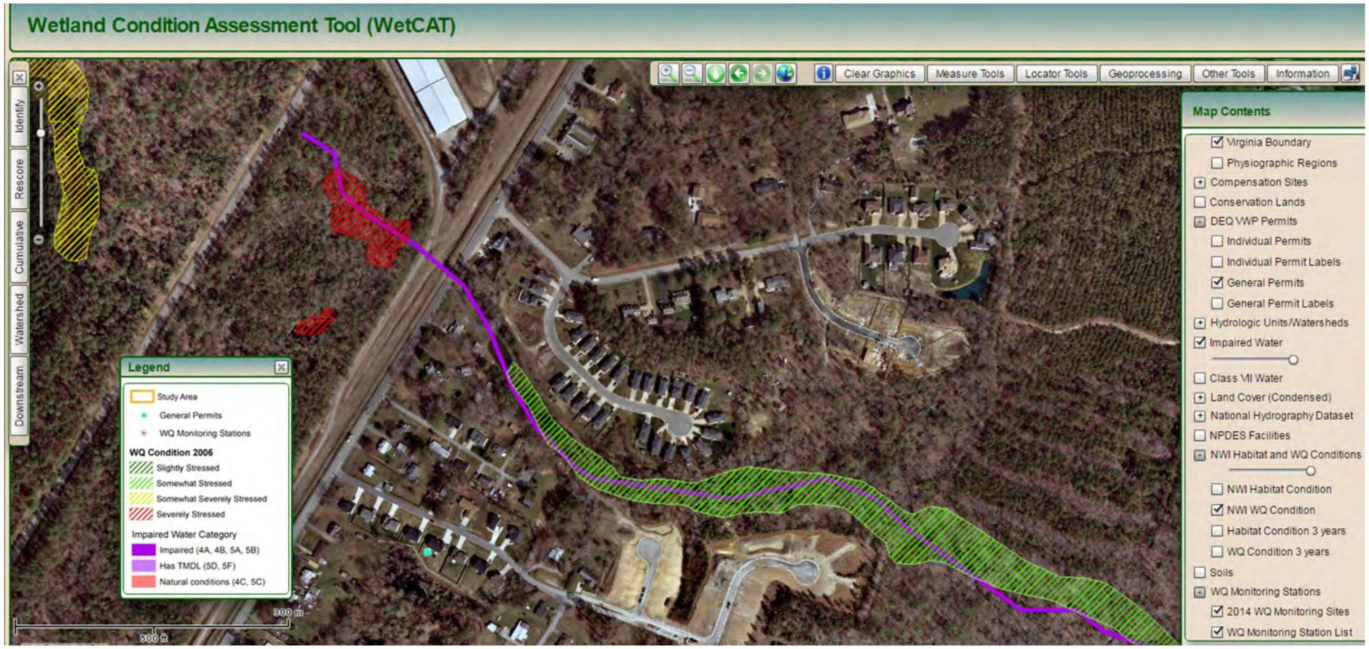

FIG. 2.2.8.1 Example of wetland water quality stress condition with impaired waters layer and permit layer.

