2008-2009 BIOLOGICAL MONITORING OF VERMONT'S WETLANDS: AN EVALUATION OF THE CHEMICAL, PHYSICAL, AND BIOLOGICAL CHARACTERISTICS OF VERMONT WETLANDS

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Introduction and Background

The purpose of this project is to build a pertinent and practical wetland bioassessment and monitoring program in order to assess wetland biological integrity and the ecological condition of Vermont's wetlands. The 2008-2009 program builds on the findings of the 2006-2007 wetland bioassessment program (VT DEC, 2008) and an EPA-funded pilot wetland bioassessment project involving vernal pools and northern white cedar swamps (VT DEC, 2003). When applicable, sampling was coordinated with on-going stream and lake bioassessment sampling, allowing the project to capitalize on the expertise of individuals currently engaged in similar monitoring projects, while branching into an area of assessment that has received little attention in Vermont.

The specific objectives of the project are to 1) conduct assessments of wetlands across a condition gradient; 2) record and gather chemical and physical data at each wetland site including water quality, hydrology, soils and landscape characteristics; 3) sample and describe the vegetation in assessed wetlands to develop vegetation-related metrics of wetland integrity; 4) sample the macroinvertebrate community in wetlands to enumerate and quantify the community, and develop metrics of wetland integrity; 5) complete rapid assessments and evaluate the ability of the methods to reflect the overall wetland condition, and 6) begin to expand the use of metrics in assessing the overall ecological health of Vermont's wetlands. All objectives are dependent on funding for the wetlands bioassessment and monitoring program. Due to of a lack of funding, macroinvertebrate samples were not collected during the 2008 or 2009 season. Over the long-term, it is expected that results from the wetlands bioassessment program may be used for: improved permitting and regulatory decisions; providing significant information for mitigation and restoration projects; and identifying the effects of environmental and anthropogenic stressors on wetlands over time.

Methods

Site Selection

A total of fifty-one wetlands were sampled in 2008 and 2009 by VTDEC Wetlands Bioassessment Program staff (Table 1). During these sampling seasons, efforts were made to localize sampling in the Southern Green Mountains, Northern Green Mountains and Southern Vermont Piedmont biophysical regions in order to fill gaps in the geographical sampling data. See Figure 1 for the distribution of sample locations throughout Vermont's biophysical regions.

Sites were selected in an effort to assess wetlands ranging in condition from reference (minimally disturbed) to highly disturbed based on landscape characteristics and historical data. Historical data was obtained from the Agency of Natural Resources' GIS database, orthophotos, and color infrared aerial photos. Sites were geographically analyzed to assess landscape characteristics such as watershed location, average buffer size, and intensity of surrounding land use. In most cases it was possible to identify the approximate wetland type (emergent marsh, scrub-shrub, or forested swamp) using aerial photographs. In addition to wetland type and perceived condition, factors influencing site selection included prior experiences with the wetland or watershed, site location and accessibility, land owner permission and sampling feasibility. Assessments included wetlands incurring a known change or impact in order to monitor the effects of the impact on wetland health and composition. Sites were also selected by considering the sampling histories of the VTDEC Lakes and Ponds Section and the Biomonitoring and Aquatic Studies Section (BASS) in order to build on the data previously collected by these programs.

Reference Sites Selection

Sites believed to be of a minimally disturbed condition were selected in order to create a baseline of disturbance level for all wetland sites. Reference sites were initially located within each biophysical region using color infrared aerial photos and orthophotos. Sites appearing to have a large, natural buffer surrounding the wetland were considered to be of reference condition. Any site meeting the low disturbance level expected from a reference condition site was then assessed for the factors listed in the site selection section. Attempts were made to ensure that at least one-third of the sites sampled were reference sites during each sampling season in order to develop a solid baseline of reference condition attributes.

Disturbed Sites Selection

Disturbed sites were selected to assess the response of wetlands to environmental and anthropogenic stressors including, but not limited to, encroachment, storm water run-off, point source pollution, filling, nutrient enrichment, hydrological modifications and farming as indicated from aerial and satellite photography. These sites were selected in an effort to encompass a range of disturbances from minimally disturbed to highly disturbed based on the amount and severity of the anthropogenic and environmental stressors. Site assessment areas also included wetlands undergoing restoration and were selected based upon the best professional judgment of the investigators.

Physical Habitat Measurements

Information about the physical environment in and surrounding each wetland site was recorded before, during, and after the site visit. At each site, wetland community size, maximum water depth, water source, water color and clarity, canopy cover, duration of inundation and saturation and modifications or alterations to hydrologic regime, substrate and habitat were recorded onto the wetland bioassessment field data sheet.

Surrounding land use, wetland connectivity, dam presence, horizontal interspersion and invasive species cover were also recorded. Latitude and longitude were determined using a Garmin hand-held GPS unit with an accuracy ranging from 3 to 20 meters based on canopy cover and satellite coverage.

Table 1. 2009 Wetland Bioassessment site locations, affiliated biophysical regions, and Cowardin wetland types.

Year	Site Name	Town	Region[1]	Wetland Type[2]
2009	Alder Branch Wetland	Granville	SGM	E/SS
2009	Barrows Brook Wetland	Stowe	NGM	F/SS
2009	Buel's Gore Wetland	Buel's Gore	NGM	E/UB
2009	Bettis Pond Wetland	Roxbury	NGM	E/SS
2009	Bingo Brook Wetland	Rochester	SGM	E/SS
2009	Burnt Meadow Brook Wetland	Peru	SGM	SS
2009	Cabot Annex Wetland	Waterbury	NGM	E/SS
2009	Elm Brook WMA Wetland	Fairfield	CV	SS
2009	Five Ponds Wetland	Braintree	NGM	F/SS
2009	Jay State Forest	Jay	NGM	E/SS
2009	John J Durand SF Wetland	Rockingham	SVP	E/SS
2009	Lamphear Road Wetland	Jamaica	SGM	E/SS
2009	Little Hollow Wetland	Rochester	NGM	E/ML
2009	Lowell Lake Wetland	Londonderry	SVP	E
2009	Lockwood Pond Wetland	Lowell	NGM	E/ML
2009	McAllister Pond Wetland	Lowell	NGM	E/SS
2009	Mollie Beattie SF Wetland	Grafton	SGM	E/F
2009	Mount Mansfield Beaver Wetland	Cambridge	NGM	E/SS
2009	Mount Tabor Wetland	Mount Tabor	SGM	E/ML
2009	Newport Town Forest Wetland	Newport Town	NGM	E/SS
2009	Newfane Town Forest	Newfane	SGM	SS
2009	Oak Lodge Wetland	Rochester	SGM	SS
2009	Pomainville	Pittsford	VV	E
2009	Potter Road Wetland	Wardsboro	SGM	E/SS
2009	Revoir Flat Wetland	Jay	NGM	E/SS
2009	Riley Bostwick WMA Wetland	Rochester	SGM	F/ML
2009	Roxbury SF Wetland	Roxbury	NGM	SS
2009	Tamarack Brook Wetland	Montgomery	NGM	F/SS
2009	Third Branch Wetland	Braintree	NGM	E
2009	Tunnel Brook Wetland	Hancock	SGM	SS
2009	West Hill Brook Wetland	Montgomery	NGM	E/ML

[1] VT Biophysical Regions: NVP = Northern Vermont Peidmont, SVP = Southern Vermont Piedmont, NGM = Northern Green Mountains, SGM = Southern Green Mountains, CV = Champlain Valley, VV = Vermont Valley, TM = Taconic Mountains.
[2] Cowardin Wetland types: AB = Aquatic Bed, E = Emergent Wetland, F = Forested Wetland, ML = Moss-lichen Wetland, SS = Scrub-shrub Wetland, UB = Unconsolidated Bottom.

Table 2 Continued. 2008 Wetland Bioassessment site locations, affiliated biophysical regions, and Cowardin wetland types.

2008	Barney Brook	Bennington	VV	E/SS
2008	Berlin Reservoir	Berlin	NVP	E/SS
2008	Branch Pond	Sunderland	SGM	E/ML
2008	Brattleboro Retreat Meadows	Brattleboro	SVP	SS
2008	Coles Pond	Walden	NVP	E/SS
2008	Curtis Pond	Calais	NVP	E/SS
2008	Kent Pond	Killington	SGM	E/SS
2008	Knapp Brook	Cavendish	SGM	E/SS
2008	Lye Brook Wilderness	Sunderland	SGM	E/ML
2008	Mill Pond	Windsor	SVP	SS
2008	Mud Pond	Newbury	NVP	E/SS
2008	North Springfield Meadow	Weathersfield	SVP	SS
2008	Old Marsh Pond	Fair Haven	TM	E/SS
2008	Schofield Fen	Hyde Park	NGM	E/ML
2008	Seymour Cedar Swamp	Morgan	NVP	F
2008	South Stream	Bennington	VV	E/SS
2008	Thetford Marsh	Thetford	SVP	E
2008	North Shore Wetland	South Burlington	CV	E
2008	Woodford Site I	Woodford	SGM	E
2008	Woodford Site II	Woodford	SGM	F

