RAPID ASSESSMENT OF FRESHWATER WETLAND CONDITION
Year-3 Development of a Rapid Assessment Method for Freshwater Wetlands in Rhode Island

RIRAM Version 1

Final Report

Prepared for

Rhode Island Department of Environmental Management
Office of Water Resources

June 2010

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RIRAM Version 1

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Executive Summary

The State of Rhode Island Department of Environmental Management (DEM) and the Rhode Island Natural History Survey (RINHS) are working to develop a rapid assessment method (RAM) for freshwater wetland condition to address a set of objectives identified by the *Rhode Island Freshwater Wetland Monitoring and Assessment Plan*. The plan identifies short-term and long-term objectives focused on enhancing the protection and management of wetlands within the State.

The RAM is being developed under guidance and funding from the USEPA in accordance with the Clean Water Act. It represents the second level of an EPA-recommended three-level approach to wetland monitoring and assessment that includes landscape-level assessment (L1), rapid assessment (L2), and intensive assessment (L3). In Year 1 (2006), two existing RAM's were chosen and simultaneously piloted in the Woonasquatucket River watershed, the *Ohio Rapid Assessment Method version 5.0, quantitative section* (ORAM) and the *Delaware Rapid Assessment Procedure version 5.0* (DERAP). In Year 2 (2007), RINHS adapted ORAM and DERAP protocols to address the State's needs and applied them in a second set of wetlands assessment units in the Upper Pawcatuck River basin. The work resulted in the development of a RI-specific RAM, RIRAM version 1 (v.1), which was recommended for further testing. RIRAM v.1 was applied in Year 3 (2008) to test and refine metrics, assess its utility in addressing state objectives, and begin validation. Year-3 work is the focus of this report.

RIRAM v.1 was designed to produce an index of stressor intensity and an index of wetland condition (based on response) that can be combined into a single relative index that reflects both. RIRAM v.1 was modified *a priori* according to feedback from peer reviewers before field assessments in fall of 2008. Main modifications included the expansion of stressor metrics, the addition of a checklist for evidence of hydrologic stress, the reorganization and revision of metrics characterizing wetland response to hydrologic and habitat stressors, and the incorporation of historic and water-withdrawal metrics into other response and stressor metrics. The modified version of RIRAM v.1 was applied to two studies; the first was a development and demonstration analysis; the second was a RAM validation analysis.

The development and demonstration study utilized 50 assessment units selected along a gradient of land use intensity within the Hunt River and Pawtuxet River (hereafter H-P) drainage basins in central RI. Assessments were conducted jointly and separately by two assessors to facilitate inter-user variability analysis in assessing RAM objectivity. Mean differences between user metric and index scores ranged from 1.9% (*Condition* index) to 8.4% (*Habitat Stressors* metric). Modified wetland response metrics were scored more precisely between users than original metrics and strongly correlated with original metric scores ($Rs=0.85$, $P<0.01$). The modified metrics were applied in all subsequent analyses in this report.

Demonstration analyses indicated expected negative relationships between wetland condition and human activity. All RIRAM indices moderately correlated (Rs~-0.59, P<0.01) with buffer development out to 300m. The cover and richness of invasive plant species correlated with surrounding land use intensity, intensity ranks of numerous individual stressors, cumulative stressors, *Condition* index, and RIRAM index scores, demonstrating expected relationships between stressors, condition, and wetland invasion. Sheet runoff inputs, general filling, nutrients, and surrounding land use metrics moderately correlated with RIRAM *Condition* index scores (Rs=0.44 to 0.56, P<0.01), while *Stressor* index scores, representing cumulative stress, strongly correlated (Rs=0.79, P<0.01).

The second study, focusing on RIRAM validation, took advantage of intensive biological and physical data being collected by Annie Curtis at 36 isolated ponds located throughout mainland RI. Curtis sampled amphibian and macroinvertebrate communities, vegetation, water quality, and surrounding land use intensity. RINHS applied RIRAM v.1 and ORAM concurrent with Curtis's work. Correlation analysis was applied to validate RIRAM v.1 in characterizing relative wetland condition for various biological functions. Physical data were applied to test whether RIRAM could detect variations in water quality and impacts of surrounding land use intensity.

Raw capture rates and egg mass densities of amphibian species commonly used to indicate vernal pool integrity correlated with RIRAM v.1 indices (Rs=0.36 to 0.62, P<0.05). Species richness of both vernal pool-preferring amphibians and of all amphibians captured likewise correlated with RIRAM. These correlations suggest that RIRAM reflects the portion of habitat suitability for amphibians determined by wetland condition. Total vegetation cover, a proxy for productivity, was modestly correlated with RIRAM indices, but macroinvertebrate richness was not. Three water quality measures associated with urban runoff, specific conductance, pH, and chlorides, correlated negatively with RIRAM. Two measures of surrounding land use intensity, including road density and % forested within 1000m and 250m, correlated with RIRAM as well. These landscape correlations offer coarse, but reliable, validation of RAM function.

While these validation analyses suggest proper RAM functionality, the evidence they supply pertains to select types of wetlands and taxa; it does not confirm broad applicability. Demonstration analyses support the validations, since similar results were derived for analogous factors across several wetland types. Confidence in RIRAM data validity and utility will only be gained through subsequent application and validations in various settings. In its finished form, RIRAM will be a useful element in wetland monitoring and assessment.

1. Introduction

1.1 Background

1.1.1 Rhode Island Freshwater Wetland Monitoring and Assessment Plan

The State of Rhode Island Department of Environmental Management (DEM) and the Rhode Island Natural History Survey (RINHS) are working to develop a rapid assessment method (RAM) to characterize freshwater wetland condition. The work is being conducted in accordance with USEPA guidelines and the *Rhode Island Freshwater Wetland Monitoring and Assessment Plan* (RI Wetland Plan; NEWIPCC and DEM 2006). The work detailed in this report builds upon work conducted in 2006 and 2007 by DEM and its partners, which is detailed in previous reports (NEIWPCC 2007; Kutcher 2009); it is intended to fulfill expectations of the USEPA and DEM, pursuant to the *Rhode Island freshwater monitoring and assessment: expanded pilot demonstration project work plan for EPA QAPP review – year 3 continuation* (DEM 2008).

Informed by wetland partners within the State and USEPA, the RI Wetland Plan identifies gaps and needs in freshwater monitoring and assessment. The Plan outlines a strategy to meet those needs through the development and application of long-term monitoring and assessment methods that integrate with other State monitoring programs. In the RI Wetland Plan, DEM and its partners identified a set of long-term and short-term objectives (NEIWPCC and DEM 2006) as follows:

Long-term objectives

- *Develop a database of information necessary to evaluate trends in wetland condition.*
- *Identify causes and sources of wetland degradation including cumulative impacts to wetlands.*
- *Identify program and policy changes needed to improve overall wetland condition statewide.*
- *Evaluate the effectiveness of wetland management and protection programs with respect to wetland condition.*

Short-term objectives

- *Prioritize wetlands (and adjacent upland habitat) for protection through open space acquisition and other land protection mechanisms.*
- *Develop and implement methods for monitoring impacts to wetlands due to water withdrawals.*
- *Monitor and assess impacts to wetlands due to loss and degradation of adjacent upland habitats (buffer zones).*
- *Monitor location and extent to which invasive species are present and affecting wetland condition.*

1.1.2 EPA Three-Level Approach

The USEPA has recommended that states adopt a three-level approach to wetland monitoring and assessment to address the policies set by the Clean Water Act (USEPA 2006). The approach supports validation and interoperability between various data types and promotes a comprehensive and coordinated strategy to data collection, storage, analysis, and application. Descriptions and applications of the three levels are outlined in Table 1.

Table 1. USEPA-recommended three-level approach to wetland monitoring and assessment

USEPA Recommended Level
Level 1: Landscape Assessment Use GIS and remote sensing to gain a landscape view of watershed and wetland condition. Typical assessment indicators include wetland coverage (NWI), land use and land cover
Level 2: Rapid Wetland Assessment Evaluate the general condition of individual wetlands using relatively simple field indicators. Assessment is often based on the characterization of stressors known to limit wetland functions e.g., road crossings, tile drainage, ditching.
Level 3: Intensive Site Assessment Produce quantitative data with known certainty of wetland condition within an assessment area, used to refine rapid wetland assessment methods and diagnose the causes of wetland degradation. Assessment is typically accomplished using indices of biological integrity or hydrogeomorphic function.

Source: USEPA 2006

1.1.3 Development and Testing of Rapid Assessment Methods

The RI Wetland Plan outlines a strategy to develop and integrate these three levels of monitoring in the State of RI over time. As a central part of that strategy, the plan calls for a Level 2, rapid wetland assessment method (RAM) to be developed from 2006 to 2011. The USEPA (2006) views rapid assessment as a prerequisite component of state monitoring programs. In an effort to take an evolutionary approach to RAM development, NEIWPPC and DEM researched existing RAM protocols being implemented by other states with the intent of adapting an existing method for use in RI. At least 13 states have developed wetland RAMs. Based on research, including a review of various State RAMs published by the USEPA (Fennessy et al. 2004), DEM selected two methods that would be piloted to assess their utility in addressing the State's monitoring objectives: (1) the *Ohio Rapid Assessment Method* (ORAM; Mack 2001) and (2) the *Delaware Rapid Assessment Procedure* (DERAP; Jacobs 2003), which has since been updated (Jacobs 2007).

The RI Wetland Plan outlines a five-year schedule for the development and testing of a rapid assessment method. The work began in 2006 and continues to present. In 2006 (Year 1), the ORAM and DERAP were simultaneously piloted in the Woonasquatucket River basin in Northern RI. The study, conducted by NEIWPPC and DEM (2006), involved the strict application of ORAM protocols, while DERAP was applied as an

ancillary checklist. The RAMs were piloted at 27 sites selected across a range of land use intensity.

In 2007 (Year 2), findings and recommendations of 2006 investigations were incorporated into efforts by RINHS to enhance and adapt the two methods for use in RI. ORAM and DERAP were modified *a priori* to improve their regional and functional relevance and were applied to 54 sites in the Upper Pawcatuck drainage basin in southwestern RI. The protocols were further modified *a posteriori* based on justifications and analyses detailed in the Year-2 report (Kutcher 2009). The outcomes of those efforts include a Rhode Island-specific RAM, RIRAM v.1, which required further development, demonstration, and validation in Year-3. These Year-3 efforts are the focus of this report.

1.1.4 RIRAM Version 1

RIRAM v.1 is an adaptation of ORAM v.5 (Mack 2001) that was modified to meet the needs of wetland conditional monitoring in RI. Modifications to ORAM included adaptations of metrics to reflect regional conditions; the reorganization of metric categories to separate stressor, condition and *value-added* metrics; more detailed wetland classification methods; and the modification of stressor and condition metrics to improve data utility and objectivity in scoring. The resulting RAM, RIRAM v.1 is provided in the form of a field datasheet as Appendix 1.