TABLE 2.2.8.2 Onsite Stressor List From Literature Review

Stressor	Reference
Sediment deposits	Detenbeck et al. (1996), Ewing (1996), Wardrop and Brooks (1998), and Pontier et al. (2004)
Eroding banks	
Active construction	Harris (1988) and Panno et al. (1999)
Potential point source discharge	Comeleo et al. (1996) and Chague-Goff and Rosen (2001)
Potential nonpoint source discharge	Hemond and Benoit (1988) and Comeleo et al. (1996)
Active agriculture/plowing	Gerakis and Kalburtji (1998), Butet and Leroux (2001), Zedler (2003), and Kalisinska et al. (2004)
Unfenced livestock	Kassenga (1997), Gerakis and Kalburtji (1998), Xu et al. (2002), and Hongo and Masikini (2003)
Active timber harvesting	Childers and Gosselink (1990), Conner (1994), Johnston (1994), and Aust et al. (1997)
Active clear cutting	Walbridge and Lockaby (1994) and McLaughlin et al. (2000)
Drain/ditch	Vickers et al. (1985), Conner (1994), and Richardson (1994)
Filling/grading	Bedford (1999) and Ehrehfeld (2000)
Dredging/excavation	Zedler (2003)
Stormwater inputs/culverts/input ditches	O'Brien (1988), Reinelt et al. (1998), Thurston (1999), and Groffman et al. (2003)
4-Lane paved road, 2-lane paved road, 1-lane paved road, gravel road, dirt road, railroad, other roadways (parking lots)	Forman and Alexander (1998), Trombulak and Frissel (2000), Houlahan and Findlay (2003, 2004), Kalisinska et al. (2004), Pontier et al. (2004), Roe et al. (2006), Hamer and McDonnell (2008), and Rooney et al. (2012)
Utility easement maintenance	Woo (1979), Magnusson and Stewart (1987), Nickerson et al. (1989)
Herbicide application	Marrs et al. (1992), Brown et al. (2004), and Edginton et al. (2004)
Dike/weir/dam	Thibodeau (1985) and Kingsford (2000)
Beaver dam	Burns and McDonnell (1998) and Gurnell (1998)
Mowing	De Szalay et al. (1996) and Rothenbücher (2005)
Brush cutting	Anderson et al. (1977), Oliver (1980), Chadwick et al. (1986), and Hanowski et al. (1999)
Excessive herbivory	Kauffman and Krueger (1984)
Invasive species present	Pimentel et al. (2000), Sakai et al. (2001), and Zedler and Kercher (2004)

literature and their suitability for management alteration (Table 2.2.8.2). NWI wetlands were stratified by physiographic province (Coastal Plain, Piedmont, Valley and Ridge, Blue Ridge, and Appalachian Plateau), wetland type, forested (FO), scrub/shrub (SS), emergent (EM), and 12-digit hydrologic unit code (HUC). Sites were selected for sampling by Generalized Random Tessellation Stratified (GRTS) sampling design (Stevens and Olsen, 2004) ($n = 2126$). Additional sites were sampled in 2010, 2011, 2013, and 2014 for periodic calibration of land cover to stressor relationships ($n = 351$).

Randomly selected wetlands were assessed for stressors from the wetland center point to within a 30 m radius circle and between 30 and 100 m radius circle and were tabulated using a programmed hand-held computer downloaded to a Microsoft Access database upon returning from the field (Fig. 2.2.8.2). Validation of the relationship between stressors, surrounding

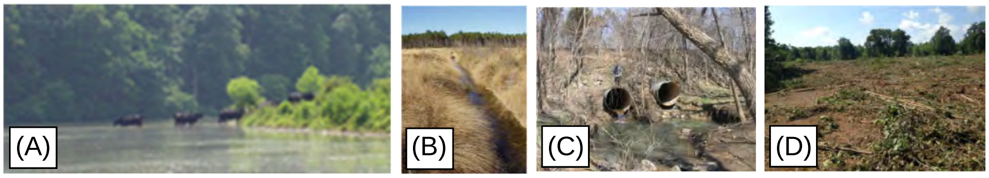

FIG. 2.2.8.2 Stressors impacting wetlands: (A) unfenced livestock access, (B) ditching, (C) culverts, and (D) brush cutting.

landscape metrics, and ecological service endpoints is a necessary step in any condition assessment model. Validation of stressor and surrounding landscape metric effects on habitat and water quality ecological services was conducted by randomly sampling 87 sites for intensive study of habitat and water quality ecosystem service.