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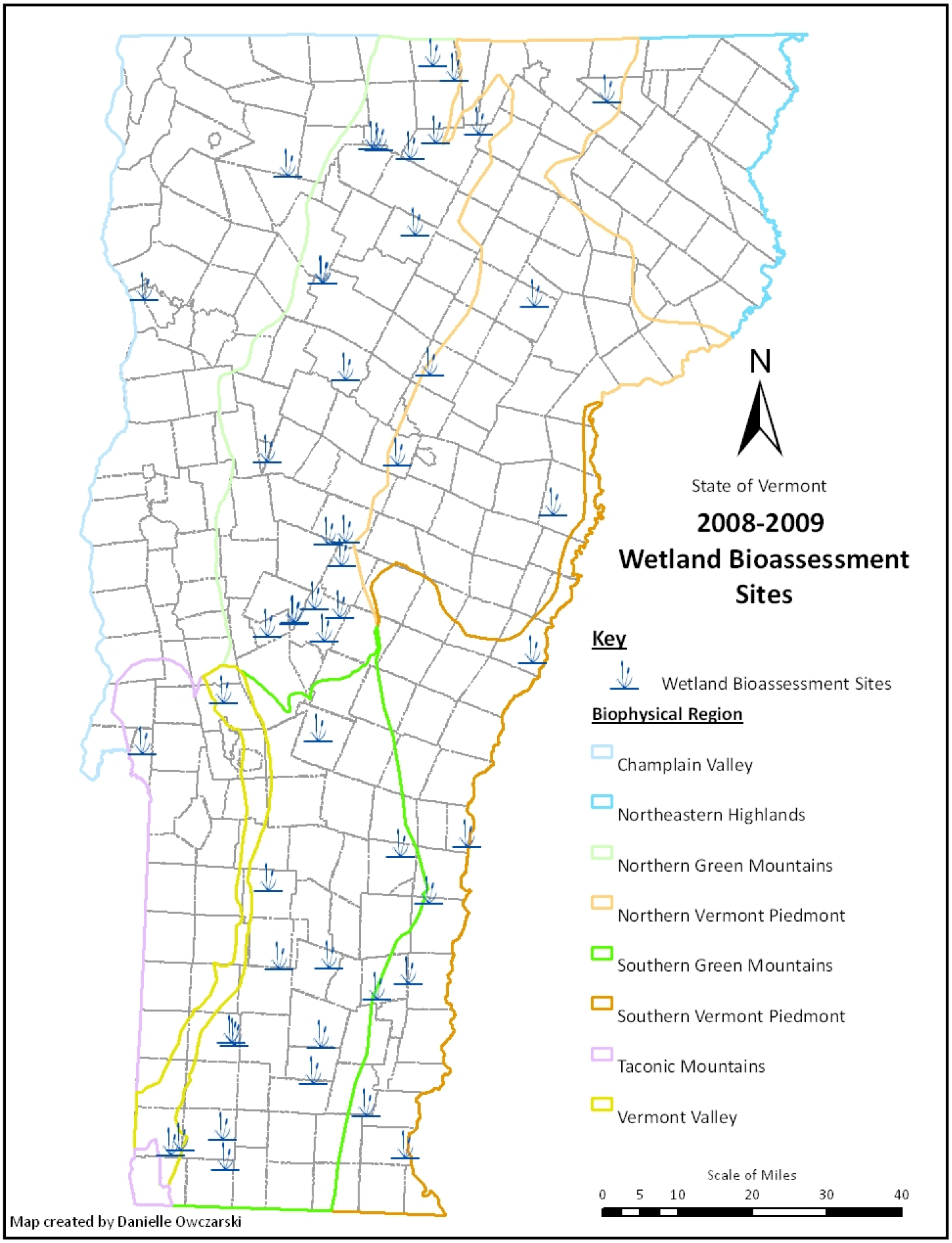
Figure **1.** Vermont wetland bioassessment sites for the 2008-2009 sampling season.



Water temperature, field pH, dissolved oxygen, field conductivity, and chlorophyll *a* were measured at most wetland sites using the Hydrolab™ Surveyor 4 and Minisonde 4 unit (Hach Environmental, Loveland, CO).

Water Chemistry Sampling and Analytical Procedures

Water samples were collected at all sites assessed in 2008 and 2009. Samples were collected following the protocol outlined in the Vermont Wetlands Bioassessment Program Quality Assurance Project Plan (VTDEC: 1999, 2003, 2005 and 2009) and (VTDEC 2007b). Water samples were collected using a grab technique and each sample was taken within 5 meters of the wetland transect within one meter of the water body and wetland vegetation border. Sample location was noted on the wetland bioassessment field sheet using a Global Positioning System (GPS) receiver.

In accordance with the VTDEC Wetlands Bioassessment Program QAPP (VTDEC 2009), field duplicate samples were collected at 10% of wetland sites. These samples were used to measure sampling precision by calculating the relative percent difference between the two samples from the wetland site.

Samples were kept at a moderate temperature in an ice chest until returned to the VTDEC R.A. LaRosa Laboratory, where they were logged into the Laboratory Information Management System (LIMS) and refrigerated until analysis. Water chemistry parameters analyzed during the 2008 and 2009 seasons are presented in Table 2. Dissolved phosphorus and chloride were filtered in the field, nitrogen samples (total persulfate nitrogen and nitrate + nitrite - water) were preserved using sulfuric acid (H_2SO_4), and metals samples were preserved using nitric acid (HNO_3) immediately upon returning to the laboratory as stated in the VTDEC laboratory protocol (VTDEC 2007a).

Conductivity, pH, dissolved oxygen, chlorophyll *a*, and water temperature were assessed in situ using a Hydrolab™ Surveyor 4 and Minisonde 4 unit (Hach Environmental, Loveland, CO). The Hydrolab™ Minisonde 4 was calibrated using vendor-certified calibration standards within 24 hours prior to its use. During the 2008 field season, due to the lack of availability of the Hydrolab equipment, water and air temperature, and pH were measured at ten sites with the Hanna HI 9026 probe. All water sampling sites corresponded with vegetation sampling sites.

Table 3**.** Water chemistry sampling parameters. Parameters are analyzed exclusively in the laboratory unless otherwise noted.

pH (field)
Dissolved Oxygen (field)
Alkalinity
Conductivity (field and lab)
Cl^-, SO_4^{2-}, NO_3, TN, TP^-, DP^-
Ca, Mg, Na, K, Hardness
Al, Fe, Mn
Color
TSS, Turbidity
Water temperature (ºC) (field)
Chlorophyll *a* (field: 2009 sites only)

Biological Sampling

Vegetation was assessed between June and September at a total of fifty-one wetlands during the 2008 and 2009 field seasons.

Vegetation

Quantitative Sampling

Vascular vegetation was sampled at each site using a transect-quadrat method. At each location a transect was laid out from the edge of a water body (stream or pond) to the upland edge of the wetland. When sampling shoreline linear patch communities with a short width (40m or less), multiple transects were set perpendicular to the shoreline. Each quadrat location within the transect was recorded using a Garmin hand-held GPS unit. Ten to twenty 1 m^2 square quadrats were placed along the transect spanning from one end of the transect to the other. Quadrats were placed along the transect approximately every 5 meters in a 50 meter or less in length wetland, 10 meters in a 60 to 100 meter in length wetland, and 15 meters in a 150 meter or more in length wetland, maximizing the number of vascular plants sampled. The location of each quadrat with respect to the entire wetland, the transect, and the corresponding quadrats was recorded on the field sheet for each assessment site. Each quadrat was numbered sequentially to mark the location of the quadrat and to accurately inventory where each plant species was located.

Every vascular plant species within the quadrat was identified to species level, where possible, and recorded on the field data sheet along with the species' percent cover within the quadrat. Non-vascular vegetation within the quadrat was identified to the lowest taxonomic level possible and its presence was noted on the field data sheet. The following general keys aided plant identification: Newcomb (1977); Petrides (1988); Ballard et al. (2004); Magee and Ahles (1999); and Gleason and Cronquist (1991). In quadrats with multiple herbaceous layers the total percentage of vegetation may have exceeded one hundred percent.

Plants which could not be identified in the field were recorded onto the field sheet and placed into a one-gallon re-sealable plastic bag. The site ID, quadrat and specimen number (ex. BUME01-01-002) of each sample was recorded onto the bag and field sheet. The plant samples were kept cool until they were returned to the laboratory, where they were refrigerated until they could be identified. Samples were identified to the highest level possible within 24 hours of sampling. Following identification, the scientific name of each sample was recorded on the field data sheet and correlated with the plant's unique identification number. The unique identification number consists of the site ID, specimen number and year collected (ex. BUME01-002-2009). High quality representative plant species samples were checked for ID, pressed, mounted, labeled and transferred to the wetland herbarium located in the VTDEC R.A. LaRosa Laboratory.

Vegetation sampling occurred once at each site between June and September in the 2008-2009 sampling seasons. A second biologist verified the identity of wetland plants at 10% of the sampling sites in order to check the accuracy of field identification. Sampling precision was confirmed by assessing vegetation along a second transect placed parallel to the original transect at 10% of sites. All vascular vegetation was identified to species level and quantified along the second transect as it was in the original transect. Vegetation type, cover, and species collected from both transects were compared and combined for sampling accuracy.

Qualitative Sampling

Vegetation was qualitatively assessed concurrently with the quantitative assessment. After all vascular plants within each quadrat had been identified, the plants surrounding the quadrat were assessed. Both biologists spent approximately three minutes observing the surrounding vegetation. The presence of any species which was within three meters of the quadrat border was noted in the field sheet. On the field sheet, the qualitative species in the three meter surrounding area was correlated with the adjacent quadrat in order to illustrate its approximate location. All plants were identified to the species level if possible. Additionally, any plant species observed along a transect which was not observed: a) within any quadrat; or b) surrounding a quadrat during the qualitative assessment; was noted on the field data sheet.

Additional Site Information

Human Disturbances

Human Disturbance Ranking (HDR)

Two different methods were utilized to characterize human disturbance in and surrounding each wetland site. The HDR method was adopted from the Vermont Wetlands Bioassessment Program's vernal pool and northern white cedar swamps project (VTDEC 2003). Two of the categories used in this method, current condition and landscape quality, were originally developed by the network of State Heritage Programs and The Nature Conservancy. The HDR method ranks human disturbance in and adjacent to each wetland by assessing disturbance severity, community condition, and landscape condition (Table 3). These variables were assessed during the level one assessment and biological sampling. Sites received a maximum of 3.0 points for disturbance severity, 3.0 points for current condition, and 4.0 points for landscape quality, for an overall maximum sum of 10.0 points (Table 3). The summation of the three scores produced a total quality score for each wetland indicating the level of human disturbance at each site. The lowest possible score, 2.0, was associated with pristine or high-quality reference sites. The disturbance severity category was assessed from a combination of factors influencing the site, including but not limited the presence or absence of hydrologic alterations, logging, agriculture, and development.