RIRAM v.1 is an observation-based RAM that produces indices of relative wetland ecological condition by the ranking and summing of stressor intensity and wetland response to stress; this closely follows EPA wetland monitoring and assessment guidelines (EPA 2006). RIRAM v.1 utilizes three metrics ranking stressor intensity, including two landscape-based metrics, an in-wetland hydrology-based metric, and an in-wetland habitat-based metric. Two wetland response metrics are likewise based on hydrologic and habitat response to stressors, while a third is based on invasive species cover and the last asks the rater for a qualitative assessment of overall habitat development (see App. 1). The RAM produces a separate score for stressors (*Stressor* index) and response (*Condition* index) that can be summed to produce a single index of relative ecological condition that incorporates both (RIRAM index). Attributes describing wetland characteristics that are not strictly stressor or response-based are not scored, but remain in the RAM to enhance baseline data and analysis.

1.2 Project Objectives

This report details work accomplished in field-year 2008 toward the development of a regionally effective RAM that addresses the monitoring objectives outlined in the RI Wetland Plan. It demonstrates methods for generating baseline data following a *rotating basin* approach to wetland monitoring consistent with surface water protocols established in the State (DEM 2005). It also outlines several important findings and recommendations representing significant progress in the development and application of a single, appropriate rapid assessment methodology capable of quantifying relative freshwater wetland condition for RI.

Specifically, Year-3 project objectives are to: (1) further refine RIRAM metrics to enhance its utility and user objectivity for conditional assessment, (2) demonstrate the ability of RIRAM data to directly address State freshwater monitoring and assessment objectives, and (3) test RIRAM validity in generating a regionally-effective, relative index of overall wetland condition.

To meet project objectives, two studies were conducted utilizing separate study areas. The first (Section 2 of this report) was a RIRAM development and demonstration study conducted on 50 sites within four contiguous wetland basins in Rhode Island. Data from this study were used to analyze metric modifications and RIRAM's utility in addressing selected monitoring objectives identified in the RI Wetland Plan (NEWIPCC and DEM 2006; Section 1.1.1). The second study (Section 3) was a RIRAM validation study conducted in 36 isolated pond wetlands throughout Rhode Island. This study used intensive biological and physical data collected by Curtis and Paton (2009) for correlation against RIRAM and ORAM data collected by RINHS during the same field season.

2. Development and Demonstration of RIRAM v.1

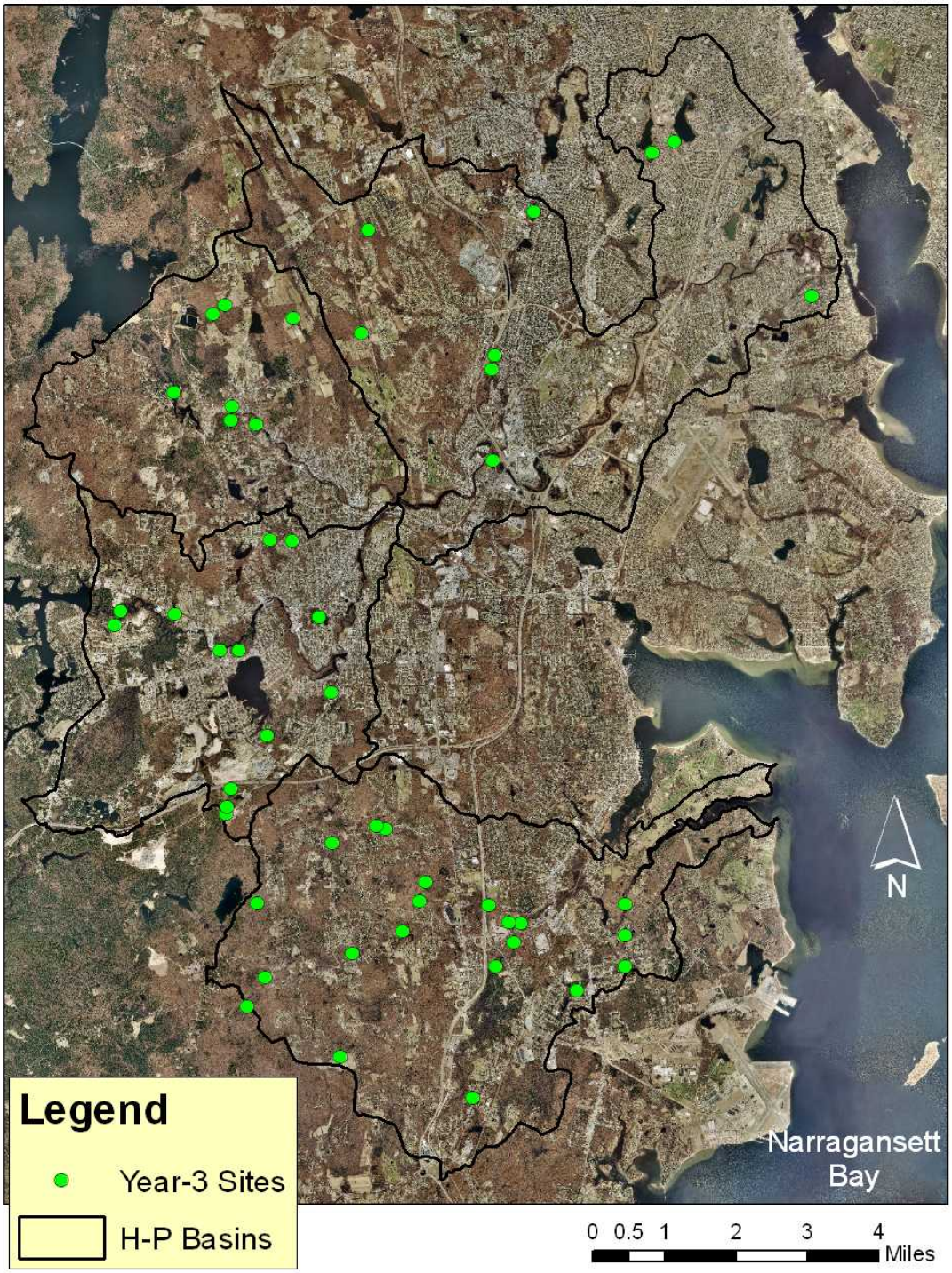
US EPA (2006) recommends a wetland monitoring program strategy designed to address State-identified objectives. Accordingly, a primary focus of RIRAM development has been to refine its utility to more effectively address the objectives identified in the RI Wetland Plan (NEIWPCC and DEM 2006; Sec. 1.1.1). Refinements have included revising and reorganizing metrics to more accurately reflect all relevant factors and minimize subjectivity between users. In this study, improvements made to RIRAM since Year 2 are analyzed for subjectivity; RIRAM data are then applied in various analyses designed to demonstrate how they may directly address selected State objectives.

2.1 Methods

The study utilized 50 assessment units randomly selected along a gradient of land use intensity within the Hunt River and Pawtuxet River (hereafter collectively H-P) drainage basins in central RI (Fig. 1). The H-P basins cover 55,000 acres and contain 8,400 acres of freshwater wetlands. The dominant wetland types (by area) are forested deciduous (46%), shrub swamp (19%), emergent wetlands (15%), and open water (derived from *Wetlands of RI—1988*, RIGIS 2009). The study area is highly developed (49% by area); primarily residential and mixed urban land covers, resulting in a largely fragmented landscape. Much of the development is clustered around major river systems that once supported numerous mills and large wetland complexes. Secondary forest covers most of the remainder (45%) of the study area (derived from *Land Use 200304*, RIGIS 2009).

Study units were assessed between September 9 and November 12, 2008. Two versions of the developmental rapid assessment method RIRAM were applied to each wetland by the principle investigator and a trained research assistant. RIRAM v.1 is the focus of this report; RIRAM version 2 will be detailed in a subsequent addendum. Data were collected and recorded on field forms and entered into a digital spreadsheet for analysis.

Figure 1. Fifty H-P sites selected for Year-3 Development and Demonstration analyses of RIRAM v.1.



2.1.1 *A Priori* Review and Modification of RIRAM v.1

Prior to applying them in the field, RIRAM protocols were reviewed by DEM and other wetland experts to assess their logical consistency and applicability to RI freshwater wetlands and to goals identified by the RI Wetland Plan. The RIRAM v.1 field form (v.1

F08) was modified from the original, recommended version (Kutcher 2009) to address feedback from reviewers. Refer to the original and modified RIRAM v.1 field forms (Apps. 1 and 2 respectively) for further clarity on the following protocol adaptations for assessments conducted in Year 3:

- Metric 3a was changed to incorporate a standard cover class of each component of habitat structure, rather than original classes that included cover and quality for each.
- Metric 3c was changed to incorporate cover class of each component of microtopography, rather than original classes that included cover and quality for each.
- Metric 6 was modified to include additional hydrologic stressors and a section offering four checklists of *evidence* of hydrologic stress, categorized by the type of stress.
- Metric 7 was modified to include additional habitat stressors.
- Formerly stand-alone metric characterizing historic significance (App. 1, Metric 8) was incorporated into metrics 8 and 9 (App. 2).
- Metric 8 (App. 2) was added to replace the original *hydrologic modification* metric (9a from App. 1) in an effort to improve rater objectivity. The original metric was retained to allow for comparisons.
- Metric 9 (App. 2) was added to replace the original *habitat alteration* metric (10a from App. 1) in an effort to improve rater objectivity. The original metric was retained to allow for comparisons.
- Metrics designed to characterize water withdrawal effects (App. 1) were incorporated into metrics 6 and 8 (App. 2).
- Metric 10a (App. 2) was recategorized (from 10c in App. 1) to include five cover classes of invasive plants instead of four, and expanded to allow for the identification of up to five invasive plant species.

2.1.2 Site Selection

Study sites were selected to compliment the existing DEM *rotating basin* surface water monitoring schedule. Four basins were selected for the study following prior surface-water monitoring work; these were the Hunt River basin and three Pawtuxet River basins, all located in the Narragansett Bay watershed in central Rhode Island. To alleviate anticipated problems with access to private properties, only wetlands on public or conserved lands were included. Utilizing ESRI ArcMap GIS software, wetland sites were randomly selected along a gradient of land use intensity as follows:

- Public and NGO open space within the H-P basins was identified by clipping RIGIS (2007) geospatial vector data-layers *State Conservation and Park Lands* and *Local and NGO Conservation and Park Lands*, to a shapefile delineating the study area, which was created from the RIGIS (2008) data-layer *NRCS HUC 12 Drainage Basins for RI*.
- The resulting polygons (of all documented open space within the basins) were each buffered by 100m, and a shapefile of the buffered properties was created. This shapefile was used to clip the RIGIS data-layer *2003-04 Land Use for RI*, which classifies land use and land cover by the Andersen Classification Scheme (1976).