Habitat ecosystem service was determined by assessing avian, amphibian, and plant community structure metrics. Avian community structure was determined by three rounds of stratified point count surveys. Surveys were conducted from 0.5 and 4.5 h after sunrise between late May and mid-July. Data collected at each point included site, date, start time, species of birds detected, distance from point center (within 50 and >50 m) of each detection, time period of detection (0–3, 3–5, 5–7, 7–10, and 10–15 min), and detection method (visual, aural, both) (Buskirk and McDonald, 1995; Hamel et al., 1996). Additional data collection included multiyear deployment of automatic recording devices during the summer breeding season for birds and in early spring for amphibians. Vocalizations of birds and amphibians were recorded for three consecutive days for 15 min at 6 a.m. and 15 min at 9 p.m., respectively. Amphibian community structure was also sampled by early and late spring 1 m sweeps of a D-ring dip net and the number per dip net sweep was used as a measure of relative abundance. Visual encounter surveys at night as well as day and night frog call surveys were also conducted. The avian and amphibian communities were determined by amphibian richness, priority wetland and neotropical migrant bird species abundance (Pashley et al., 2000), and the priority in flight index (Pashley et al., 2000; Mehlman et al., 2004).

Water quality ecosystem service was determined by potential disruption of water residence time in wetlands. In general, anaerobic conditions exist in hydric wetland soils, and this condition is necessary for denitrification processes to take place within these soils (Groffman et al., 2002). Much of the water quality improvement (at least with respect to nitrates) occurs in shallow groundwater within the rooting zone of the wetland vegetation and, generally, water quality improvement will be greatest when the water resides within this zone for longer periods of time (Mayo and Bigambo, 2005). Thus, assessing the capacity of a wetland to improve water quality depends on water table elevation and the residence time of the water in this zone. In addition, impervious surfaces can result in a large amount of water discharge, resulting in creek or stream incision, and alter wetland vegetation composition (Groffman et al., 2003). In our model we assumed that anthropogenic stressors that modify existing wetland hydrology are critical to the wetlands water quality service condition and those stressors that are associated with landscape metrics were targeted for analysis. We assessed water quality ecosystem service by analyzing total dissolved nitrogen (TDN), total dissolved phosphate (TDP), and total suspended solids (TSS) in water samples from wetlands where possible. Water samples were obtained from wetland systems monthly and after rain events. Samples were transported to the laboratory and analyzed using a SKALAR SANplus Continuous Flow Analyzer.

Additional habitat and water quality ecosystem service validation sampling included stream incision ratios and plant community composition. Stream incision ratios in headwater or riverine wetlands were calculated by sampling 1 m intervals along a 50 m stream segment and measuring bank full height and bank height (Rosgen, 2001). Wetland plant community composition was sampled by the Bitterlich plotless method (Basal Area Factor = 2) at three areas and by measuring tree species diameter at breast height (DBH). All woody stems >1 m tall and <5 cm DBH in three 1.9 m radius plots were recorded for each Bitterlich sample point. Wetland indicator status (IS) (Lichvar, 2012) was recorded for all species. To measure a potential shift in wetland plant community to “drier” plant communities over time due to stream incision, the incision ratio (stream bank height/bank full height) was compared with a tree and sapling wetland plant community wetland indicator status index (PCWIS). The PCWIS index was calculated as

$$\frac{\sum \#\text{sapling species} \times \text{indicator status}/\#\text{Saplings}}{\sum \#\text{tree species} \times \text{indicator status}/\#\text{Trees}}$$

where the obligate wetland species IS (Indicator Status) equals 1, facultative wetland species IS equals 2, facultative species IS equals 3, facultative upland species IS equals 4, and upland species IS equals 5. A PCWIS index below 1.0 indicates a shift toward more wet conditions while a PCWIS above 1.0 indicates a shift toward more dry conditions. The PCWIS index was compared with landscape metrics to determine associations.

Stressors were compared to the remotely sensed surrounding landscape metrics to determine the strength and direction of association using Pearson Product-Moment Correlation, where both the stressors and landscape metrics were considered ratio variables. Data were checked for normality using the Ryan-Joiner test and for nonnormal distributions, the Fisher's z' transformation or the Spearman Rank Order correlation was used (Minitab®, 2010). Avian and amphibian community sound signature similarities were examined with nonparametric multidimensional scaling (nMDS) and analysis of similarities (ANOSIM) in PRIMER 6.0 (Clarke and Warwick, 2001). MDS ordinates sites based on similarities in sound signature makeup, using rank order of distances to map out relationships. Sites with high similarity are placed close together on the MDS map. A Euclidean distance coefficient was used to calculate the similarity matrix. Factors were overlaid on the MDS plot to visualize community groupings in relation to land use and stress level. Subsequently, ANOSIM was used to test relationships among land use and stress level.