Table 4**.** Disturbance ranking parameters for physical site assessment. Each site received a score for current condition of the community, landscape quality, and disturbance severity. These factors were combined to produce an overall physical assessment site score.

Current Condition of Community: 1 = Great, no signs of anthropogenic disturbance, no exotics, etc. 2 = Moderate, some signs of anthropogenic disturbance, exotics, etc. 3 = Poor, obvious signs of anthropogenic disturbance, lots of exotics, etc.
Landscape Quality: 1 = Surrounded by >1000 acres of intact matrix of natural communities 2 = Surrounded by forest or undisturbed communities but there may be developed land or clearcutting nearby 3 = Surrounded by fragmented forest, agricultural land or rural development 4 = Surrounding area intensely developed
Disturbance Severity: **0 =** no disturbances **1 =** minimal disturbance **2 =** moderate disturbance **3 =** significant disturbance

Vermont Rapid Assessment Method (VRAM)

In an effort to better characterize the vegetation communities and anthropogenic stressors surrounding the assessment sites, each wetland was scored using the Vermont Rapid Assessment Method. The Vermont Wetlands Bioassessment Program adopted the VRAM v 1.0 parameters from the Ohio Rapid Assessment Method v 5.0 for Wetlands (Mack, 2001). The Vermont Wetlands Bioassessment Program incorporated this assessment method in an effort to improve upon the disturbance assessment criteria adopted from the Vermont Wetlands Bioassessment Program's vernal pool and northern white cedar swamps project. The VRAM combined scores from six metrics assessing: (1) wetland area (size), (2) upland buffers and surrounding land use, (3) hydrology within the wetland, (4) wetland habitat alteration, (5) special wetlands, and (6) plant communities, interspersion, and microtopography. Metric one scores ranged from 0-6; metric two, 1-14; metric three, 5-30; metric four, 3-20; metric five, 0-10; and metric six, -4-20. The maximum score was 100.

Each wetland was given a score ranging between 0 and 100 based upon the VRAM metrics. A high score designates a site with little or no disruption; scores decrease with increased levels of human disturbances and lack of vegetation community diversity.

To calculate the VRAM score, wetlands were assessed both in the field and at the desktop using digital black and white orthophotos, Vermont Significant Wetland Inventory (VSWI) maps, and color infrared aerial photos. VRAM scores were calculated after the site assessment and took into consideration the location of the sampling site in the wetland. Metrics 1 and 2, wetland area and buffer size, were measured by using Vermont Agency of Natural Resource's (ANR) GIS orthophotos and infrared aerial photos. Wetland area was measured according to the overall wetland size in relation to the plant transect location. Metrics 3 and 4, hydrology and habitat alteration, were measured by using ANR GIS maps and historical data, and in the field. Metric 5, special wetlands, was scored based on vegetation data indicating the natural community type as specified by Wetland, Woodland, Wildlands: A Guide to the Natural Communities of Vermont (Thompson and Sorenson, 2000), and also by using the VT state/federal threatened or endangered species GIS layers. Metric 6, plant communities, interspersion, and microtopography, was distinguished in the field after a thorough observation of plant species and community layout. Specific stressors affecting natural hydrology and habitat, such as ditching and mowing, were also recorded on the VRAM field sheet. The final VRAM score was compared to the site's physical, biological, and chemical data in order to measure accuracy and track correlations between the parameters.

Data Analysis Methods

Precision and Accuracy

Precision and accuracy were analyzed in a method identical to that employed by the Vermont Wetlands Bioassessment Program's vernal pool and northern white cedar swamps evaluation (VTDEC 2003). The analysis methods described in the 2003 report are reiterated here. Results from replicate field samples (water chemistry and vegetation) were compared to estimate sampling precision. Percent standard error (PSE) or relative percent difference (RPD) was used to describe precision. Analytical precision and accuracy for water chemistry was estimated by calculating RPD of duplicate analyses and percent recovery/percent bias of spiked samples.

Biological Data

Vegetative results were compared against the resultant human stressor scores (VRAM and HDR) from each site to begin to identify any potential causal relationship between wetland stressors and biological response. Comparisons were made between human disturbance scores from each wetland site and vegetative species richness, percent non-native taxa, percent sedges, and percent grasses.

Water Chemistry Data

Maximum, minimum and average water chemistry results were calculated from the combined data of the fifty wetland sites sampled. Aluminum, alkalinity, sulfate, iron, nitrate+nitrite-water, and total suspended solids had results that were measurable to a minimum level. The minimum level was interpreted as the final result when running the mathematical and statistical analysis. The HDR score was used to compare the water quality results of high and low disturbance wetlands. Sites with a score of 3 or lower were compared to sites with a score of 7 or higher. Sigma Stat© 3.1 software was used to run the statistical tests. Water chemistry results from Lye Brook Wilderness were not used due to improper collection techniques.

Site Reports

Fifty-one individual site reports for 2008-2009 are provided in Appendix A and B. The site report includes the physical setting, surrounding landscape condition, vegetation, and physical and chemical characteristics of each wetland site. A map illustrating the assessment location and surrounding landscape is also included with each report.

Results

Physical and Chemical

Water Chemistry

Water chemistry results varied widely between wetland sites and disturbance levels. Results presented in Table 4 show the maximum, minimum, and average value for each chemistry parameter sampled in 2008-2009. Berlin Reservoir, Cabot Annex Wetland and Woodford Site I are the most common outliers in the table. Sites of excellent condition were more common in the minimum result group, while sites of poor condition were more common in the maximum result group.

The Berlin Reservoir wetland site is located adjacent to the 286 acre Berlin Reservoir. A Class 3 town road separates the reservoir and the assessment site and an interstate and state highway run parallel 0.4 kilometers to the east. The reservoir is the drinking water supply for 2300 residents and 250 businesses in Montpelier. The site received a moderate disturbance rating and is partially bordered by residential and agricultural land. It is also contiguous with a large white cedar swamp and a large patch (0.18 ha) of reed canary grass (*Phalaris arundinacea*). The Berlin Reservoir site had the lowest level of aluminum (less than 10 ug/L) and the highest levels of calcium (46 mg/L), total calculated hardness (TCH) (136 mg/L), total phosphorus (292 µg/L) and alkalinity (136 mg $CaCO^3$/L). The high calcium, TCH and alkalinity levels are a direct reflection of the underlying porous limestone of the Waits River rock formation. The wetland also had elevated levels of conductivity (398.0 µmhos/cm), chloride (41.2 mg/L), sodium (27.6 mg/L) and filtered phosphorus (54.3 µg P/L) compared to minimally disturbed sites. The conductivity, chloride and sodium levels may be a result of run-off from the interstate and state highway. In 2005, the Berlin Pond Watershed Conservation Project Report stated that 21 percent of the watershed land is publicly owned and the 79 percent that is privately owned is primarily undeveloped. A Source Protection Plan and Water Conservation Study and Plan were developed in 2001 and 2002 in order to protect the municipal drinking water supply.

Cabot Annex Wetland is located 20 meters west of Route 100, which is a heavily traveled state highway. The wetland parallels the highway and is also adjacent to a substation owned by Green Mountain Power. The culvert that is supposed to deliver water to the wetland from the north has been compacted and filled under the driveway to the substation. The water sample was collected in the wetland from a pool of clear water that bubbled out from the crushed stone of the driveway. The site had the highest levels of chloride (102 mg/L), conductivity (528 µmhos/cm), turbidity (48.6 NTU), and chlorophyll *a* (13.41 µg/L). The high levels may stem from a combination of factors from highway run-off to inadequate flow. This site also had the lowest levels of TCH (0.17), dissolved oxygen (9.8 mg/L) and percent dissolved oxygen (29.2 %).

Woodford Site I is a minimally disturbed site and is located in the Green Mountain National Forest (GMNF). This site serves as a catch basin for Reservoir Brook after it leaves Stamford Pond, flows through a number of newly built beaver wetlands, and crosses a maintained Forest Service road. This site had five times the amount of iron as the second ranked iron result at 24.6 mg/L. There is no evidence as to why the iron levels are high. Woodford Site I also had the lowest levels of sulfate (less than 0.5 mg/L) and the highest levels of aluminum (1.14 mg/L), nitrogen (2.27 mg N/L), apparent color (500 HU) and total suspended solids (120 mg/L). The water sample was taken from a slow moving stream that meanders through an emergent marsh and sedge meadow. The highly tannic water reflects the breakdown of organic matter throughout the site and the hydrologically connected wetlands.

Table 5. Water chemistry results for 2008-2009 wetland sites.