- The resulting [LU of (property + buffer)] polygons were analyzed to determine the proportion of *Urban or Built-up Land* (the remainder being natural lands) within each, and coded accordingly. The polygons were then sorted (i.e. ranked) according to these human-use intensity proportions. Proportions ranged from 0.00 to 1.00. Sixty polygons were selected evenly along that entire gradient from a random starting point between 0 and *n*/60.
- From those polygons, privately owned conservation properties were dropped to alleviate anticipated access problems; leaving 52 properties.
- The centermost wetland unit, >50% contained within each of the remaining properties, was selected for assessment. If a property did not contain at least 50% of a viable wetland unit (see Section 2.1.3), it was replaced by the next closest conserved property containing a viable unit.

Permission to access study sites was gained through telephone and email solicitation of fee and easement owners. Sites that were not available for access were replaced by the next closest conserved property containing a viable assessment unit. Fifty two study sites (i.e. assessment units) were selected by the above methods; one assessment unit was disqualified for falling outside of the H-P basin; another was removed due to time and access constraints; resulting in *n*=50 assessment units (Fig. 1).

2.1.3 Determination of Assessment Unit Boundaries

GIS was used to facilitate the delineation of assessment units according to ORAM protocols (Mack 2002). ORAM protocols determine wetland assessment unit boundaries through a set of rules that differentiate units primarily by hydrologic discontinuity. The entire wetland unit is assessed. This differs from some protocols (e.g. DERAP, Jacobs 2007) that select a standard-sized plot within each wetland unit as an “assessment area”. The existing geospatial wetlands data-layer, *Wetlands of Rhode Island, 1995* (RIGIS 2008) was used as a preliminary wetland identification tool. However, the RIGIS data were insufficient in accuracy to determine assessment unit boundaries, so actual assessment unit delineations were *heads-up* (on-screen) digitized from 2004 leaf-off color digital orthophotography (RIGIS 2007).

2.1.5 Assessments

RAM Site Investigations

Sites were accessed on foot or by canoe, when necessary. Two investigators, a wetlands scientist and a trained field assistant, conducted the site investigations. The perimeter and multiple transects of each site were assessed when possible, otherwise assessments were made by accessing as many points as possible. For the first 27 assessments, one RIRAM v.1 assessment was conducted per assessment unit, jointly. For the last 23 assessment units, assessors first conducted assessments separately to facilitate inter-user analysis, then jointly.

Field maps of each site, produced using GIS, were utilized for field orientation and determining wetland community and buffer characteristics. Each map contained a

backdrop of 2004 leaf-off color aerial photography at a scale sufficient to illustrate wetland habitats and surrounding land uses, and included a delineation of the assessment unit, a delineation of the boundary of conserved land, a scale bar, and identifying information. A Trimble *GeoXT* cartographic GPS unit was loaded with the same information, primarily for spatial confirmation and ground-truthing site delineations.

An interim field guide to invasive freshwater wetland plants of RI was utilized in the field to help in invasive plant species identification. The guide was conceived and created by the RINHS in 2007 by compiling information from existing data sources.

Remote Investigations

Data obtained during field investigations were updated, complemented, or completed via GIS analysis before data entry. The following GIS operations were undertaken before data entry. Refer to RIRAM v.1 F08 field form (App. 2) for clarification:

- Wetland size was determined to answer Metric 1.
- The RIGIS (2008) *FEMA Statewide Flood Zone Map* data-layer was overlaid to determine whether each wetland fell within a designated 100-year floodplain to partly answer submetric 2b.
- RINHS (2008) rare species geospatial data were buffered and laid over sites to determine any occurrences of state/federal threatened or endangered species, to partly answer Metric 4 by determining the potential presence of rare species.
- The RIGIS (2008) *Sewered Areas* data-layer was overlaid to partly answer Metric 5 by determining the presence of sewers.
- The RIGIS (2007) *Community Wellhead Protection Areas* and *Non-community Wellhead protection Areas* data-layers were overlaid to partly answer Metric 6 by determining the presence of groundwater pumps.

GIS Analysis

Percent cultural (developed and agricultural) cover was determined for four nested buffer zones using ESRI ArcMap GIS. First, each assessment unit was buffered by 30m, 50m, 100m, and 300m. The resulting buffer donuts were intersected with RIGIS *Land Use 2003-2004* geospatial data to create land use buffer donuts; % cultural cover was then quantified in each by updating geospatial statistics and summing the areas.

2.2 Results

2.2.1 Data Summary

RIRAM investigations were conducted on a sample of 50 freshwater wetlands within the H-P basins in 2008. Total area of assessed wetlands was 445 acres and sites ranged from 0.4 to 53 acres with a mean size of 8.9 acres. The dominant wetland type within the sample (by presence per site) was forested, with shrub swamp, emergent wetlands, riverine and palustrine open water, and aquatic bed comprising the remainder. The following statements in this section are derived from H-P basin sample data collected in 2008 (see App. 3 for associated bar graphs).

The dominant HGM classes were *Depressional* and *Riverine*. The majority (66%) of wetlands were at least partly groundwater fed, while 60% were at least partly surface-water fed. 86% of wetlands were part of a natural complex, 60% were within a riparian corridor, 60% buffered surface-waters from land use, and 60% acted as floodplain buffers. Most wetlands were >0.7m in maximum depth and the majority were seasonally flooded.

Twenty-four percent of the sample wetlands contained mature swamps, mostly dominated by red maple (*Acer rubrum*), and 2% contain Atlantic white cedar swamps. About one third (30%) of all wetlands contained vernal pools, while fens or bogs were component in 6%. Twelve percent of our sample was documented as significant bird habitat and 10% was known to contain threatened or endangered species.

Buffers of the majority of H-P wetlands sampled (76%) were >50% intact, while the remainder (14%) were >50% degraded. Most common stressors within a 100-m buffer zone were raised roads and trails (86% of sites), residential development (72%), commercial/industrial development (40%), and channelized streams and ditches (38%).

The most common hydrologic in-wetland disturbance was sheet runoff inputs (48%). Over half of all wetlands were hydrologically affected by road beds (40%), railroad tracks (6%), or dikes (6%). Nutrient enrichment was evident at 24% of H-P study sites while ditching and dredging affected 18%. Twenty-two percent of sites were not affected by hydrologic alteration.

Fifty-eight percent of our H-P study sites were filled by road or railroad construction, while other filling affected 48%. Trash dumping occurred at 38% of sites and organic waste dumping was found at 16% of sites. Twenty-six percent of sites were dredged or ditched and 20% had trails running within or adjacent to them. Thirty-eight percent of sites showed evidence of recent vegetation removal. Approximately 40% of H-P wetlands sampled appeared to have no signs of hydrologic alterations, while 22% of sites were not affected by direct habitat alteration.

Invasive plant species were present at 82% of our study wetlands, mostly in small numbers (<5% total cover); however, invasive plant cover was >50% at 10% of our sites. The most common invasive species observed was European buckthorn (*Rhamnus frangula*), followed by Japanese barberry (*Berberis thunbergii*), mostly growing in intermittent streambeds. The invasive vine Oriental bittersweet (*Celastrus orbiculatus*), while not generally found within wetlands, was intertwined with or covering wetland vegetation at 20% of our study sites.

RIRAM v.1 index statistics for the H-P basins are summarized in Table 2 and in Appendix 3.

Table 2. Basic statistics of RIRAM v.1 index scores from 50 wetlands in the H-P basins.

Statistic	RIRAM v.1 Indices		
	Stressor	Condition	RIRAM Index
Valid cases	50	50	50
Mean	16.5	21.5	38.0
Std. Deviation	6.1	7.0	12.5
Skew	0.1	0.2	0.2
Minimum	5.2	9.6	14.8
Maximum	28.0	34.0	61.6
Range	22.8	24.4	46.8
5th percentile	6.7	11.1	19.4
10th percentile	8.2	12.8	20.7
25th percentile	11.6	14.9	27.3
Median	17.6	21.3	37.1
75th percentile	20.8	27.5	46.7
90th percentile	26.0	32.9	57.5
95th percentile	27.3	33.0	60.5

2.2.2 RIRAM v.1 Development

A priori modifications were made to RIRAM v.1 prior to field assessments in Year 3 (Section 2.1.1). These modifications were analyzed for preservation of analogous function and enhancement of utility and objectivity, where appropriate.

Inter-user Variability

Inter-user variability was analyzed to assess the objectivity of the metrics and indices within RIRAM v.1. Three tests were performed; first, Spearman Rank correlation analysis was applied to determine the scoring precision between users; second, a t-test was run to determine whether mean scores were different between users; and third, the percent mean difference (%MD) was calculated to determine the average difference in score, represented by the percent of the total range of points in the metric. Refer to Table 3 for results listed in order of ascending %MD.

Table 3. RIRAM v.1 metric scores for 23 wetlands within the H-P basins assessed by two separate raters.

	Observer 1		Observer 2				
Metric	Mean	SD	Mean 2	SD	r_s*	P-value**	%MD
5a. Buffer	3.35	2.35	3.22	2.02	0.97	0.38	2.17
5b. Surrounding Landcape	4.72	1.32	4.78	1.20	0.93	0.56	2.97
10a. Invasive plant score	3.65	1.53	3.48	1.59	0.89	0.33	5.07
9. Wetland response to habitat alteration	5.49	1.73	5.52	1.45	0.86	0.86	3.56
6a. Hydrologic stressors	3.17	2.10	3.65	2.04	0.85	0.04	5.28
10b. Overall habitat development score	4.22	1.31	4.09	1.35	0.84	0.42	3.99
7. Habitat stressors	3.52	2.23	3.65	1.82	0.76	0.66	8.39
8. Wetland response to hydrologic alteration	5.61	2.57	6.01	2.63	0.71	0.14	3.77
Stressor Total	14.77	7.16	15.30	5.83	0.92	0.33	3.85
Condition Total	18.97	6.33	19.10	6.29	0.93	0.71	1.89
Total Index	33.73	12.55	34.40	11.24	0.97	0.33	2.07

*Spearman rank correlation coefficient; P<0.01 for all

**Paired t-test results

%MD = absolute (mean user difference in metric scores / metric range) x 100

The *Total Index* and *5a Buffer* were the most precisely scored indices between the users, indicated by nearly perfect correlation (Rs) values, while original *Hydrologic* and *Habitat*

Modification metrics (8x and 9x) and the new *Hydrologic Alteration* scores (metric 8) were least precise. Metrics 9x and 6a *Hydrologic Stressors* were the only two metrics that were scored differently between users, by about 5% of each metric's range. Metric 7 *Habitat Stressors* was the least dependable metric, scoring, on average, 8.4% different between users (although not a significant difference overall).