Classification and Regression Tree (CART) (JMP®, 2009) analysis was used to look for patterns between selected landscape metrics and ecosystem service endpoints and to weight landscape metrics. CART partitions were used to develop formula scoring thresholds and to cross-validate stressors with ecosystem endpoints.

RESULTS

Landscape metrics that showed a moderate to strong association ($r > 0.25$, $P < 0.05$) with stressors were selected for comparison to the ecosystem service endpoints of habitat and water quality. Some stressors showed weak or no association with surrounding landscape metrics and, because the model uses remotely sensed landscape metrics to determine condition score, those stressors were removed from consideration. Those stressors that showed a moderate to strong association with surrounding landscape metrics are listed in Table 2.2.8.3. Two stressors (sediment deposits and eroding banks) that did show a moderate to strong association with the surrounding landscape were removed after quality assurance checks revealed difficulty in distinguishing between anthropogenic activity and natural episodic events in the field.

Landscape metrics that showed moderate to strong association with stressors and with habitat and water quality ecosystem service endpoints are listed in Table 2.2.8.4. Stressor groups showed similar frequency across time within physiographic province (Fig. 2.2.8.3). Dominant stressors were vegetation alteration (brush cutting and mowing) and roads with a higher frequency of ditching and draining and filling in the Coastal Plain and higher frequency of unfenced livestock access in the Piedmont and Valley and Ridge, Blue Ridge, and Appalachian Plateau (Fig. 2.2.8.3).

CART partitions were used to develop wetland condition scoring thresholds (Table 2.2.8.5) and the scoring formulas. Dichotomous thresholds within individual landscape metrics were scored as 0.1 (most stressed) or 1.0 (least stressed) while multiple thresholds were standardized from 0.1 to 1.0 and scored linearly. Landscape metrics in the scoring formula were weighted by frequency of association with ecosystem service endpoints. For example the landscape metric "proximity to other wetlands" was associated with the two ecosystem service endpoints of amphibian richness and neotropical migrant bird species abundance and was weighted by a factor of two.

Overall wetland habitat and water quality condition stress levels were placed into four categories (slightly stressed, somewhat stressed, somewhat severely stressed, and severely stressed) determined by breaks in scoring distributions (Table 2.2.8.6). The use of distinct condition categories allowed the expression of wetland condition in terms of stress level, a concept useful for managers and the public (Van Sickle and Paulsen, 2008).

A subset of 128,422 NWI coastal plain and piedmont wetlands (920,084 acres) in Virginia was analyzed. Wetland condition scores for both habitat and water quality showed shifts over a 10-year period from 2001 to 2011. Overall wetland habitat considered severely and somewhat severely stressed increased from 24.2% in 2001 to 27.3% in 2011 with a concurrent decrease in wetlands considered somewhat stressed and slightly stressed from 75.8% in 2001 to 72.7% in 2011. Wetlands with water quality condition considered severely and somewhat severely stressed increased from 42.5% in 2001 to 43.5% in 2011 with a concurrent decrease in wetlands considered somewhat stressed and slightly stressed from 57.4% in 2001 to 56.6% in 2011 (Table 2.2.8.7). Condition scores averaged by 12-digit HUC are shown for three years (2001, 2006, and 2011) in Fig. 2.2.8.4.