Parameter	*Maximum*	*Site Name*	*Minimum*	*Site Name*	*Average*	*n=1*
Alkalinity (mg $CaCO_3$/l)	136	Berlin Reservoir	-1.25	Branch Pond Wetland	30.62	n=50
Aluminum (ug/L)	1140	Woodford Site I	< 10	Berlin Reservoir	89.13	n=43
Chloride (mg/L)	102	Cabot Annex Wetland	0.21	Old Marsh Pond	12.36	n=48
Conductivity (µmhos/cm)	528	Cabot Annex Wetland	16	Lamphear Road Wetland	108.44	n=50
Sulfate (mg/L)	14.5	Barrows Brook Wetland	0.5	Woodford Site I; Potter Road Wetland	3.15	n=50
Sodium (mg/L)	48.2	Third Branch Wetland	0.16	Little Hollow Wetland	6.71	n=47
Magnesium (mg/L)	11.9	Barney Brook Wetland	0.18	Branch Pond Wetland	1.76	n=47
Potassium (mg/L)	1.86	Kent Pond Wetland	0.05	Roxbury SF Wetland	0.58	n=47
Calcium (mg/L)	46	Berlin Reservoir	0.59	Branch Pond Wetland	10.75	n=47
Total Calculated Hardness (mg/L)	136	Berlin Reservoir	0.17	Cabot Annex Wetland; Bingo Brook Wetland; Lockwood Pond Wetland	31.85	n=50
Iron (ug/L)	24600	Woodford Site I	50	Seymour White Cedar Swamp	1220.73	n=47
Manganese (ug/L)	1115	Five Ponds Wetland	5	Elm Brook Wetland	175.76	n=47
Nitrate + Nitrite - Water (mg-N/L)	0.25	Elm Brook Wetland	< 0.05	33 Sites	0.07	n=50
Nitrogen, Total - Persulfate (mg-N/L)	2.27	Woodford Site I	0.1	Newfane Town Forest; Alder Branch Wetland	0.39	n=50
Phosphorus (ug P/L)	292	Berlin Reservoir	5.65	Mt. Mansfield Beaver Wetland	34.74	n=50
Filtered Phosphorus (ug P/L)	63	North Springfield Meadow	5	Mt. Mansfield Beaver Wetland	16.41	n=50
Solids, Total Suspended (mg/L)	120	Woodford Site I	< 1	9 Sites	8.37	n=50
Turbidity (NTU)	48.6	Cabot Annex Wetland	0.49	Barrows Brook Wetland	3.15	n=50
Temp (°C)	24.02	Oak Lodge Wetland	11.77	Mollie Beattie SF Wetland	18.13	n=31
SpCond (µs/m)[2]	497.1	Cabot Annex Wetland	12.5	Lamphear Road Wetland	81.33	n=31

Parameter	*Maximum*	*Site Name*	*Minimum*	*Site Name*	*Average*	*n=1*
pH	7.61	Coles Pond Wetland	4.7	Mount Tabor Wetland	6.52	n=46
Chlorophyll *a*[2]	13.41	Cabot Annex Wetland	0.83	Bingo Brook Wetland	4.09	n=19
DO (%)[2]	100	Oak Lodge Wetland	29.2	Cabot Annex Wetland	71.73	n=31
DO (mg/L)[2]	9.8	Pomainville Wetland	2.41	Cabot Annex Wetland	6.51	n=31
Color (HU)	500	Woodford Site I	7.5	Newfane Town Forest	79.72	n=47

[1] Lye Brook Wilderness water quality results were not included because the water sample was taken improperly.
[2] The results of these parameters include only the 2009 sites.

Branch Pond and Mount Tabor wetlands had the lowest levels of alkalinity (-1.25 $CaCO_3$/L and 0.93 $CaCO_3$/L), calcium (0.59 mg/L and 1.38 mg/L), and pH (4.81 and 4.7) respectively. Branch pond also had the lowest level of magnesium (0.18 mg/L). Both sites are located at high elevations in the Southern Green Mountains within an acid impaired watershed. Both sites have a very low disturbance ranking despite the affects of the acid deposition.

Statistical tests were performed comparing water quality results of minimally disturbed and highly disturbed sites using Sigma Stat© 3.1 (Table 5). The HDR score was used to define the rate of disturbance for the two groups. Two tests were used to analyze the data: the t-test for groups with a normal distribution and the Mann-Whitney Rank Sum test for the groups that failed the t-test. Eleven out of twenty-five parameters showed statistically significant results. The eleven parameters (highlighted yellow in Table 5 to indicate statistical significance) were alkalinity, calcium, chloride, lab and field conductivity, magnesium, pH, potassium, sodium, sulfate and TCH. All statistically significant water quality parameters exhibited higher results in disturbed sites and lower results in minimally disturbed sites. The distinction of low pH levels at minimally disturbed sites indicates there may be a connection linking high elevation sites, acid deposition, and disturbance severity, since the majority of minimally disturbed sites and acid deposition occurs at higher elevations.

Additional water chemistry data collected over time will result in more robust statistical data. As a result, water quality criteria could be utilized to indicate the disturbance severity in a wetland site. In combination with physical and biological attributes, water chemistry can provide a valuable measure of the overall condition of a site. Deteriorated water quality indicates the presence of environmental stressors, including point or non-point pollution, and the overall environmental stress load of the wetland.

Table 6. T-test (t) and Mann-Whitney rank sum test (M-W) results for water chemistry parameters comparing minimally disturbed and highly disturbed sites. Means are presented for the t-tests and medians for the Mann-Whitney rank sum tests. Yellow indicates parameters with a statistically significant P value of ≤0.009.

Parameter	Mean or Median		P-Value	Test Used
	Reference Sites[1]	Disturbed Sites[2]		
Alkalinity (mg CaCO3/L)	9.05	38.05	0.002	M-W
Aluminum (ug/L)	51.5	26	0.034	M-W
Calcium (mg/L)	3.66	11.275	0.002	M-W
Chloride (mg/L)	2	13.8	0.001	M-W
Chlorophyll *a*	4.22	4.39	0.938	t
Color, Total Visual (Pt-Co)	60	25	0.045	M-W
Lab Conductivity (umhos/cm)	27.35	202	0.001	M-W
Field Conductivity (µs/m)	23.6	158.7	0.001	M-W
Dissolved Oxygen (%)	66.48	77.37	0.305	t
Dissolved Oxygen (mg/L)	5.973	7.135	0.256	t
Iron (ug/L)	625	589.25	0.469	M-W
Magnesium (mg/L)	0.53	1.555	0.001	M-W
Manganese (ug/L)	66	95.2	0.861	M-W
Nitrate+Nitrite-Water (mg-N/L)	0.05	0.05	0.239	M-W
Nitrogen (mg-N/l)	0.365	0.305	0.416	M-W
pH - Alkalinity	5.913	6.841	0.003	t
Total Phosphorus (ug P/L)	15.7	15.97	0.984	M-W
Dissolved Phosphorus (ug P/L)	10.11	10.75	0.463	M-W
Potassium (mg/L)	0.14	0.835	0.001	M-W
Sodium (mg/L)	0.42	6.735	0.001	M-W
Sulfate (mg/L)	1.62	3.45	0.006	M-W
Temperature (°C)	18.014	18.249	0.887	t
TSS (mg/L)	1.25	2.07	0.211	M-W
TCH (mg/L)	10.59	31.1	0.002	M-W
Turbidity (NTU)	1.49	1.63	0.843	M-W

[1] Minimally disturbed sites are defined as sites that achieved an HDR score of 3 or less.
[2] Highly disturbed sites are defined as sites that received an HDR score of 7 or more.

Human Disturbances

Four of the sites assessed in 2008-2009 received the lowest possible (highest quality) Human Disturbance Rank (HDR) score, while no sites received the highest HDR score (lowest quality). During the 2008-2009 sampling season, the lowest score any site received was 2 and the highest score received by any site was 9 (Table 6). Sites receiving a score less than 3 were considered to be in reference condition; those receiving scores ranging from 3.5 to 6.5 were considered to be in moderate condition; and sites receiving scores of 7.0 or greater were considered to be in poor condition. Based upon this standard, a total of 15 sites in 2008-2009 were deemed to be in reference condition and 17 sites were identified as being in poor condition.

The six sites with the highest HDR score indicating a level of high disturbance were Mill Pond, Third Branch Wetland, Barrows Brook Wetland, Brattleboro Retreat Meadows, North Springfield Meadow, and Pomainville.

Mill Pond and Brattleboro Retreat Meadows (BRM) are located in southern Vermont along the Connecticut River. Although the area is home to many threatened and endangered species, it is also an area of urban congestion. The HDR score accurately reflects the disturbed condition of both sites. Mill Pond is primarily disturbed by sedimentation from riverbank deposits being carried downstream by Mill Brook into the southern end of Mill Pond. The soil profiles taken in the wetland were dominated by coarse sand and gravel at more than one meter in depth indicating that the wetland substrate was formed by the sedimentation. A medium sized patch of the noxious plant *Phragmites australis* had established itself atop the gravel/sand substrate in the wetland. The public has introduced the prospect of dredging the water body in order to reduce the impact of the sediment load. The pond has also suffered from multiple Eurasian milfoil outbreaks, which are being controlled by a local volunteer. All disturbance factors were covered in the HDR categories.

BRM is also impacted by sedimentation and is an island populated by plant species tolerant of anthropogenic disturbance. The island's vegetation is significantly different than the vegetation that borders the lake and is isolated from the rest of the surrounding wetlands. The majority of the surrounding wetlands are largely broad-leaved cattail and deep bulrush marshes. The surrounding area along the border of the wetlands comprises agricultural land and urban development. The water body was formed by damming the junction of the West and Connecticut River, and continues to change as more sediment is deposited and water channels change course.

Third Branch Wetland and Barrows Brook Wetland are both impacted by encroachment and road surface run-off and litter. The vegetation at Third Branch Wetland does not coincide with the HDR results, however the surrounding vegetation shows disturbance and has been negatively affected by the narrow buffer and anthropogenic disturbance. The vegetation within and surrounding Barrows Brook Wetland reflects the high disturbance and narrow buffers.

Table 7. Human Disturbance Ranking (HDR) results using methods adopted from the 1999-2000 Vermont Vernal Pools and White Cedar Swamps Program methods. *Italics* denote sites scoring 3 or lower (low disturbance); boldface denotes sites scoring 7 or greater (high disturbance). All other sites are considered of moderate condition.