Modifications to Response Metrics 8x and 9x

Response metrics originally adopted from ORAM were modified *a priori* to increase objectivity. These metrics contribute to the *Condition* index. A goal of the modification was to replicate and document the subconscious steps an investigator takes in rating the original metrics (refer to App. 2). To determine whether this goal was met, scoring of the developmental metrics (8 and 9) was compared to the original metrics (8x and 9x). Table 4 shows strong correlations between the developmental and original metric scores, including the combined scores for both. This indicates analogous scoring utility.

Table 4. Spearman rank correlation coefficients and probabilities of developmental versus original RIRAM v.1 response metrics from 50 sites in the H-P basins.

Metrics	Rs	P
8 vs 8x	0.80	<0.01
9 vs 9x	0.71	<0.01
8+9 vs 8x+9x	0.85	<0.01

In Table 3 and Table 5, inter-user variability analysis is used to investigate the relative objectivity of developmental response metrics compared with the original metrics. Note that both developmental metrics 8 and 9 outperformed the original metrics in %MD measurements and in t-tests. Metric 9 outperformed the original in rater precision (higher Rs), while Metric 8 was nearly the same as the original (Table 3). Finally, the combined scores of metrics 8 and 9 outperformed the original metrics by all measures (Table 5).

Table 5. Combined original and developmental RIRAM response metric scores assigned to 23 wetlands within the H-P basins by two separate raters.

	Observer 1		Observer 2				
Metric	Mean	SD	Mean 2	SD	r_s*	P-value**	%MD
8x + 9x ORAM	10.52	3.73	11.33	4.01	0.66	0.09	4.6
8 + 9 RIRAM	11.10	3.95	11.53	3.92	0.84	0.15	2.4

*Spearman rank correlation coefficient; P<0.01 for all
**Paired t-test results
%MD = absolute (mean user difference in metric scores / metric range) x 100

Since the developmental response metrics are analogous to and more objective than the original ORAM metrics, their substitution is applied to demonstration and validation analyses detailed in subsequent sections of this report, and recommended for use in RIRAM v.1.

2.2.3 RIRAM v.1 Demonstration Analyses

Three analyses are provided below to demonstrate the utility RIRAM v.1 in addressing wetland monitoring objectives identified in the RI Wetland Plan (NEWIPCC and DEM 2006). The following objectives are addressed:

Short-term objectives

- *Monitor and assess impacts to wetlands due to loss and degradation of adjacent upland habitats (buffer zones).*
- *Monitor location and extent to which invasive species are present and affecting wetland condition.*

Long-term objective

- *Identify causes and sources of wetland degradation including cumulative impacts to wetlands.*

Effects of Surrounding Land Use on Wetland Condition

The first demonstration analysis addresses the impacts to wetlands due to loss and degradation of vegetated buffers. To demonstrate how RIRAM might be applied, land use intensity within nested buffer zones was compared to RIRAM indices using Spearman rank correlation. Percent cultural (developed and agricultural) cover was used as a proxy for land use intensity within each of the following zones: 30m, 50m, 100m, and 300m. Percent cultural cover within each buffer-zone was correlated against *Condition*, *Stressor*, and *Total* RIRAM v.1 indices (minus landscape metric scores) to determine the strength of correlation for each pairing and to reveal any trends in effective buffer zone width (Fig. 2).

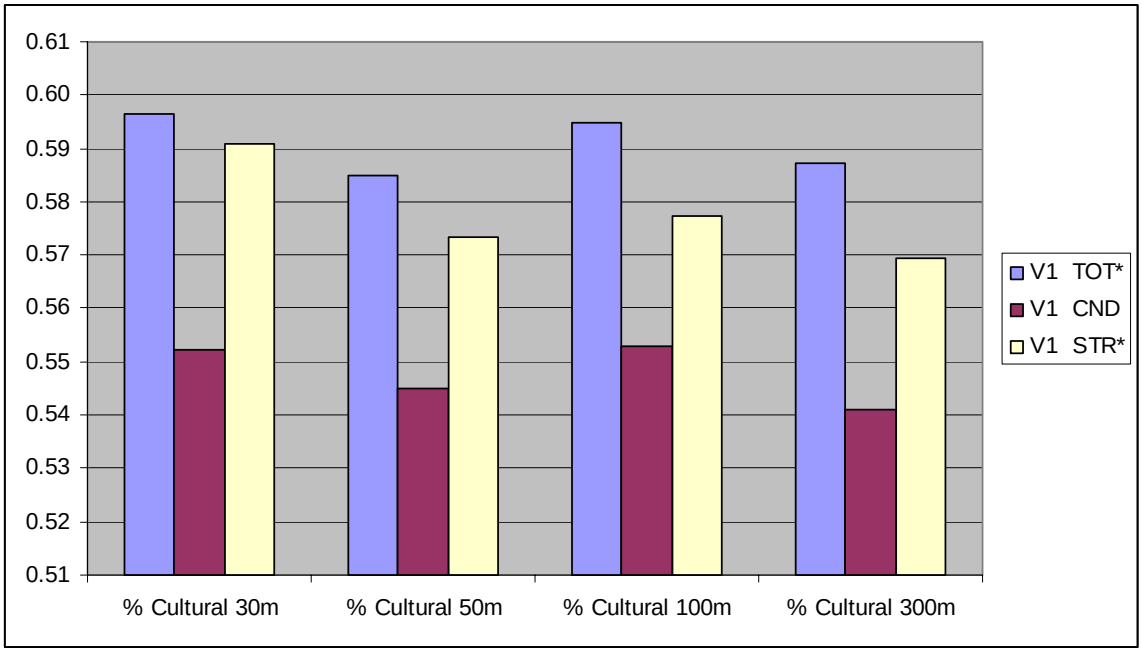


Figure 2. Absolute values of Spearman rank correlation coefficients (y-axis) between land use cover indices (x-axis) at various surrounding buffer-zone widths and RIRAM v.1 indices (series) of *total* score (TOT), *condition* score (CND), and *stressor* score (STR) for 50 assessment units in the H-P basins. P<0.01 for all. *minus landscape metrics

Figure 2 shows that the intensity of land use within buffer widths from 30m to 300m is correlated with all three measures of condition contained within RIRAM v.1. All RIRAM indices suggest that land use effects are similar across buffer-zone distances, and that surrounding land use intensity is at least partly responsible for wetland stresses and their

impacts. They also suggest that land use as far as 300m from a wetland may have an impact on its condition. This method of analysis could be further applied to determine if thresholds of impacts from land use exist, e.g. if correlations grow stronger or weaker as development intensity increases.

Total index correlations (*Total* index being the sum of stressor and condition scores) suggest that *Stressor* and *Condition* indices may work synergistically to characterize wetland response to landscape stress. This provides support for combining the metric categories into a *Total* index for certain applications.

Relationships between Invasive Plants and Wetland Condition

Another short-term objective for wetland monitoring identified in the RI Wetland Plan is to *monitor the location and extent to which invasive species are present and affecting wetland condition.* To demonstrate how RIRAM could be applied to address this objective, the 50 H-P assessment units were analyzed by summarizing species, mapping by cover class, and correlation of RIRAM v.1 indices versus invasive plant species % cover and species richness.

Nineteen invasive plant species were identified within our H-P study sites (Table 6). Many of these are wetland species, but some are upland (UPL) or upland-preferring (FACU) species that have encroached into the wetlands. For example, Oriental bittersweet (*Celastrus orbiculatus*; UPL) was overgrowing wetland flora from the edges of several wetlands, indicating buffer impacts. Barberry (*Berberis thunbergii*) and wild rose (*Rosa multiflora*), both FACU, were present mainly in floodplain wetlands, suggesting hydrologic impacts in some cases.

Figure 4 demonstrates how RIRAM data could be used to produce mapping products for decision support and outreach. Invasive plant species location is illustrated in relation to surrounding land use intensity. Color-coding depicts cover of invasive species by cover class, least intense being green and the most intense being red, laid over an analogous depiction of land use intensity generated from RIGIS *Land Use 2003-2004* geospatial data. Similarity in color coding between the two datasets illustrates the relationship between land use and invasive species incursion.

Although numerous factors may affect the establishment of invasive plant species, Figure 4 shows a general trend toward plant invasions occurring in approximate positive relationship to surrounding land use intensity. Table 7 clarifies and details relationships between invasive plant species occurrence and various stressors in the H-P basins. As suggested in Figure 4, Table 7 suggests that buffer degradation and land use in the surrounding landscape had a moderate-strength effect on invasive plant species cover and richness within our assessment units. The strongest within-wetland stressor effects on plant species invasion were nutrient enrichment, sheet runoff, and general filling (note that ranks are subtracted from *Stressor* and *Total* indices, hence negative coefficient values). This concurs with many other studies that conclude wetland invasion is often facilitated by nutrient enrichment, sedimentation, and filling (e.g. Bertness et al. 2002). *Stressor* and *Condition* indices indicate that stressors can have a cumulative effect on

increasing invasive species occurrence and species invasion can, in-turn, impact wetland condition (Table 7).

RIRAM v.1 data indicate that expected human-induced plant invasion processes may affect wetlands predictably on a wide scale; thus they might be predictably avoided or mitigated. Applied this way, RIRAM data could be a valuable tool in supporting invasive species prevention and control efforts for the State.

Table 6. Occurrences of invasive plant species observed within 50 study sites in the H-P basins

Scientific name	Common name	Percent of sites
Rhamnus frangula	European buckthorn	40
Celastrus orbiculatus	Oriental bittersweet	38
Berberis thunbergii	Japanese barberry	28
Rosa multiflora	Multiflora rose	28
Phragmites australis	Common reed	24
Lonicera morrowii	Morrow's honeysuckle	16
Phalaris arundinacea	Reed canary grass	14
Polygonum cuspidatum	Japanese knotweed	14
Cabomba caroliniana	Fanwort	8
Solanum dulcamara	Climbing nightshade	8
Euonymus alatus	Burning bush	6
Lythrum salicaria	Purple loosestrife	4
Myriophyllum sp.	Water milfoil sp.	4
Elaeagnus umbellata	Autumn olive	2
Ligustrum vulgare	European privet	2
Najas minor	Brittle water nymph	2
Polygonum perfoliatum	Mile-a-minute vine	2
Polygonum sachalinense	Giant knotweed	2
Rorippa naturtium-aquaticum	True watercress	2

Figure 3. Invasive plant species % cover at 50 H-P basin sites in 2008 against surrounding land use intensity.