TABLE 2.2.8.3 Stressors That Show a Moderate to Strong Association, $r > 0.25$ ($P < 0.05$) With Landscape Metrics

Landscape Metrics Stressors	Natural	Developed	Pasture	Row Crops	Road Density	Natural Drainage	Developed Drainage	Pasture Drainage	Row Crops Drainage	Road Density Drainage
Dam/dike/weir										+0.28 (0.01)
Timber harvest (1–5 year)	+0.37 (0.05)					+0.39 (0.05)				
Livestock access			+0.28 (0.01)	+0.66 (0.01)					+0.65 (0.01)	
Point source discharge	−0.62 (0.01)	+0.73 (0.01)				−0.51 (0.06)	+0.61 (0.01)			+0.48 (0.05)
Active agriculture/ plowing	−0.25 (0.06)		+0.79 (0.01)	+0.28 (0.01)		−0.46 (0.05)		+0.57 (0.01)		
Drain/ditch	−0.32 (0.01)	+0.34 (0.01)			+0.35 (0.01)		+0.25 (0.01)			+0.58 (0.01)
Filling/grading	−0.46 (0.05)	+0.79 (0.01)			+0.64 (0.01)	−0.37 (0.01)	+0.55 (0.01)			+0.40 (0.01)
Stormwater inputs, culvert and ditch inputs	−0.28 (0.01)	+0.30 (0.01)			+0.58 (0.01)					+0.55 (0.03)
Roads	−0.63 (0.01)	+0.64 (0.01)			+0.70 (0.01)	−0.53 (0.01)	+0.53 (0.01)			
Mowing	−0.67 (0.01)	+0.61 (0.01)	+0.37 (0.05)		+0.66 (0.01)	−0.62 (0.01)	+0.60 (0.01)	+0.64 (0.01)		+0.57 (0.01)
Brush cutting	−0.47 (0.01)		+0.38 (0.05)	+0.33 (0.01)		−0.60 (0.01)	+0.31 (0.01)	+0.72 (0.01)		+0.45 (0.01)
Invasive plant species		+0.35 (0.01)			+0.27 (0.01)					

Minus sign (−) equals a negative association and plus sign (+) equals a positive association.

TABLE 2.2.8.4 Ecosystem Service Endpoints Associated With Landscape Metrics

	Landscape Metrics Within 200 m									
Ecosystem Service Endpoints	**Natural**	**Developed**	**Pasture**	**Row Crops**	**Road Density**	**Natural Drainage**	**Developed Drainage**	**Row Crops Drainage**	**Size**	**Proximity to Other Wetlands**
Habitat										
Amphibian richness		X			X					X
Priority wetland bird species abundance			X			X	X		X	
Priority in flight index		X		X	X					
Neotropical migrant bird species abundance		X						X		X
Plant community wetland indicator status index		X								
Water quality										
Total dissolved nitrogen	X									
Total dissolved phosphate										
Total suspended sediment									X	
Plant community indicator status index		X								