Site ID	Primary Disturbance[1]	Disturbance Severity[2]	Landscape Quality[3]	Current Condition[4]	Rank[5]
Mill Pond	**Sedimentation**	**3**	**3**	**3**	**9**
Third Branch Wetland	**Highway**	**2.5**	**3.5**	**2.5**	**8.5**
Barrows Brook Wetland	**Agriculture**	**2.5**	**3**	**2.5**	**8**
Brattleboro Retreat Meadows	**Agriculture**	**3**	**2**	**3**	**8**
North Springfield Meadow	**Agriculture**	**2**	**3**	**3**	**8**
Pomainville	**Agriculture**	**2**	**3**	**3**	**8**
Barney Brook	**Agriculture**	**2.5**	**2.5**	**2.5**	**7.5**
Newfane Town Forest Wetland	**Invasive Plant**	**2**	**2.5**	**3**	**7.5**
Revoir Flat Wetland	**Agriculture**	**2**	**3**	**2.5**	**7.5**
Buel's Gore Wetland	**Sedimentation**	**2**	**2.5**	**2.5**	**7**
Berlin Reservoir	**Agriculture**	**2**	**3**	**2**	**7**
Burnt Meadows Brook	**Channelization**	**2**	**3**	**2**	**7**
Cabot Annex Wetland	**Highway**	**2**	**3**	**2**	**7**
Five Ponds Wetland	**Agriculture**	**2**	**3**	**2**	**7**
Kent Pond	**Residential**	**2**	**3**	**2**	**7**
Oak Lodge Wetland	**Residential**	**2**	**3**	**2**	**7**
Seymour White Cedar Swamp	**Agriculture**	**2**	**3**	**2**	**7**
Elm Brook WMA Wetland	Agriculture	1	3	2	6
Mud Pond	Residential	1	3	2	6
North Shore Wetland	Residential	1	3	2	6
Old Marsh Pond	Invasive Plant	1	3	2	6
South Stream	Residential	1	3	2	6
Thetford Marsh	Agriculture	1	3	2	6
McAllister Pond Wetland	Residential	1	3	1.5	5.5
Curtis Pond Wetland	Residential	1	2	2	5
Jay State Forest Wetland	Utility (Power line)	1	2	2	5
Knapp Brook	Historical Use	1	2	2	5
Bingo Brook Wetland	Historical Use	1	1.5	2	4.5
Lowell Lake Wetland	Rural Development	1	2	1.5	4.5
Alder Branch Wetland	Historical Use	0	2	2	4
John J Durand SF Wetland	Forest Management	1	2	1	4
Mollie Beattie SF Wetland	Forest Management	1	2	1	4
Potter Road Wetland	Rural Development	1	2	1	4
Riley Bostwick WMA Wetland	Forest Management	1	2	1	4
Woodford Site II	Highway	1	2	1	4
Newport Town Wetland	Rural Development	1	1.5	1	3.5

Site ID	Primary Disturbance[1]	Disturbance Severity[2]	Landscape Quality[3]	Current Condition[4]	Rank[5]
Bettis Pond Wetland	*Beaver Dam Failure*	*0*	*2*	*1*	*3*
Coles Pond	*Residential*	*1*	*1*	*1*	*3*
Lamphear Road Wetland	*None*	*0*	*2*	*1*	*3*
Little Hollow Wetland	*Historical Use*	*0*	*2*	*1*	*3*
Mt Mansfield Beaver Wetland	*Sedimentation*	*0*	*2*	*1*	*3*
Mt Tabor Wetland	*Acid Rain*	*0*	*2*	*1*	*3*
Roxbury SF Wetland	*Beaver Dam Failure*	*0*	*2*	*1*	*3*
Schofield Wetland	*Historical Use*	*1*	*1*	*1*	*3*
Tamarack Brook Wetland	*Forest Management*	*0*	*2*	*1*	*3*
Tunnel Brook Wetland	*Historical Use*	*0*	*2*	*1*	*3*
West Hill Brook Wetland	*ATV Use*	*0*	*2*	*1*	*3*
Branch Pond	*Acid Deposition*	*0*	*1*	*1*	*2*
Lockwood Pond Wetland	*None*	*0*	*1*	*1*	*2*
Lye Brook Wilderness	*Acid Deposition*	*0*	*1*	*1*	*2*
Woodford Site I	*None*	*0*	*1*	*1*	*2*

1 The degree of, but not the presence of, the primary disturbance is relative to the site's overall condition.
2 Disturbance severity out of a range of 0 to 3 points.
3 Landscape quality out of a range of 1 to 4 points.
4 Current condition out of a range of 1 to 3 points.
5 Ranking is the sum of each site's disturbance severity, current condition, and landscape quality scores.
*Higher numbers indicate a higher level of human disturbance.

North Springfield Meadow and Pomainville are impacted by mowing and show a poor current condition and landscape quality as a result of agricultural practices. Pomainville is a wildlife restoration area and is being managed by the State of Vermont. North Springfield Meadow is located upstream from the North Springfield Reservoir and is not currently being used for agriculture. Small shrubs are beginning to grow back and wetland plants have established themselves in the inundated areas of the meadow. These wetlands are in a state of recovery.

The four sites with the lowest HDR score, indicating a very low level of disturbance, are Woodford Site I, Lye Brook Wilderness, Lockwood Pond Wetland, and Branch Pond Wetland. The HDR score accurately reflects the high quality vegetation found at each site and lack of anthropogenic disturbance with the exception of acid deposition.

The main weakness of the HDR is its lack of specificity. The HDR does not separate the main indicators (hydrology, habitat, vegetation, e.g.) of biological integrity, nor does the HDR score the sites based on a particular stressor or the level of recovery. This inadequacy leaves the site evaluators without proof as to why a site may be disturbed, what aspect might be the cause of the disturbance or if the site is in the process of recovery. Also, a quantitative description or measure of the individual levels in each metric will build a stronger and more useful data set. In comparison, the simplicity of the method and its ability to accurately reflect the site condition based on few factors is beneficial given an abbreviated site visit.

In contrast, the Vermont Rapid Assessment Method (VRAM) systematically scores each metric leaving behind a more detailed story about the disturbance level of each site. When the method was adopted from the Ohio Rapid Assessment Method (ORAM) for wetlands, very few changes were made to the criterion prior to implementing it to address the biological integrity of Vermont's wetlands. The changes were as follows: replacing Ohio special wetlands with Vermont rare wetlands and adjusting the scoring gradient to more accurately reflect Vermont's wetland status. The original scoring criterion of the ORAM was used primarily for regulation of wetlands, rather than solely for the assessment of biological integrity. For example, because a site is a special wetland does not necessarily mean it is of high quality. In addition, a site that is not a special wetland, has low species richness and diversity, small size and lack of horizontal interspersion will score low despite the fact that it is in reference condition. The scoring indicates whether or not each metric has a certain level of function and value as well as disturbance and recovery, making this scoring method more adequate for use in regulation than for condition. It was expected on the outset of using this method that changes would need to be made to address the differences in stressor indication in Vermont versus Ohio. This expectation was supported when using the method to assess wetland condition in Vermont.

VRAM score results provided disturbance ranges from 32 to 94 out of a maximum of 100 points (Table 8). Lower scores indicate a greater degree of disturbance. Sites with scores between 85 and 100 are considered to be of reference condition; of moderate condition between 64 and 84; and of disturbed condition between 0 and 65. Using this rubric, sixteen sites sampled in 2008-2009 were considered to be in poor condition. The sixteen sites that scored below 65 were also considered to be in poor condition according to the HDR except for Kent Pond and Berlin Reservoir. All sixteen sites were considered to be disturbed sites using the Level 1 assessment. Berlin Reservoir achieved a moderate condition rating using the VRAM in comparison to the HDR because of the extra weight on vegetation communities and hydrology. Kent Pond also received a higher condition rating based on vegetation, habitat, and hydrology. The VRAM scoring method determines that the more developed the wetland vegetation community, habitat and hydrology is in a site, the better the wetland is able to deal with stressors. As a result, the site has a higher condition rating.

A weakness in the VRAM is its inability to determine all reference sites or sites in excellent condition. Only nine sites scored above 85, in comparison to fifteen sites that scored 3 or less using the HDR method. Six of the sites that did not receive a reference score from the VRAM were in excellent condition with the exception of Mount Tabor which is affected by acid deposition. The six sites showed no evidence of anthropogenic disturbance within the wetland, such as non-natives, hydrology or habitat alteration, or substrate disturbance. The remaining site, Bettis Pond Wetland, showed very little sign of disturbance within the wetland except for a few non-native plants.

John J Durand State Forest Wetland was included as a reference site according to the VRAM scoring method and was considered moderate according to the HDR method. The scoring of the HDR landscape quality metric prevented the site from being rated as a reference site. There were no disturbances observed in the wetland but the land around the site was being managed for open space and road access.

Table 8. Vermont Rapid Assessment Method (VRAM) adopted from the Ohio Rapid Assessment Method (ORAM). Sites listed in boldface indicate a total score of 65 or lower (high disturbance). Sites listed in *italics* indicate a total score of 85 or higher (low disturbance).