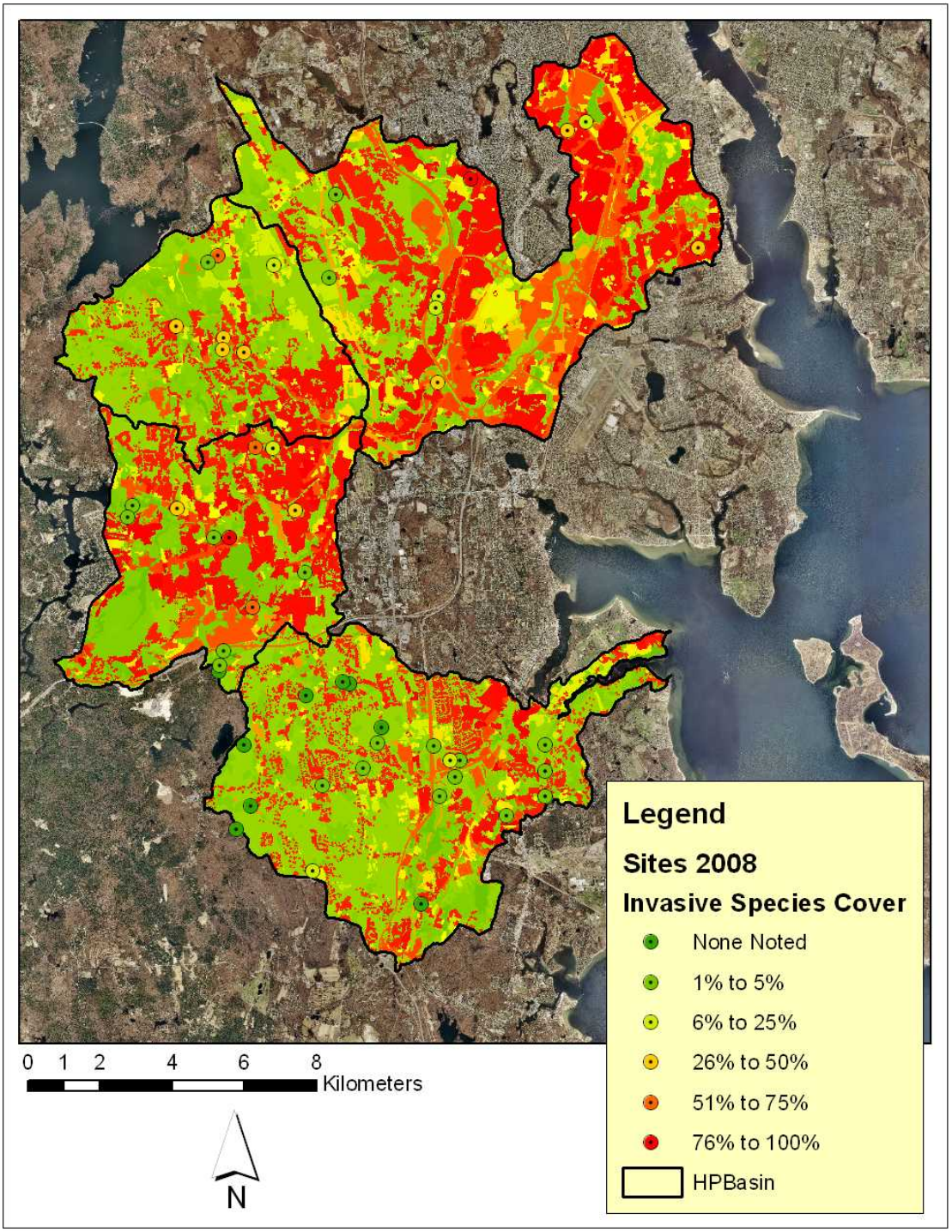


Table 7. Significant Spearman rank correlation coefficients (Rs) of RIRAM v.1 stressor ranks and indices versus invasive plant species cover class scores and species richness at 50 H-P sites in 2008. Higher *Stressor Total* index indicates less stress. Higher *INSP Cover* scores indicate less cover of invasive species. Higher *Landscape Metrics* scores indicate less intense land use.

Metric / Metric Category	INSP Cover Score		INSP Richness	
	Rs	P	Rs	P
Landscape Metrics				
5b. 100-m Weighted Buffer	0.38	< 0.01	-0.52	< 0.01
5a. % Cultural Cover 50m	0.40	< 0.01	-0.41	< 0.01
Hydrologic Stressors				
6a. Nutrient enrichment	-0.56	< 0.01	0.31	0.01
6a. Sheet runoff inputs	-0.45	< 0.01	0.36	< 0.01
6a. Road bed	-0.26	0.03	0.29	0.02
Habitat Stressors				
7. Other filling	-0.37	< 0.01	0.42	< 0.01
7. Dumping organic waste	-0.31	0.01	0.30	0.02
7. Roads / railroads	-0.29	0.02	0.32	0.01
Metric Categories				
Stressor Total	0.58	< 0.01	-0.64	< 0.01
Condition Total*	0.70	< 0.01	-0.64	< 0.01
RIRAM V1 Total Index*	0.68	< 0.01	-0.67	< 0.01

*minus invasive sp. metric

Effects of Stressors on Wetland Condition

Just as stressors can predictably contribute to the establishment of invasive species, stressors may individually or cumulatively contribute to the degradation of wetland condition in general. A long-term objective identified in the RI Wetland Plan is to *identify causes and sources of wetland degradation including cumulative impacts to wetlands.* To demonstrate how RIRAM v.1 might address this objective, the 50 H-P assessment units were analyzed by correlation of RIRAM *Stressor* ranks and indices against the RIRAM *Condition* index. Results indicate which stressors were most strongly associated with wetland degradation, and whether multiple stresses had cumulative impacts on wetland condition.

Table 8. Significant Spearman rank correlation coefficients (Rs) of RIRAM v.1 *stressor* ranks and index score versus *condition* index scores at 50 H-P sites in 2008. Higher *Landscape Metrics* scores indicate less intense land use. Higher *Stressor Total* index indicates less stress.

Metric / Metric Category	Condition		Metric / Metric Category	Condition	
	Rs	P		Rs	P
Landscape Stressors			*Habitat Stressors*		
5a. % Cultural Cover 50m	0.52	< 0.01	7. Other filling	-0.56	< 0.01
5b. 100-m Weighted Buffer	0.52	< 0.01	7. Dumping trash	-0.38	< 0.01
			7. Dumping organic waste	-0.34	0.01
Hydrologic Stressors			7. Roads / railroads	-0.29	0.02
6a. Sheet runoff inputs	-0.56	< 0.01	7. Mowing	-0.29	0.02
6a. Nutrient enrichment	-0.44	< 0.01	7. Clear cutting	-0.24	0.05
6a. Road bed	-0.38	< 0.01			
6a. Dike	-0.26	0.03	*Metric Category*		
6a. Stormwater inputs	-0.25	0.04	Stressor Index	0.79	< 0.01

Our data suggest that sheet runoff, nutrient inputs, and general filling were the main in-wetland contributors to wetland degradation in the H-P basins, while degradation of buffers and surrounding land use were also modestly correlated with wetland condition (Table 8). Cumulative stress (as represented by the *Stressor Total* metric category) was strongly correlated with wetland condition.

RIRAM v.1 data helps clarify the relationships among various stressors and wetland condition and demonstrates the effects of cumulative impacts on wetland condition. These data could be further applied to identify stressor thresholds and quantify the impacts of specific and multiple stressors on various wetland types. When applied in this way, RIRAM data could be valuable in assessing and minimizing wetland impacts during planning, and identifying activities most closely associated with wetland degradation.

2.3 Conclusions

RIRAM v.1 was modified to simplify the characterization of attributes, document evidence of stressors, update available habitat stressors, refine certain metric classes and minimize the subjectivity of certain metrics characterizing wetland response to cumulative stress (App. 2). The modified RIRAM was tested at 50 sites within our study area and the resulting metrics and indices were applied to demonstrations of the RAM's utility in addressing goals set by the RI Wetlands Plan (2006). Inter-user analyses indicated that the modifications enhanced the RAM's objectivity and utility in characterizing relative condition. Demonstration exercises conducted with the enhanced RAM supported those indications.

Three measures of inter-user variability representing user precision, statistical difference of means, and percent mean difference of scores all indicated a high degree of objectivity and reliability in RIRAM scoring indices and most metrics. This is likely in part due to assessors having worked together on several prior assessments and running assessment transects (silently) together before conducting RAMs separately; but this partly controlled for misinterpretation and misapplication of methods and focuses analysis results on RAM objectivity. Enhanced *condition* metrics, modified to reflect subconscious steps made in the original subjective metrics, were scored analogous to (Rs = 0.85) and more precisely than the original metrics with less average difference between users (Table 5).

A demonstration analysis on the effects of buffer degradation on wetland condition indicated that land use intensity was correlated with wetland condition to at least 300m. All buffer-zone widths correlated similarly with RIRAM indices. However, it is unclear whether larger buffer-zone correlations are an artifact of relationships with smaller buffer-zones that strongly affect wetland condition or if RIRAM is actually detecting remote impacts such as cumulative water pollution inputs from upstream development. Reapplication of this analysis using spatially exclusive (non-overlapping) buffer zones may help clarify these relationships.

The percent cover and species richness of invasive plants was expectedly correlated with several RIRAM stressor metrics and indices. Nutrient enrichment, sheet runoff, and general filling were most strongly correlated with invasive plant establishment in H-P

wetlands; these correlations may indicate stressor contributions to invasive species establishment and success. Correlations with the *Stressor* index (summing all significant and non-significant stressor metric scores) were stronger than with any individual metric, suggesting that cumulative stresses may act synergistically to facilitate invasive species success. Moderate to strong correlations with the *Condition* index demonstrate invasive species' resulting influence on wetland health.

Stressors within or surrounding a wetland may predictably affect wetland condition. Stressors having the strongest influence on wetland condition were determined by correlation analysis of various stressor metrics with the RIRAM *Condition* index (Table 8). Sheet runoff, nutrient enrichment, and general filling were among the highest contributors to wetland degradation within the study area. A much stronger correlation between the *Stressor* index (summing all significant and non-significant stressor metric scores) and the *Condition* index demonstrate the important effect of cumulative stress on wetland condition.

These analyses demonstrate how RIRAM could be applied to address objectives identified by the RI Wetland Plan. RIRAM data collected over a longer term could be used to identify trends relating to condition and stressors, such as stressor-response thresholds, synergistic stressor impacts, and impacts specific to particular wetland types or regions. And important to the project goals, these analyses indicate (through expected correlations) proper function of RIRAM v.1 in providing applicable (numeric), relative indices of wetland stress, response, and overall condition.

3. Validation of RIRAM v.1

Validation analyses were conducted by comparing RIRAM v.1 data to ORAM (Mack 2002; EPA Level 2), intensive biological and physical (EPA Level 3), and Landscape (EPA Level 1) data at 36 sites. Certain biological communities can reflect wetland ecological integrity because they are sensitive to environmental change and will predictably respond to cumulative stressor impacts (USEPA 2002a). Wetlands surrounded by high-intensity land uses are more likely to be stressed by nutrient, toxin, and sediment inputs, which can affect biological communities and degrade ecological integrity (USEPA 2002b).