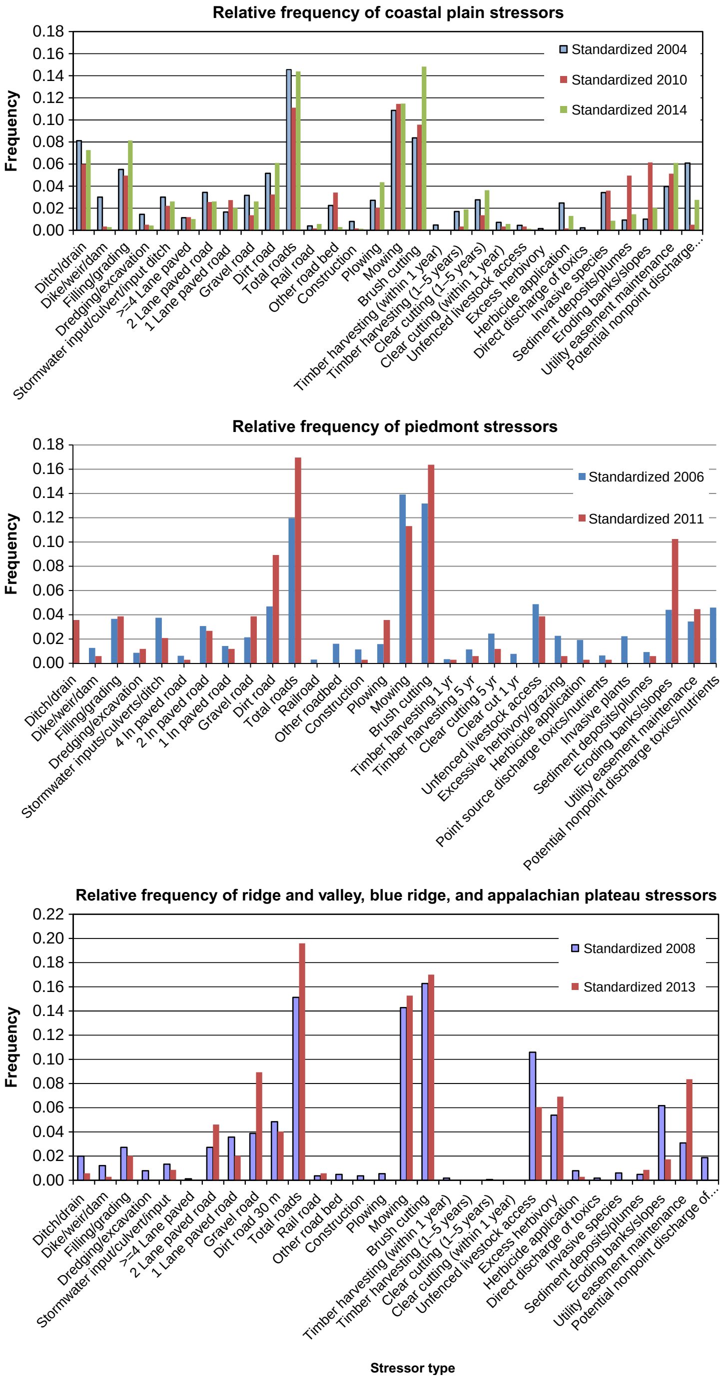

FIG. 2.2.8.3 Standardized frequency of stressors in Coastal Plain wetlands (2004, 2010, 2014; $n=1575$), Piedmont (2006, 2011; $n=662$), and Ridge and Valley, Blue Ridge, and Appalachian Plateau (2008, 2013; $n=240$).

TABLE 2.2.8.5 Scoring Thresholds for Landscape Metrics
Habitat
Within a 200 m buffer
Percent developed land (>1%, >9%, >21%)
Percent wetlands (<12%, <5%)
Percent pastureland (>2%)
Percent row crops (>5%)
Road density (>19, >31)
Size of the wetland (<5.4 acres)
Within a 200 m buffer in the contributing drainage

Continued

TABLE 2.2.8.5 Scoring Thresholds for Landscape Metrics—cont'd
Percent developed land (>1.4%)
Percent row crops (>3%)
Percent natural land (<72%)
Water quality
Within a 200 m buffer
Percent natural land (<71%)
Percent developed land (>1%)
Size of the wetland (<2.4 acres)

TABLE 2.2.8.6 Scoring Thresholds for Wetland Habitat and Water Quality Stress

Score	Stress Level
Habitat	
≥0.90	Slightly stressed
0.90< and ≥0.60	Somewhat stressed
0.60< and ≥0.30	Somewhat severely stressed
<0.30	Severely stressed
Water quality	
1.0	Slightly stressed
0.7	Somewhat stressed
0.4	Somewhat severely stressed
0.1	Severely stressed

TABLE 2.2.8.7 Wetland Habitat and Water Quality Condition Stress Level for the Coastal Plain/Piedmont Wetlands of Virginia for 2001, 2006, and 2011

	Water Quality 2001		Water Quality 2006		Water Quality 2011		
Condition Score	*n*	%	*n*	%	*n*	%	Stress Level
0.1	18,113	14.1	18,615	14.5	18,751	14.6	Severely stressed
0.4	36,478	28.4	36,750	28.6	37,055	28.9	Somewhat severely stressed
0.7	51,654	40.2	51,174	39.8	51,063	39.8	Somewhat stressed
1.0	22,147	17.2	21,883	17.0	21,553	16.8	Slightly stressed
Total	128,422	100	128,422	100.0	128,422	100	
	Habitat 2001		**Habitat 2006**		**Habitat 2011**		
Condition Score	***n***	**%**	***n***	**%**	***n***	**%**	**Stress Level**
0.1 < 0.30	5433	4.2	6684	5.2	6936	5.4	Severely stressed
0.30 < 0.60	25,679	20.0	28,169	21.9	28,104	21.9	Somewhat severely stressed
0.60 < 0.90	60,946	47.5	59,677	46.5	59,498	46.3	Somewhat stressed
0.90–1.00	36,364	28.3	33,892	26.4	33,884	26.4	Slightly stressed
Total	128,422	100	128,422	100.0	128,422	100	