Site ID	Primary Disturbance[1]	Metric[2]						VRAM[3]
		1	2	3	4	5	6	
Burnt Meadow Brook Wetland	**Highway**	**3**	**0**	**9**	**9**	**0**	**11**	**32**
Barrows Brook Wetland	**Highway**	**4**	**3**	**15**	**6**	**0**	**9**	**37**
Third Branch Wetland	**Highway**	**4**	**2**	**11**	**11**	**0**	**10**	**38**
Oak Lodge Wetland	**Residential**	**2**	**4**	**16**	**10**	**0**	**7**	**39**
Five Ponds Wetland	**Agriculture**	**2**	**4**	**19**	**10**	**0**	**7**	**42**
Revoir Flat Wetland	**Agriculture**	**4**	**4**	**13**	**14**	**0**	**8**	**43**
Mill Pond	**Sedimentation**	**3**	**9**	**13**	**4**	**10**	**4**	**43**
Cabot Annex Wetland	**Highway**	**3**	**5**	**15**	**14**	**0**	**12**	**49**
Brattleboro Retreat Meadows	**Agriculture**	**2**	**7**	**15**	**5**	**10**	**13**	**52**
Newfane Town Forest	**Invasive Plant**	**4**	**8**	**28**	**7**	**0**	**6**	**53**
Buel's Gore Wetland	**Highway**	**3**	**6**	**22**	**7**	**0**	**16**	**54**
Pomainville Wetland	**Agriculture**	**6**	**10**	**22**	**7**	**0**	**10**	**55**
North Springfield Meadow	**Agriculture**	**4**	**8**	**17**	**15**	**0**	**11**	**55**
Barney Brook	**Agriculture**	**5**	**9**	**23**	**8**	**0**	**14**	**59**
Elm Brook WMA Wetland	**Agriculture**	**2**	**9**	**30**	**15**	**0**	**4**	**60**
Seymour White Cedar Swamp	**Highway**	**4**	**6**	**19**	**14**	**5**	**16**	**64**
Jay State Forest	Highway	4	9	20	18	0	21	72
Knapp Brook Wetland	Historical Use	4	14	21	18	0	16	73
McAllister Pond Wetland	Residential	4	6	25	19	0	20	74
Berlin Reservoir	Highway	4	12	29	15	0	14	74
Thetford Marsh	Agriculture	5	12	25	16	0	16	74
South Stream	Highway	5	12	23	15	0	20	75
Riley Bostwick WMA Wetland	Forest Management	2	11	30	20	0	13	76
Kent Pond	Highway	5	11	25	16	0	19	76
Bingo Brook Wetland	Historical Use	4	14	29	18	0	12	77
Woodford Site I	None	4	14	26	19	0	15	78
Tunnel Brook Wetland	Historical Use	4	14	28	18	0	15	79
Potter Road Wetland	Rural Development	4	14	24	17	0	20	79
Mount Tabor Wetland	Acid Deposition	3	14	30	18	0	14	79
Alder Branch Wetland	Historical Use	6	14	25	16	0	19	80
Lowell Lake Wetland	Rural Development	4	14	26	20	0	16	80
Woodford Site II	Highway	4	12	25	19	5	16	81
Old Marsh Pond	Invasive Plant	4	14	21	17	10	15	81
Lamphear Road Wetland	None	3	14	29	20	0	16	82
Mud Pond	Residential	4	14	27	17	0	20	82

Site ID	Primary Disturbance[1]	Metric[2]						VRAM[3]
Mollie Beattie SF Wetland	Forest Management	6	14	24	19	0	20	83
Little Hollow Wetland	Historical Use	2	14	26	20	10	11	83
Bettis Pond Wetland	Beaver Dam Failure	4	14	30	19	0	16	83
Lockwood Pond Wetland	None	4	14	26	20	0	20	84
North Shore Wetland	Residential	4	11	26	15	10	18	84
Newport Town Forest Wetland	Rural Development	6	13	25	18	0	22	84
Curtis Pond	Residential	3	14	30	20	0	17	84
Mt. Mansfield Beaver Wetland	*Highway*	*5*	*14*	*30*	*18*	*0*	*20*	*87*
West Hill Brook Wetland	*Forest Management*	*4*	*14*	*29*	*20*	*0*	*20*	*87*
Roxbury State Forest Wetland	*Beaver Dam Failure*	*5*	*14*	*30*	*19*	*0*	*19*	*87*
John J Durand State Forest Wetland	*Forest Management*	*5*	*14*	*29*	*20*	*0*	*20*	*88*
Tamarack Brook Wetland	*Forest Management*	*6*	*14*	*29*	*20*	*0*	*20*	*89*
Coles Pond	*Residential*	*4*	*14*	*28*	*19*	*5*	*20*	*90*
Branch Pond	*Acid Deposition*	*3*	*14*	*28*	*20*	*10*	*17*	*92*
Schofield Fen	*Historical Use*	*2*	*14*	*30*	*20*	*10*	*17*	*93*
Lye Brook Wilderness	*Acid Deposition*	*4*	*14*	*27*	*20*	*10*	*19*	*94*

[1] The degree of, but not the presence of, the primary disturbance is relative to the site's overall condition.
[2] Each metric assesses a different aspect of the wetland's condition. Metric one assesses wetland area (size), metric two assesses upland buffers and surrounding land use, metric three assesses the hydrology within the wetland, metric four assesses wetland habitat alteration and development, metric five accounts for any special wetlands (e.g. alpine peatland), and metric six assesses the plant communities, interspersion and microtopography of the wetland. Metric one scores range from 0-6; metric two, 1-14; metric three, 5-30; metric four, 3-20; metric five, 0-10; and metric six, -4-20. The maximum score is 100.
[3] Score is the sum of the six metrics.

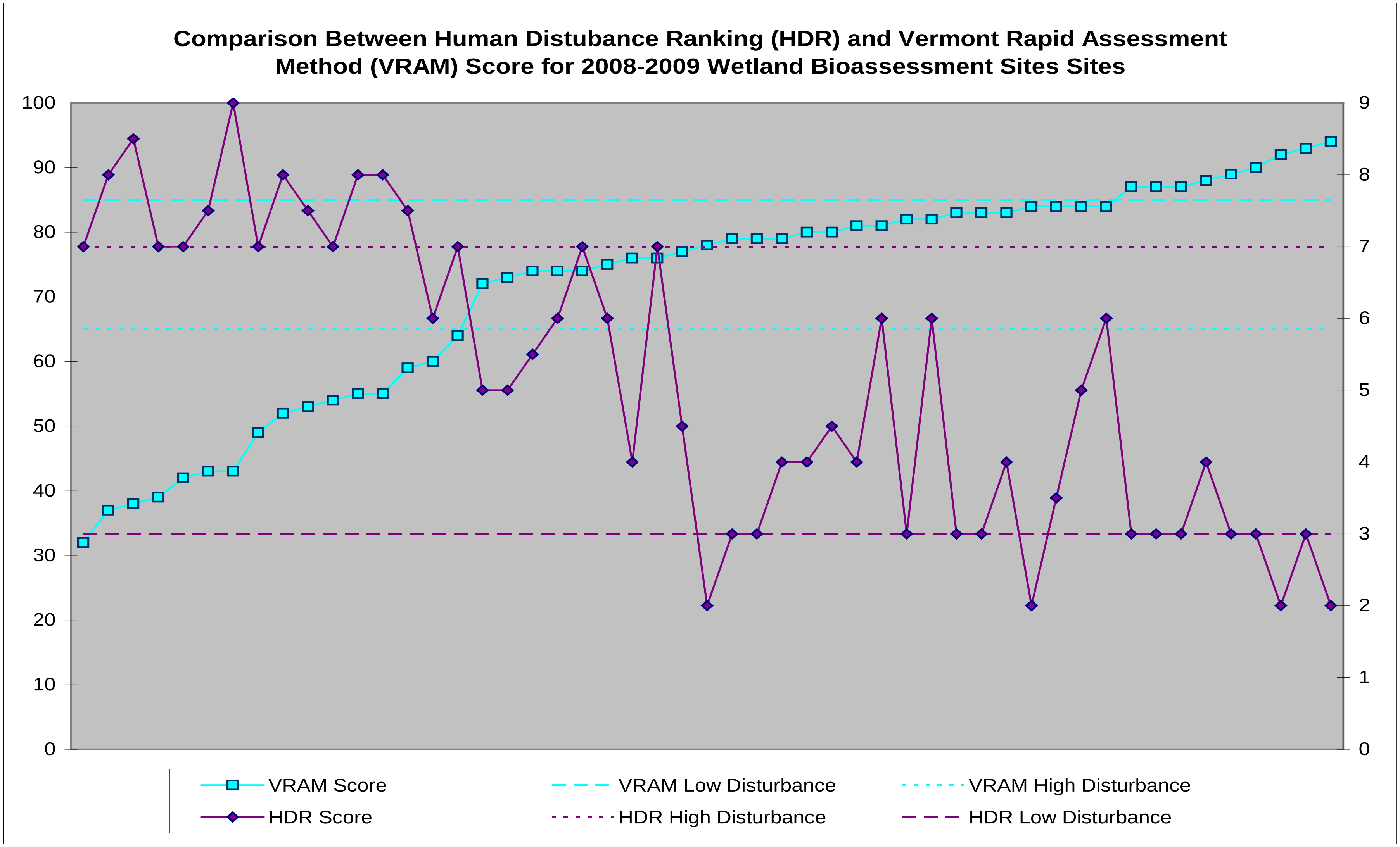
Another example of scoring weakness in the VRAM method is the special wetlands metric. The North Shore Wetland is one of the three Class One Wetlands in the State of Vermont. This site was mainly rejected as a reference site in the Level 1 assessment because of the low buffer and moderate surrounding land use. The lake adjacent to the site is Lake Champlain, which is vulnerable to considerable disturbance and is impaired from agricultural and urban area runoff as well as municipal wastes. The HDR method took into account the North Shore Wetland's disturbance severity and landscape quality pushing the site into the moderate disturbance category, whereas the VRAM focused less in those areas and more in hydrology, habitat, and special wetlands, resulting in a higher score of 84.

More weight placed on upland buffers and surrounding land use, and less weight placed on special wetlands and vegetation, may result in the VRAM's ability to more accurately represent each site's condition rather than its function and value. A wetland that supports a rare community or a threatened or endangered species warrants protection whether or not the wetland is disturbed.