RIRAM provides indices that may characterize wetland condition as it relates to affecting certain biota or other specific functions. Because no known biological or physical indicator (e.g. amphibian breeding capacity) can represent wetland condition across all potential functions (i.e. overall condition), biological and physical data must be viewed as indicating condition for a subset of the total functions a wetland may possess. Because RIRAM evaluates stressors and impacts to the various attributes that can affect a wetland's natural capacity to provide numerous functions and values, it may serve as a better measure of overall wetland condition. In this light, RIRAM may be applied as a high-resolution measure against which various biological indicators are evaluated, acting as the independent variable during validation exercises, where L1 landscape data are more commonly applied. RAM data have been previously used in this capacity (e.g. Andreas et al. 2004; Micacchion 2004).

Accordingly, the following validation exercises simultaneously evaluate all levels of monitoring data, assessing to what extent RIRAM (L2) data can characterize condition for specific functions, and to what extent L3 data can represent overall condition, while L1 data act as a coarse, but reliable measure of stressor intensity. Having no ultimate measure of condition, inter-validation between all three levels of monitoring data may be necessary to incrementally piece together the body of evidence needed to support the concept of characterizing overall wetland condition.

3.1 Methods

RIRAM v.1, ORAM, and various biological and physical variables were measured at 36 isolated wetlands. This effort took advantage of a chance opportunity to work with A. Curtis and P. Paton from the University of RI, who are working on evaluating rapid assessments for fauna in isolated ponds (Paton 2007, Curtis and Paton 2009). Curtis and Paton supplied biological and physical data to facilitate validation analyses against RIRAM v.1 data, which were collected by RINHS. RINHS also collected ORAM data, which has been previously inter-validated against amphibian and floral biological data (Micacchion 2004, Andreas et al. 2004)

3.1.2 Site Selection / Study Sites

Validation study sites were located throughout mainland RI (Fig. 5). Thirty-six sites were selected by Curtis and Paton (2009) according to a stratified random approach that

utilized three levels of surrounding land use intensity: high, moderate, and low. Sites ranged in size from 0.4 to 3.5 acres.

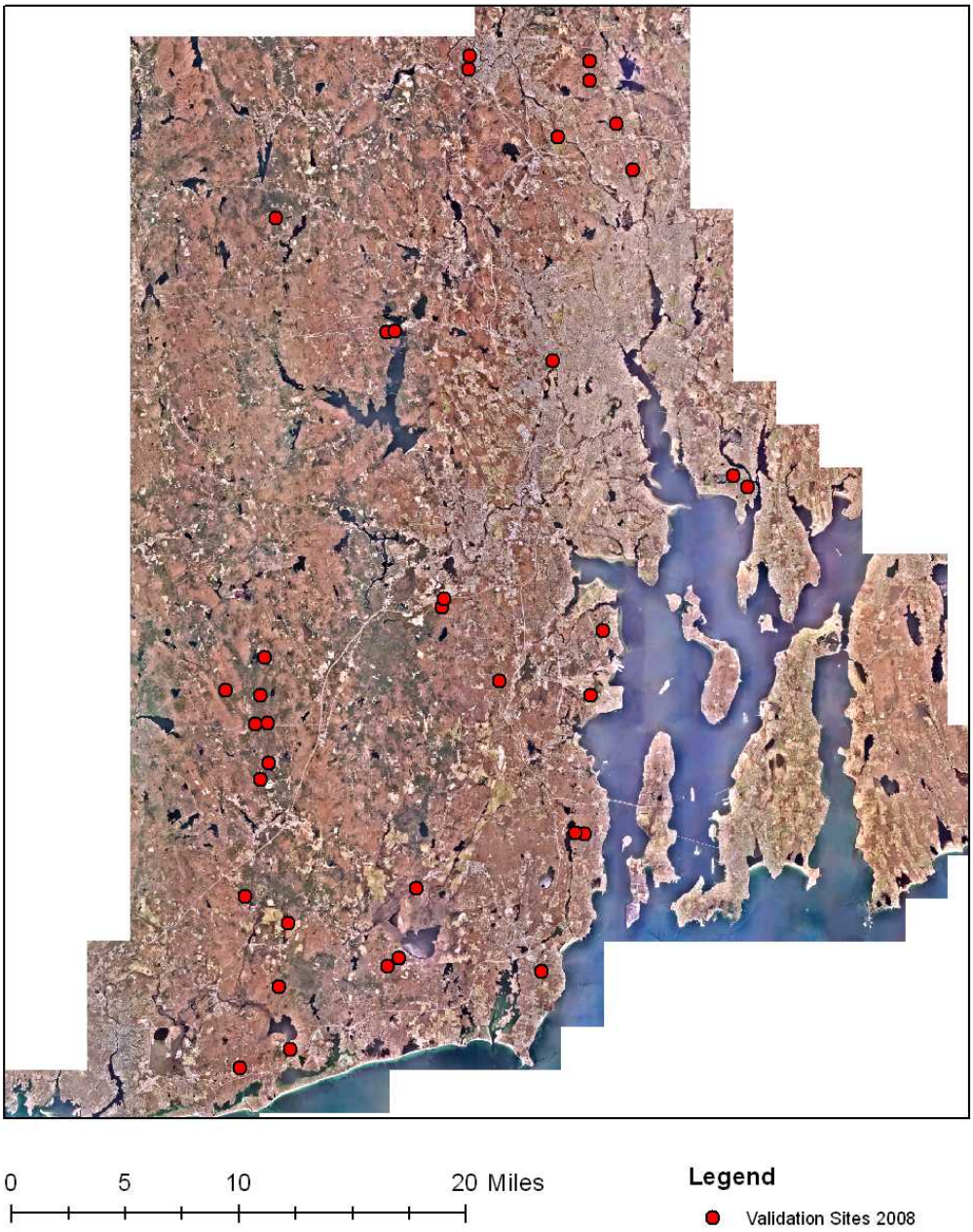


Figure 4. Locations of 36 Year-3 validation sites for RIRAM v.1

3.1.3 Sampling of Biological Data

Curtis sampled biological data at the 36 validation sites from March to October, 2008 (Curtis and Paton 2009). Biological data used for RIRAM validations were chosen based on ecological significance. They include wood frog (*Rana sylvatica*) and spotted

salamander (*Ambystoma maculatum*) egg mass densities, total vegetation cover, amphibian density and species richness, and invertebrate species richness.

Egg Mass Density Surveys

Egg mass surveys were conducted by Curtis according to Curtis and Payton (2009). Wood frog and spotted salamander egg masses were counted at each assessment unit four times each during the peak of breeding season for each species. Egg masses were quantified by wading along the perimeter of the flooded area of each wetland and tallying all egg masses observed. The largest number counted in a single sampling effort was used to calculate egg mass density by dividing the number by the area of the flooded basin. Basin area was calculated by the delineation of the flooded basin using photo-interpretation of georectified springtime aerial digital photography and automating area calculations using GIS. Area estimates were validated with field measurements of maximum basin area for the 2008 growing season (See Curtis and Paton 2009).

Total Vegetation Cover

Vegetation surveys were conducted by Curtis according to Curtis and Payton (2009). Vegetation % cover data for various floral life forms and strata were collected at each site throughout the growing season. Line intercept methods were used along one longitudinal and two transverse transects to estimate cover for the following vegetation groups: persistent emergent, non-persistent emergent, in-pond woody species, pond-margin woody species, aquatic bed, sphagnum mosses, other mosses, seedlings, and canopy. RINHS summed cover values for these groups to create an index of total vegetation cover.

Dip-net Surveys

Dip-net surveys were conducted by Curtis according to Curtis and Paton (2009). Curtis used a D-frame dip-net to sample all microhabitats of each pond by sweeping the net along the bottom at regular intervals. The number of sweeps made per pond was based on pond circumference. These data were used here to determine non-adjusted estimates of species richness for each site. Raw capture rates (represented by the mean number of individuals per sweep) are used here as a proxy for relative species density.

3.1.4 Sampling of Physical Data

Water Quality

Curtis sampled water quality data at 35 of the validation sites from May 28 to May 29, 2008, when chloride and nitrate levels tend to peak. Six water samples were collected from each site. The samples were analyzed in a climate-controlled laboratory for chloride, total nitrogen, and pH concentrations, and for specific conductance. For each variable, the average measure from the six samples was used for analysis (Curtis and Paton, 2009).

Landscape Degradation

Curtis quantified two measures of land use intensity within two buffer zones surrounding each study site according to Curtis and Paton (2009). Landscape measures used were road

density and % forested habitat at 1000-m and 250-m distances each. Values were derived using existing RIGIS (2008) data and GIS analysis (see Curtis and Paton 2009).

3.1.5 Rapid Assessment Methods

RAM Field Investigations

Sites were accessed on foot. One trained investigator assessed the perimeter and multiple transects of each validation site. Between four and six sites were assessed per day. The investigator conducted a RIRAM v.1 and ORAM assessment for each site. RIRAM methods were applied as described in Section 2.1.5 of this report, while ORAM was applied according to Mack (2001).

Field maps of each site were utilized for orientation and determining wetland community and buffer characteristics. Each map contained a backdrop of 2004 leaf-off color aerial photography at a scale sufficient to illustrate wetland habitats and surrounding land uses, with a delineation of the assessment unit, a delineation of the boundary of conserved land, a scale bar, and identifying information overlaid. A field guide to invasive freshwater wetland plants of RI was used to assist in invasive species identification.

RAM Remote Investigations

Data obtained during field investigations were updated, complemented, and completed via GIS analysis before data entry using the same methods outlined in Section 2.1.5.

3.2 Results

3.2.1 Biological Data

RIRAM v.1 indices significantly correlated with several biological measures collected by Curtis at the 36 validation sites (Table 9, Fig. 6). Selected results are presented and discussed here.

Wood Frog Egg Mass Density and Capture Rates

All RIRAM indices, *Condition*, *Stressor* and *Total* were correlated with wood frog egg mass densities (WFEMD) and wood frog capture rates (WFCR; Table 9). Wood frog breeding capacity is recognized regionally (e.g. MA, ME, VT, and RI) as a major indicator of vernal pool integrity (a vernal pool is a common type of isolated pond). The data indicate that RIRAM may characterize habitat condition for this ecological function, and that WFEMD and WFCR may act as indicators of overall condition for certain isolated ponds. Note that RIRAM v.1 outperformed ORAM in predicting WFEMD and WFCR. This is likely due to ORAM containing *value-added* metrics that may dilute its characterization of condition (Kutcher 2009).