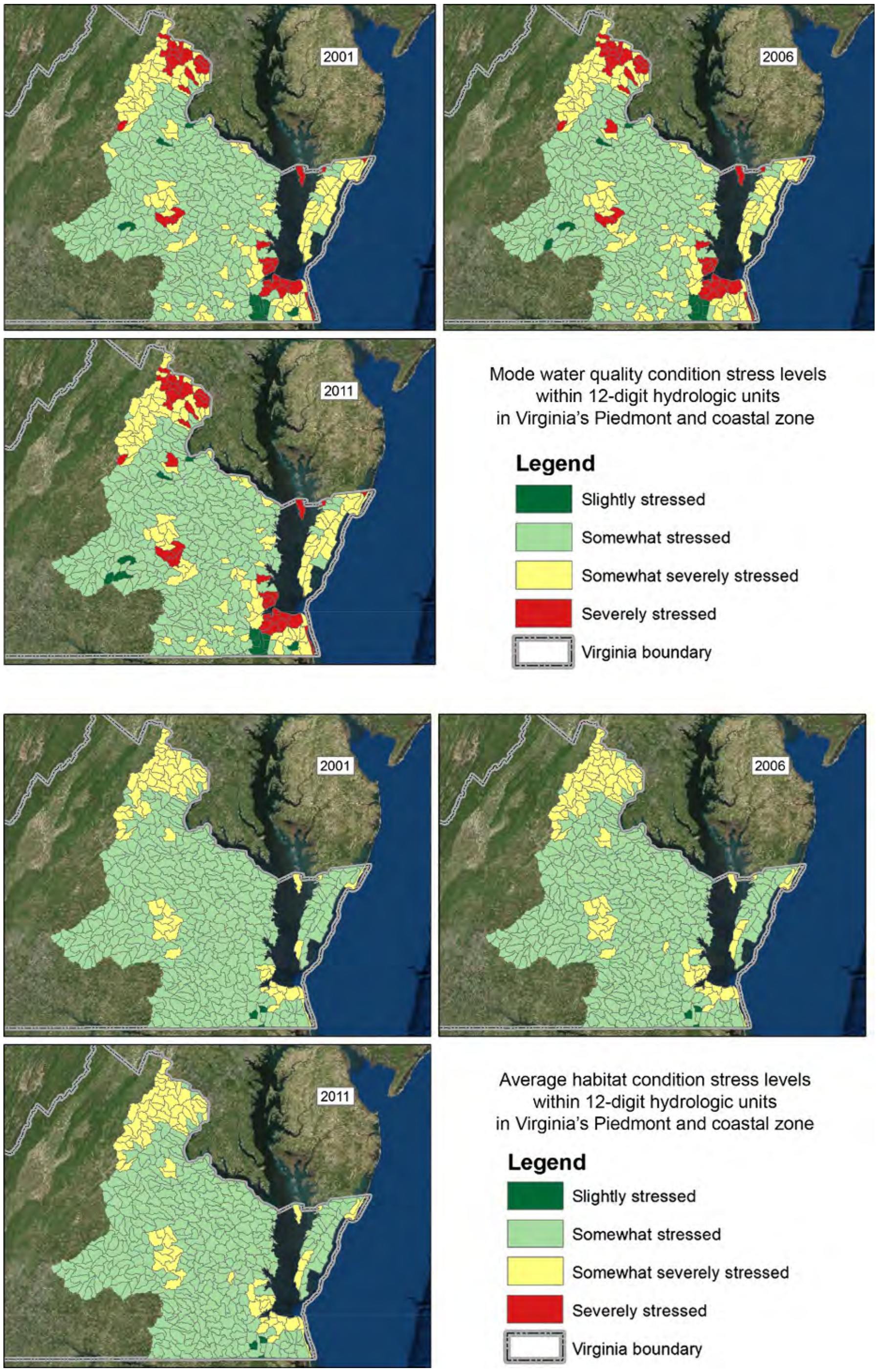

FIG. 2.2.8.4 Wetland condition scores by 12-digit HUC for habitat ecosystem service and water quality ecosystem service in the Coastal Plain/Piedmont wetlands of Virginia for the years 2001, 2006, 2011.

DISCUSSION

WetCAT uses a multiple services, multitiered, service capacity impairment approach to derive a wetland condition score that can be used to rate a wetland's capacity to perform habitat and water quality ecosystem services. This was developed specifically to inform management of nontidal wetland condition. Because the model is designed to work with remotely sensed information rather than direct field observations, it predicts the occurrence of relevant stressors in the areas surrounding a wetland. As such it focuses on factors that are or can be managed—namely the landscape stressors that affect a wetland's natural ecosystem service capacity. This assessment does not compare a wetland to some pristine optimum. Instead it seeks to assess the degree to which the wetland is functioning below its full natural capacity to provide ecosystem services, specifically for habitat and water quality services. The assessment does not seek to rate wetlands on the basis of the absolute rate at which those ecosystem services are provided. It assumes that wetlands are naturally very variable in the performance of services and the maximum potential level of performance also varies widely across seemingly similar wetlands. From this perspective, what matters most in the management of wetlands is avoidance or minimization of anthropogenic impacts that degrade a wetland's capacity to perform an ecosystem service, thus the scoring protocol rates wetlands based on the probability that conditions in the surrounding landscape will create stressors that reduce ecosystem service capacity.

We used landscape metrics from remotely sensed data coupled with ground calibration and ecosystem service endpoint validation to provide census-level condition assessment information for wetlands that can be scaled from individual wetlands to watersheds to physiographic region. Other studies have shown the utility of using GIS or remotely sensed land cover data to produce reliable condition assessments (Fairbairn and Dinsmore, 2001; King et al., 2005; Brazner et al., 2007; Rooney et al., 2012; Herlihy et al., in press). If remotely sensed data on land cover and landscape metrics can be obtained at regular intervals (e.g., every 5 years), status and trend analysis on wetland capacity to perform ecosystem services can be provided, over various scales, to managers, regulators, and other stakeholders.