Comparisons between the VRAM and HDR results from all sites indicate more similarities than differences in the two methods (Figure 2), especially in their ability to distinguish sites in poor condition. Figure 2 also illustrates the disparities between the two methods in identifying sites in reference condition. Further data analysis has indicated that the VRAM method is generally more consistent in assessing the stressors impacting wetland condition. For instance, the VRAM metrics can be used to compare anthropogenic modifications to hydrology and water quality or vegetative communities, where the HDR cannot.

In many instances, vegetation and water chemistry data supported the conclusions describing wetland condition drawn by the both the VRAM and HDR method. The VRAM picks up where the HDR leaves off in condition analysis and has been helpful in identifying the shortfalls of the HDR. Conversely, the HDR method has been useful in revealing the tendency of the VRAM to judge a site based more upon its functions and values than its condition. As a result, both methods should be used in the future until they can be combined to create a more comprehensive and accurate measure of biological integrity and condition. Overall, the final score derived from each method is an indicator of site condition and biological integrity.

Figure 2. Comparison between HDR and VRAM scores for 2008-2009 wetland bioassessment sites.



Biological

Vegetation, macroinvertebrates, algae, and fish assemblage measurements can provide insight into the overall health of a wetland and indicate how a site is reacting to the stressors placed upon it. The probability exists that a greater number of stressors will decrease the number of intolerant native species in a site. A disturbed site tends towards more generalized or tolerant, and exotic species which can adapt to a fluctuating or ecologically compromised environment. Similarly, intolerant native species diversity and richness can equate to higher biological integrity of the wetland, making vegetation and other assemblages valuable parameters to study while investigating the health of a wetland. Macroinvertebrates were not collected during the 2008-2009 seasons due to lack of funding, therefore only vegetation was measured.

Vegetative analysis showed some correlation between disturbance level and vegetation characteristics (Tables 7, 8 and 9). Reference and disturbed sites were chosen based on the combined VRAM and HDR results. Plants that were not identified down to species were not included in the total vegetative species count.

Tunnel Brook Wetland had the highest species richness of all reference sites, totaling 65 plant species. Oak Lodge Wetland had the highest species richness of all sites in poor condition with a total of 60 plant species. Woodford Site I had the lowest species richness of all reference sites, totaling 21 plant species, while Brattleboro Retreat Meadows, had the lowest species richness of all sites in poor condition with a total of 16 plant species (Table 7). Both results show little difference in plant species richness between reference and disturbed sites.

The mean and standard deviation value of vegetative species for disturbed sites was 37.47 and 10.51, and 38 and 11.96 for reference sites, indicating little difference between the numbers of vegetative species for either disturbance types.

Table 8. 2008-2009 Vermont wetland bioassessment and monitoring results of quantitative vascular vegetation assessment. Reference sites[1] are in *italics*; disturbed sites[2] are in **boldface**.

Site Name	# Species in Transect	Cover % Carex	Cover % Grasses	Cover % of Invasive, Noxious and/or To Watch Species[3]	Cover % Non-Native[4]
Pomainville	**28**	**25.0**	**60.4**	**60.4**	**1.1**
Revoir Flat Wetland	**40**	**14.0**	**57.9**	**56.5**	**0.1**
Elm Brook WMA Wetland	**51**	**0.1**	**52.1**	**42.1**	**0.0**
Brattleboro Retreat Meadows	**23**	**0.0**	**0.0**	**36.9**	**36.9**
Newfane Town Forest	**27**	**10.1**	**11.1**	**32.4**	**32.4**
Berlin Reservoir	**39**	**14.9**	**45.7**	**27.3**	**0.0**
Oak Lodge Wetland	**60**	**4.2**	**41.2**	**14.2**	**25.8**
Mill Pond	**41**	**12.0**	**4.6**	**14.2**	**16.0**
Kent Pond	**33**	**12.8**	**31.5**	**13.3**	**13.3**
Five Ponds Wetland	**54**	**7.9**	**13.1**	**6.8**	**0.3**
Old Marsh Pond	28	33.2	4.8	4.2	4.2
North Springfield Meadow	**41**	**15.6**	**17.3**	**4.1**	**1.2**
Thetford Marsh	29	4.1	6.5	3.2	10.0
Burnt Meadow Brook Wetland	**43**	**15.9**	**19.8**	**2.8**	**0.0**
North Shore Wetland	35	22.2	12.4	2.8	3.3
Jay State Forest	43	25.4	26.9	1.2	0.0
Barrows Brook Wetland	**45**	**2.9**	**17.0**	**1.0**	**0.0**
Buel's Gore Wetland	**40**	**8.8**	**62.23**	**1.0**	**0.1**
Mollie Beattie SF Wetland	50	17.7	13.4	0.9	0.9
South Stream	46	24.2	16.3	0.3	2.4
Alder Branch Wetland	41	9.4	4.2	0.0	1.7
Barney Brook[5]	**52**	**18.4**	**22.5**	**0.0**	**1.0**
Bettis Pond Wetland	*45*	*51.7*	*1.7*	*0.0*	*0.0*
Bingo Brook Wetland	45	10.2	8.1	0.0	1.1
Branch Pond	*28*	*27.4*	*5.5*	*0.0*	*0.0*
Cabot Annex Wetland	**40**	**5.2**	**6.1**	**0.0**	**0.0**
Coles Pond	*54*	*23.2*	*0.0*	*0.0*	*0.0*
John J Durand SF Wetland	*42*	*27.5*	*14.3*	*0.0*	*0.0*
Knapp Brook	33	32.1	25.2	0.0	0.0
Lamphear Road Wetland	*31*	*20.0*	*21.9*	*0.0*	*0.0*
Little Hollow Wetland	*30*	*22.5*	*1.2*	*0.0*	*0.0*
Lowell Lake Wetland	65	3.3	32.2	0.0	0.0
Lockwood Pond Wetland	*41*	*66.1*	*14.4*	*0.0*	*0.0*
Lye Brook Wilderness	*31*	*30.9*	*0.5*	*0.0*	*0.0*
McAllister Pond Wetland	39	25.8	41.7	0.0	0.0
Mt Mansfield Beaver Wetland	*48*	*48.1*	*6.4*	*0.0*	*0.0*
Mount Tabor Wetland	*30*	*35.1*	*16.1*	*0.0*	*0.0*
Mud Pond	42	31.9	11.3	0.0	0.0
Newport Town Forest Wetland	54	3.1	21.5	0.0	0.0
Potter Road Wetland	38	15.7	17.4	0.0	0.0
Riley Bostwick WMA Wetland	47	7.5	4.4	0.0	41.1

Site Name	# Species in Transect	Cover % Carex	Cover % Grasses	Cover % of Invasive, Noxious and/or To Watch Species[3]	Cover % Non-Native[4]
Roxbury SF Wetland	*45*	*7.4*	*23.0*	*0.0*	*0.0*
Schofield Fen	*33*	*25.8*	*6.0*	*0.0*	*0.0*
Seymour White Cedar Swamp	**44**	**25.9**	**5.8**	**0.0**	**1.9**
Tamarack Brook Wetland	*57*	*27.3*	*21.5*	*0.0*	*0.0*
Third Branch Wetland	**27**	**42.8**	**0.0**	**0.0**	**0.0**
Tunnel Brook Wetland	*59*	*11.1*	*18.4*	*0.0*	*0.0*
West Hill Brook Wetland	*31*	*10.6*	*33.6*	*0.0*	*0.0*
Woodford Site I	*25*	*42.6*	*40.5*	*0.0*	*0.0*
Woodford Site II	44	25.7	15.9	0.0	0.0
Curtis Pond	40	*	*	*	*

[1]Reference sites were chosen based on the combined VRAM and HDR results.
[2]Disturbed sites were chosen based on the combined VRAM and HDR results.
[3] The plant lists were taken from the Vermont Department of Agriculture, Food and Markets 2003 Quarantine #3 - noxious weeds list and the Invasive Species Watch List for Vermont created by the VT Invasive Exotic Plant Committee.
[4]Non-native percent included only plants found within the quadrats in the transect area.
[5]Barney Brook was planted with a wetland conservation seed mix and may not accurately represent what the site would be like in its natural condition.

Table 9. Vegetative mean and standard deviation values for 2008-2009 wetland sites.

	# Vegetative Species		% Carex cover		% Grass cover		% Non-native cover	
	Mean	S^2	Mean	S^2	Mean	S^2	Mean	S^2
Disturbed Sites (n=15)	37.47	10.51	13.91	10.29	24.47	21.41	3.41	3.36
Reference Sites (n=17)	38	11.96	28.57	17.94	15.47	12.17	0	0

Table 10. T-test (t) and Mann-Whitney rank sum test (M-W) results for vegetation parameters comparing minimally disturbed and highly disturbed sites. Means are presented for the t-tests and medians for the Mann-Whitney rank sum tests. Yellow indicates statistically significant outcomes (P = <0.05).

Parameter	Mean or Median		P-Value	Test Used
	Reference Sites[1]	Disturbed Sites[2]		
# Species in transect	31	39	0.940	M-W
Cover % Carex species	27.30	12.79	0.014	M-W
Cover % grass species	15.47	24.48	0.162	t
Cover % Invasive, Noxious and/or To Watch species	0	2.8	0.003	M-W
Cover % non-native species	0	0.30	<0.001	M-W

Third Branch Wetland had the highest percentage of *Carex* spp. for the disturbed sites at 42.8 percent, while Lockwood Pond Wetland had the highest percentage of sedges for reference sites at 66.1 percent. Brattleboro Retreat Meadows had the lowest percentage of *Carex* spp. for the disturbed sites at 0 percent, while Little Hollow Wetland had the lowest percentage of sedges for reference sites at 1.2 percent. The mean and standard deviation value of percent *Carex* spp. for disturbed sites was 13.91 and 10.29, and 28.57 and 17.94 for reference sites, indicating reference sites are more likely to have a higher percentage of *Carex* species than disturbed sites. A statistical difference with a P value of 0.014 was found using the Mann-Whitney Rank Sum test to support this theory (Table 9).