Spotted Salamander Egg Mass Density

Spotted salamander egg mass density (SSEMD) showed a significant, weak correlation with RIRAM v.1 *Stressor* and *Total* indices (Table 9). Spotted salamanders are also recognized regionally as vernal pool indicator species. The data suggest that spotted salamanders may be more sensitive to landscape degradation than to in-pool condition

(Table 10). Their breeding presence may be a useful partial indicator of condition in isolated wetlands, especially relating to buffer integrity. The data also suggest that RIRAM v.1 is capable of characterizing isolated wetland condition with respect to spotted-salamander reproductive capacity. ORAM was not significantly correlated with SSEMD.

Amphibian Species Richness

Amphibian species richness is represented by two categories according to Curtis and Paton (2009): (1) all amphibians (total amphibian species richness—TASR) and (2) amphibians preferring seasonal over perennial hydroperiods (seasonal amphibian species richness—SASR). SASR includes all species except for bull frog (*Rana catesbeiana*), green frog (*R. clamitans*), and red-spotted newt (*Notopthalmus viridescens*). Both TASR and SASR correlated with all RIRAM v.1 indices, but not with ORAM (Table 9). Amphibian species richness has previously been shown to be a weak indicator of wetland condition in itself (e.g. Micacchion 2004). This may be particularly true in the Northeast where some amphibian species may preclude others through predation. The data suggest that SASR may be a better indicator of isolated pool condition than TASR; likely because predator species, which may thrive on intermediate levels of disturbance, do not increase its value.

In effect, SASR acts as a rudimentary IBI incorporating two Coefficients of Conservatism (C of C's). C of C's are weighting factors applied to species based on attributes such as commonness, obligation to habitats, and native status; they are generally applied to produce a weighted richness index. Here, simple C of C's for SASR apply as follows: seasonal pond amphibians = 1; perennial pond amphibians = 0. Methods have been developed to enhance amphibian species data by assigning multiple C of C's to various species and incorporating them into a weighted model. One such model has been shown to characterize wetland *value-added* condition reasonably well in comparisons to ORAM data ($R=0.58$, $P<0.01$) and a more complex amphibian IBI model has been developed to correlate with ORAM more strongly ($R=0.76$, $P<0.01$; Micacchion 2004). Development of an effective amphibian-based IBI to characterize wetland condition in this region is beyond the scope of this project. However, the correlations indicate the potential of amphibian community composition for the characterization of condition for isolated wetlands in RI. The data also suggest that RIRAM v.1 may characterize wetland condition for certain amphibian communities. Further work will be needed to determine the strength and utility of this relationship.

Total Vegetation Cover

Total vegetation cover (TVEG) was calculated as the sum of selected vegetation strata cover collected by Curtis. TVEG, which functions here as a simple vegetation-based IBI representing habitat productivity, was correlated with all RIRAM v.1 indices (Table 9). TVEG may be a relevant biological indicator of condition because our validation sites were all isolated ponds; this partly standardized the natural variability of vegetation structure across the sites. Although using this index would not be relevant across varied wetland types, here it provides a viable measure of vegetation integrity to the degree that vegetation is naturally similar among sites.

A more complex vegetation index utilizing C of Cs (described in the above section) would likely provide a more reliable and broadly applicable IBI, and a better correlation with RIRAM. Developing vegetation C of Cs is beyond the scope of this project. However, even without weighting factors, these data suggest that RIRAM characterizes wetland condition relating to vegetation productivity, and that a regional vegetation-based IBI could be developed to provide a useful measure of overall wetland condition.

Here, ORAM correlates more closely with TVEG than RIRAM v.1 (Table 9). This is likely due to *value-added* metrics inherent in ORAM affecting its characterization of condition. ORAM *value-added* metrics are largely based on natural vegetation structure and composition, which are also inherently represented in TVEG. Both ORAM and TVEG include vegetation structure and composition components that are largely inherent and therefore do not purely represent condition; this similarity in function between the indices likely contributed to a closer correlation with ORAM.

Other Biological Data

Single vegetation cover measures that correlated with RIRAM indices were sphagnum (Rs=0.36, P=0.02), other mosses (Rs=0.48, P<0.01), and seedlings (Rs=0.30, P=0.04), while more pervasive groups such as canopy, persistent emergent, woody within-wetland, woody edge, sapling, aquatic bed, and floating algae were not correlated; these must have contributed synergistically to the TVEG index.

Capture rates of marbled salamanders (*A. opacum*), another vernal pool indicator species, correlated with RIRAM *Stressor* and *Total* indices, but not with RIRAM *Condition* or ORAM (Table 9). Macroinvertebrate species richness (MINSR) showed little promise for characterizing isolated wetland condition, although enhancing the data through IBI development could change that interpretation (Table 9). Interestingly, WFEMD was negatively correlated with MINSR (Rs=-0.43, P<0.01), which may indicate a predator-prey relationship.

Table 9. Spearman rank correlation coefficients and probability values among various biological, rapid, and landscape indices collected at 36 isolated wetlands in RI in 2008. Biological data provided by A. Curtis 2008.

	RIRAM Stressor	RIRAM Condition	RIRAM Total	ORAM Total
Wood Frog Egg Mass Density				
Correlation coefficient	0.59	0.58	0.62	0.42
two-sided significance	<0.01	<0.01	<0.01	0.01
Spotted Salamander Egg Mass Density				
Correlation coefficient	0.39	0.30	0.36	0.28
two-sided significance	0.02	0.07	0.03	0.09
Wood Frog Capture Rate				
Correlation coefficient	0.51	0.51	0.54	0.36
two-sided significance	<0.01	<0.01	<0.01	0.03
Marbled Salamander Capture Rate				
Correlation coefficient	0.38	0.28	0.37	0.33
two-sided significance	0.02	0.10	0.03	0.05
Seasonal Amphibian Species Richness				
Correlation coefficient	0.40	0.45	0.46	0.28
two-sided significance	0.02	<0.01	<0.01	0.10
Total Amphibian Species Richness				
Correlation coefficient	0.35	0.42	0.40	0.31
two-sided significance	0.03	0.01	0.01	0.06
Total Vegetation				
Correlation coefficient	0.41	0.50	0.46	0.63
two-sided significance	0.01	<0.01	<0.01	<0.01
Macroinvertabrate Richness				
Correlation coefficient	-0.19	-0.06	-0.14	0.10
two-sided significance	0.26	0.75	0.42	0.58

Table 10. Spearman rank correlation coefficients and probability values between RIRAM stressor categories and spotted salamander egg mass density collected at 36 isolated wetlands in RI in 2008. Biological data provided by A. Curtis 2008.

	SSEMD
RIRAM Landscape* Stressors	
Correlation coefficient	0.48
two-sided significance	<0.01
RIRAM In-Wetland Stressors**	
Correlation coefficient	0.27
two-sided significance	0.11

* Metric 5 score
** Sum of Metric 6 and Metric 7 scores

3.2.2 Physical Data

Three physical measures of water quality were correlated with RIRAM v.1 data at 35 validation sites. These included specific conductivity, pH, and chloride concentration; total Nitrogen concentration was not correlated. All landscape metrics generated by Curtis were correlated with all RIRAM v.1 indices.

Specific Conductivity

Specific conductivity (SC) is a measure of conductive ion concentration often used as an indirect measure of total dissolved solids and salts, which, in freshwater systems, are often associated with water pollution from runoff. All RIRAM indices were negatively correlated with SC (Table 11). This suggests that RIRAM indices may reflect runoff pollution and its impacts on wetlands. WFEMD was also negatively correlated with SC ($Rs=-0.40$, $P<0.01$), which provides further evidence that both may indicate isolated wetland condition.

Hydrogen Ion Concentration (pH)

Hydrogen ion concentration (pH) is an indicator of acidity, which may affect amphibian breeding success (Pierce et al. 1984), although cited thresholds were not approached at our sites. All indices of RIRAM are negatively correlated with pH (Table 11). However, pH may be a tricky indicator for wetlands because it varies according to wetland type, water level, weather, and seasonal and daily cycles. Once standardized, pH generally positively correlates with specific conductance, perhaps due to both being associated with inputs of minerals that contribute ions (F. Golet, personal communication). Correlations between RIRAM and pH suggest that RIRAM may indicate water pollution from runoff.

Chlorides

Chlorides are a suite of salts based on Chlorine and a metal. Elevated levels of chlorides in waters are generally associated with roadside and agricultural runoff, industrial waste, pesticides, and sewer treatment effluent. All indices of RIRAM v.1 were negatively correlated with chloride values from Curtis (Table 11). This also suggests that RIRAM indices may indicate pollution inputs and their impacts on wetlands.

Landscape Degradation

Curtis calculated landscape metrics to serve as coarse condition proxies. All Curtis landscape metrics were significantly correlated with RIRAM indices (Table 12). This was expected since landscape degradation metrics are incorporated in RIRAM *Stressor* and *Total* indices. Landscape metrics are not incorporated in the RIRAM *Condition* index, thus those correlations demonstrate *Condition*'s expected function of characterizing wetland response to external stresses. Moderate correlations with measures out to 1000m likely reflect covariation with smaller buffer-zones, not direct wetland impacts, since it seems unlikely that RIRAM detects stresses or impacts stemming from the outer portions of such a large zone. ORAM also incorporates similar landscape metrics; however, ORAM did not correlate with road density at either buffer-zone width and was not as closely correlated with % forested habitat as RIRAM.

Other Physical Measures

Total Nitrogen levels were not correlated with any RAM indices (Table 11). Total Nitrogen is a direct measure of the concentration of one of two major nutrients that can affect wetlands. Although metrics rating evidence of nutrient inputs are included in RIRAM, RIRAM did not detect Nitrogen variation or wetland response to that variation; likely because Nitrogen levels at all Validation sites were well below levels that would affect vegetation or other nutrient indicators (L. Greene, personal communication).

Physical measures collected by Curtis characterizing hydroperiod and basin depth were not considered in analysis because they were expected to be more innate wetland characteristics than indicators of condition.

Table 11. Spearman correlation coefficients and probability values between water quality variables and rapid indices collected at 36 isolated wetlands in RI in 2008. Physical data provided by A. Curtis 2008.

	RIRAM Stressor	RIRAM Condition	RIRAM Total	ORAM Total
Specific Conductance				
Correlation coefficient	-0.63	-0.71	-0.68	-0.58
two-sided significance	<0.01	<0.01	<0.01	<0.01
pH				
Correlation coefficient	-0.54	-0.54	-0.55	-0.41
two-sided significance	<0.01	<0.01	<0.01	0.02
Chlorides				
Correlation coefficient	-0.49	-0.54	-0.52	-0.64
two-sided significance	<0.01	<0.01	<0.01	<0.01
Total Nitrogen				
Correlation coefficient	0.02	-0.13	-0.05	-0.21
two-sided significance	0.90	0.45	0.79	0.23

Table 12. Spearman correlation coefficients and probability values between Landscape measures and rapid indices collected at 36 isolated wetlands in RI in 2008. Landscape data provided by A. Curtis 2008.