WetCAT uses the NWI as the wetlands coverage and census frame. While the NWI has variable detection rates, particularly for isolated and small wetlands (Baldwin and de Maynadier, 2009; Leonard et al., 2012), it remains the only comprehensive digital wetland coverage for Virginia. It is recognized that the utility of the wetland condition assessment model is dependent on the resolution and accuracy of the remotely sensed data and the ability to acquire similar data in the future. The delineation of individual wetland drainage areas will be improved as more light detection and ranging (LIDAR) data become available to refine the digital elevation models. In addition, landscape metrics and stressor relationships may change over time as various landscape best-management practices are voluntarily implemented or required. Periodic recalibration of the landscape-stressor relationship is necessary to detect such a change if it occurs.

The time series coastal plain/piedmont assessment suggests that current management programs are probably far from achieving the no net loss of function goals set by both federal and state governments. For both water quality and habitat ecosystem services, the current management practices that focus on keeping disturbances out of wetland boundaries is probably insufficient to preserve functional capacity. The stressors affecting wetland ecosystem services are largely created in the surrounding landscape. This implies that a new focus on preserving or restoring buffers around wetlands may be a means for attaining the goal.

WetCAT provides the potential for targeting management efforts based on assessment results. These include the mitigation/compensation potential suggested by the buffer condition mentioned above or landscape setting (Bedford, 1996). Another issue is linking wetland condition and impaired water designations for stratified management efforts (more stringent protection in some areas than others) or perhaps, stratified compensation requirements for permitted impacts.

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