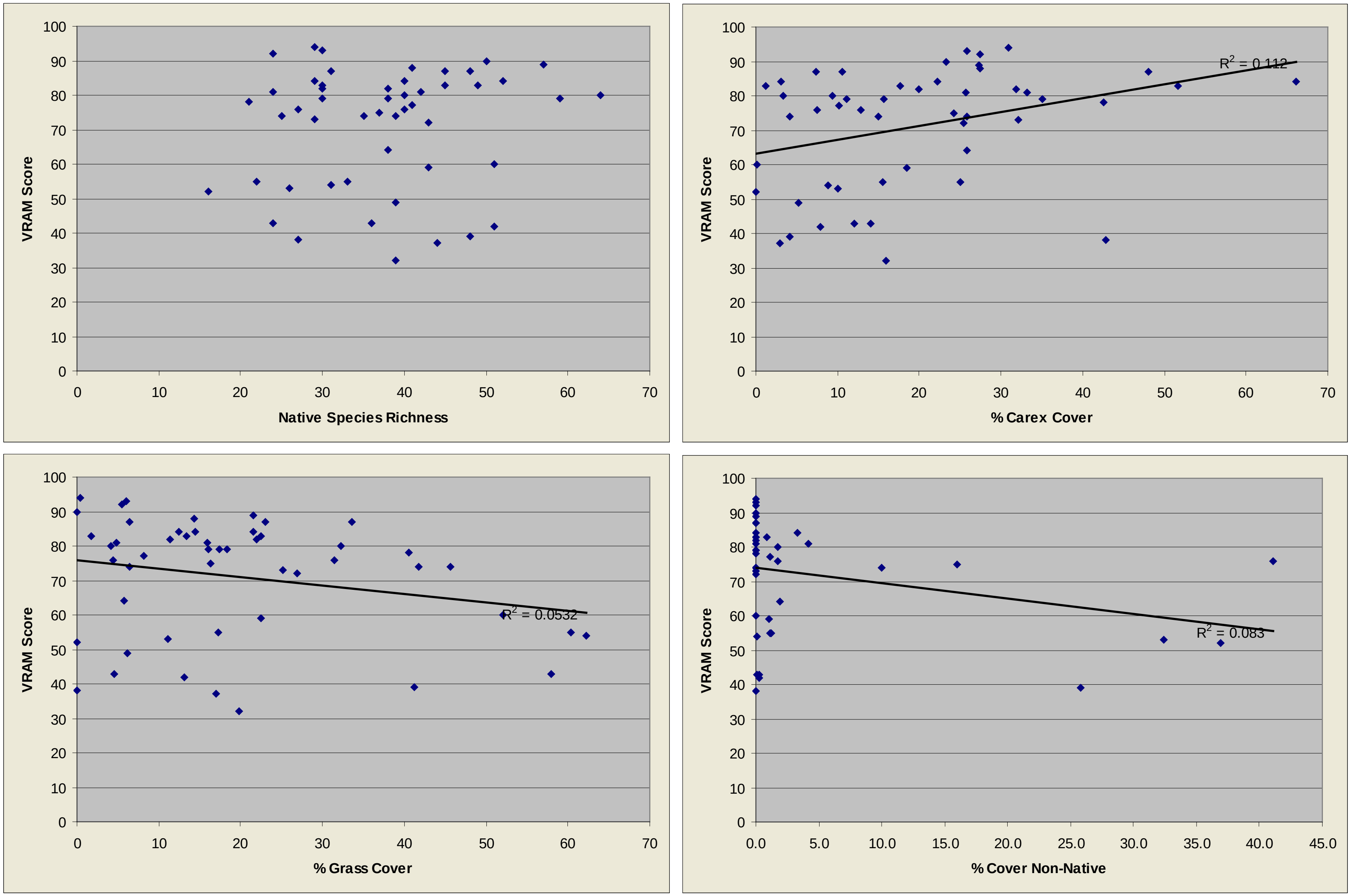
Buel's Gore Wetland had the highest percentage of grasses for a disturbed site, at 62.23, while Woodford Site I contained the highest percentage for a reference site at 40.5. The lowest percentage of grasses was the same for both disturbed and reference sites at 0 for Brattleboro Retreat Meadows and Coles Pond. This data suggests that percent grasses should not be used as an indicator of disturbance. The mean and standard deviation value of percent grasses for disturbed sites was 24.47 and 21.41, and 15.47 and 12.17 for reference sites. The statistical data in Table 9 suggests there is no difference between the amount of grass cover in disturbed and reference sites.

Reference wetland sites had the highest percentage of *Carex* species, suggesting that a strong presence of *Carex* is a good indicator of biological integrity or minimal disturbance. Inversely, the disturbed sites had the highest mean for number of vegetative species demonstrating that high species diversity is not necessarily an accurate indicator of low disturbance. Brattleboro Retreat Meadows had the highest percentage of non-native species for a disturbed site, at 35.72 percent and all reference sites were lacking the presence of non-native plants. While the percentage of non-native species may not indicate the level of disturbance, the presence of them should be an accurate indicator of some level of disturbance. All disturbed sites had a measurable amount of non-native species, while all fifteen reference sites had none.

Species richness, percentage of sedges, grasses and non-native taxa was measured exclusively against the VRAM score for 50 wetland sites from 2008 to 2009 (Figure 3). All four figures show no correlation between VRAM and the four parameters.

Vascular plants identified to species level have been listed for all 51 wetland sites surveyed from 2008 to 2009. A total of 372 species have been identified. Of the 372 species, 207 were found in reference sites, 220 were found in moderate sites, and 248 were found in disturbed sites. A total of 45 plant species were found only in reference sites, 41 were found only in moderate sites, 80 were found only in disturbed sites, and 103 were found in all three disturbance level sites. The numbers represent a trend of species diversity from reference to disturbed sites. The assumption is that reference sites contain a lower number of site specific plants, as the sites become moderately disturbed the number of species that can be found there increases as well as the number of tolerant species, and as the disturbance rises to a critical point the number of species rises and widely tolerant and non-native taxa are the primary vegetative cover. More research undertaken may indicate this trend to be true.

Figure 3. VRAM comparison against vegetative species richness, percent *Carex* cover, percent grass cover, and percent non-native species for 2008-2009 wetland sites.



This data can also be used in order to create a state specific Floristic Quality Assessment Index (FQAI). Factors that should be considered in the rating of each plant's tolerance level are frequency (the total of sites where the species was identified), preference (the type of site condition(s) the species was specific to), and site condition average (the average of the site condition scores for each species). Other parameters may be added to create a more accurate rating system. Although an FQAI rating system is valuable, it should not be the only measurement of condition for a site. Biological, chemical and landscape assessments should be combined to attain an overall representation of site condition.

Conclusions and Program Recommendations

The past four years have provided the Wetlands Bioassessment Program with a foundation upon which to develop a sustainable biomonitoring program and, ultimately, metrics which can be used to determine wetland condition throughout the State of Vermont. The parameters that have been studied will allow multiple facets of wetland health – wetland chemistry, vegetation, macroinvertebrates, and physical characteristics – to be combined in an effort to have a comprehensive view of wetland quality. It is the long-term intention of the wetlands bioassessment program to build on the current results to create a database of wetland quality that can be ultimately used in permitting and regulatory decisions. Understanding wetland quality will allow appropriate mitigation and restoration efforts and ensure that wetlands of high ecological quality are protected and those of poor quality are improved. The efforts of the Vermont Wetlands Bioassessment Program have started the VT DEC working in an appropriate direction toward achieving these goals.

There are some considerations the program will examine prior to extending the program into the future. Most biological sampling methods have been refined and tested for wetlands, and have been performed with good success. The applicability of the methods, feasibility of use and implementation, and the quality of the data has made the current methods most appropriate for the program. The National Wetland Condition Assessment in 2011 will provide additional monitoring and assessment methods that can be integrated into Vermont's program.

The New England Interstate Water Pollution Control Commission is leading the effort to establish a Floristic Quality Assessment Index for New England and New York. Wetland Program staff are on the Technical Committee for the development of this index, which should be useful in evaluating the vegetation data collected to date.

Similarly, the wetland rapid assessment methods should be refined to appropriately characterize wetlands in Vermont and also identify relevant stressors and their intensity. The HDR method does not specify environmental stressors and their effect on wetland conditions, and the VRAM needs to be weighted correctly in order to more accurately address wetland condition rather than function or value. Combining these methods may result in a more precise measure of biological integrity and condition within a sampled site regardless of wetland type. The assessment method should evolve to most accurately reflect wetland condition as the program progresses.

If the goal is to maximize the overall data set and ultimately create a database of quality in a faster timeframe, wetland site selection and sampling should be limited to wetlands that have some form of surface water in order to assess water quality. While a small dataset from 2006-2007 had confirmed the supposition that stream- and lake-associated wetland data should not be combined or compared due to innate differences, further analysis of 2008-2009 sites has shown little significant difference in vegetation or water chemistry between open and flowing water wetland types.

It is the intention of the Program to sample wetland sites throughout Vermont to produce an initial database of wetland quality and information. Sites should be selected based upon access, wetland type, size, and wetland quality to obtain an understanding of wetlands spanning different size and quality classes. Mitigation and restoration sites should also be sampled in order to monitor created and restored wetland efforts. Ultimately, the successful implementation of a bioassessment program that can sustain itself for several years should be able to meet and surpass these goals, effectively improving the understanding, protection, and restoration of Vermont's wetlands.

For the 2010 sampling season, the focus will be on filling in the gaps across the biogeophysical regions of the state. The 2011 field season will be in conjunction with the National Wetland Conditional Assessment. Going forward to 2012 and beyond, wetland monitoring and assessment will be incorporated into the rotational basin assessment program.

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