	RIRAM Stressor	RIRAM Condition	RIRAM Total	ORAM Total
Road Density 1000 m				
Correlation coefficient	-0.48	-0.41	-0.44	-0.32
two-sided significance	<0.01	0.01	0.01	0.06
Road Density 250 m				
Correlation coefficient	-0.40	-0.37	-0.39	-0.32
two-sided significance	0.02	0.03	0.02	0.06
% Forested 1000 m Buffer				
Correlation coefficient	0.55	0.44	0.49	0.38
two-sided significance	<0.01	0.01	<0.01	0.02
% Forested 250 m Buffer				
Correlation coefficient	0.71	0.51	0.60	0.54
two-sided significance	<0.01	<0.01	<0.01	<0.01

3.3 Conclusions

All validation results point toward the proper functioning of RIRAM v.1 in providing a relative representation of wetland condition. Correlations with biological and physical indicators of wetland integrity indicate proper RAM function in all three indices: *Stressors*, *Condition*, and *Total*. This was expected, since RIRAM v.1 is based on intensity of in-wetland and landscape stressors, and the response of the wetland vegetation to cumulative stress (see App. 2). So, the cumulative intensity of stresses acting on a wetland incrementally reduces its RIRAM score and is likewise expected to incrementally diminish habitat suitability for biota; and because RIRAM is designed to score wetlands on a continuum ranging from pristine to destroyed, biotic response will necessarily fall somewhere within the RAM's range.

Validation results indicate that RIRAM v.1 reflects relative condition for a number of biological functions, predictably correlating with accepted biological measures of isolated pond integrity. RIRAM was positively correlated with raw capture rates (relative density) of three amphibian species commonly used to indicate vernal pool integrity: wood frogs, spotted salamanders, and marbled salamanders; and with wood frog and spotted salamander egg mass density. Likewise, RIRAM positively correlated with total and seasonal-pool-preferring amphibian species richness. RIRAM also correlated with total vegetation cover, which was used as a proxy for vegetation productivity. RIRAM was not correlated with raw capture rates of macroinvertebrates.

RIRAM correlations with biological measures were mostly moderate or weak (Rs<0.70), but this must be interpreted within the context of all contributing factors. Natural factors such as hydroperiod, geographic location, proximity to other ponds, pond size, and natural vegetation structure and composition affect biological communities as well. Although wetland condition may have a strong affect on certain species, it can only act as a portion of the total factors determining habitat suitability. The fact that RIRAM v.1 is

positively associated with species thought to indicate pond integrity suggests that it reflects that portion of suitability determined by condition. Development of IBIs incorporating coefficients of conservatism would likely produce stronger correlations, but this was beyond the immediate scope of this project.

Moderate and strong correlations with indicators of runoff pollution suggest that RIRAM detects wetland degradation caused by the impairment of water quality. Interestingly, RIRAM takes no physical measures of water quality; it instead rates land use intensity, buffer degradation, hydrologic alterations, and habitat alterations (all of which are potential sources of runoff pollution), and considers wetland response. These validation data suggest that runoff pollution has a relatively strong effect on overall wetland condition. Our Development and Demonstration analyses concur (see Section 2.2.3, Tables 7 and 8).

As expected, RIRAM correlated with all measures of landscape integrity calculated by Curtis. Landscape (L1) data are unique here in that they are strictly objective, quantitative, and controlled; unaffected by user skill, weather conditions, time of year, or other biases and uncertainties of L2 (RAM) and L3 (intensive biological and physical) data. Thus, landscape data provide reliable, albeit coarse, validation of proper RAM function.

4. Discussion

4.1 RIRAM Development

4.1.1 Determination of Assessment Boundaries

Determining assessment unit boundaries is a critical first step in wetland rapid assessment, since it may affect the outcome of the RAM. Methods for determining assessment boundaries are detailed in ORAM v.5.0 (Mack 2001). These methods were adequate for assigning assessment boundaries for our Development and Demonstration sites because they were located in a fragmented landscape. For more pristine areas containing vast, interconnected wetland complexes, the methods may be insufficient to break the wetlands into reasonably-sized assessment areas.

Removing *value-added* metrics from the scoring in RIRAM v.1 lowers the importance of using highly-standardized unit determination methods, since characteristics commonly related to size (e.g. area, complexity of vegetation structure and composition, depth) are not included in the scoring. RIRAM v.1 rates the assessment unit by stressors and condition alone and is intended to assess the unit chosen. In this regard, RIRAM is more flexible in its application since, depending on the objective, an entire wetland or a partial wetland can be assessed. Nevertheless, Mack protocols should be applied as strictly as possible, unless the objectives of the effort require otherwise. Rules may need to be added to address the vast, interconnected wetland complexes common in RI.

Current geospatial data available for RI are deficient for determining assessment units due to mapping errors and inaccuracies. Updating high-resolution geospatial data in RI has been identified as a monitoring priority in the RI Wetland Plan. The National Wetlands Inventory is currently working on a dataset for RI. Whether this is detailed enough to address the variety of needs identified in the Plan has yet to be determined. The continuation of RAM application on a rotating basin schedule and the availability of high-resolution electronic imagery, position the State to produce or refine wetland geospatial data incrementally, in concert with RAM investigations.

4.1.2 Site Selection

Revised site selection methods were developed in Year-3. The operative change was the inclusion of the conservation property in determining % developed land within the buffer. The use of a closed buffer polygon (rather than a donut, as previous) provided a smoother land use intensity gradient than in Year-2. Counterproductive was a lack of proximate, analogous replacement sites for units that could not be accessed. Due to this, many of our most stressed potential sites were not replaced in the study (mainly farm sites). Access to agricultural wetlands would enhance the development of the RAM, since it would likely provide assessment units at the lower end of the condition spectrum. RINHS will work with DEM in Year-4 to ensure greater access to agricultural wetlands.

4.1.3 Field and Remote Investigations

RIRAM assessments were conducted by a combination of field and remote investigations. Time to complete an assessment ranged between two and five hours,

averaging two assessment units per day. This fits the definition of rapid assessment according to EPA (Fennessy et al. 2004). The process of site access and assessment has become more efficient with practice. Detailed assessment methods will be documented in guidance literature as the RIRAM approaches a finished product.

4.1.4 RIRAM v.1 Metrics and Indices

RIRAM meets all the criteria laid out by Fennessy et al. (2004) in an EPA review and recommendations document of rapid assessment methods for assessing wetland condition. First, it measures wetland condition, presented as a numeric value along a continuum ranging from degraded to pristine. Second, it is rapid; it takes less than half of a day to conduct. Third, RIRAM is an on-site assessment; it does not rely exclusively on landscape inferences of land use or wetland potential. Finally, RIRAM can be verified through empirical analysis, as demonstrated in this report.

RIRAM follows further recommendations from Fennessy et al. (2004). RIRAM is not confounded by *value-added* metrics that increase index values according to natural attributes such as size, diversity, and geographic setting, thus it is "blind" to wetland type; i.e. it is not driven by wetland type or by scoring functions and values; instead, index values are determined by the relative severity of stressors and general wetland response to cumulative stress. Also, the analyses indicated that RIRAM is objective and repeatable. Finally, RINHS is working on establishing RIRAM validation through analysis with Level 3 data, as recommended (Section 3).

Inter-user variability analyses (Section 2.1) indicated a high degree of precision for RIRAM indices and most individual metrics between users, with mean scoring differences ranging from two to four percent for indices. For inter-user data, both assessors accessed and assessed all sites at the same time, running assessment transects together (silently) before scoring separately. I would not expect such high precision between two trained assessors scoring each wetland on completely separate surveys. Inter-user variability is not a problem of rapid assessment alone. Biological surveys are also subject to user-biases, such as skill and interpretation of methods, as well as weather, time of year, and numerous other influencing factors. With both types of data, results need to be viewed in terms of trends and not absolutes, as inconsistencies are almost inevitable.

Section 2.2.2 provides evidence to support the replacement of original ORAM condition metrics with more objective and detailed analogous metrics developed for RIRAM v.1. The improved metrics were used to calculate RIRAM v.1 index scores used in demonstration and validation analyses; all analyses indicate that RIRAM v.1 functions properly in this format.

A second version *RIRAM v.2* was also tested at the 50 H-P sites in Year 3 (see Section 2.1). This version incorporates concepts and components of RIRAM v.1 into a more intuitive and systematic model that utilizes an evidence-based approach. It is expected that v.2 will provide analogous and enhanced utility compared with v.1. The results of RIRAM v.2 tests will be provided subsequently as an addendum to this report.

4.2 RIRAM Applications and Limitations

Our demonstration exercises provide examples of applications of RIRAM data in the context of State monitoring and assessment objectives (Sec. 1.1.1). The analyses suggest that RIRAM v.1 provides effective relative indices for elucidating relationships between individual stressors, cumulative stressors, wetland condition, invasive species, and landscape degradation. The data provided by RIRAM may be further utilized in queries to shed light on other common and unforeseen questions regarding wetland condition. But RIRAM data must be applied with caution until its validity in representing relative wetland condition has been thoroughly confirmed through further analysis.

While the validation analyses suggest proper RAM functionality, the evidence they supply pertains to select types of wetlands and taxa; it does not confirm broad applicability. The validation analyses indicate that RIRAM may reflect ecological integrity for amphibian communities using isolated ponds, and detect stresses from landscape degradation and runoff pollution. Concurrence of analogous results from our demonstration analyses lends confidence to the validations. For example, demonstrations of the effects of surrounding land use on wetland condition in H-P basins concur with landscape validations based on Curtis's data. Likewise, both studies indicate that RIRAM v.1 may detect impacts of runoff inputs. Further validation analyses are needed to confirm RIRAM validity in characterizing wetland condition for all types of wetlands and for various functions and values. Confidence in RAM application will only grow relative to a growing body of supporting evidence of its functionality and utility; this should be a focus of further work.

RIRAM produces relative indices; they are not direct measures of condition or stress. Similarly, RIRAM does not quantify wetland functions or values and is not intended to categorize wetlands by levels of protection. RIRAM is designed to compare each wetland to its own theoretical pristine state. Deviations from pristine are given intensity-rank scores that are summed to characterize total deviation from pristine; i.e. the change from full integrity, which defines condition (USEPA 2006). This allows RIRAM to be applied in characterizing relative condition across wetland types and identifying reference sites. RIRAM v.1 makes no attempt to quantify stressor intensity on a proportional basis per wetland, which would improve relativity between wetland types and sizes. RIRAM v.2, discussed in a forthcoming addendum to this report, does employ both intensity and proportionality.

RIRAM data are not based on any direct measurements. All metrics are based on inference, estimation, or interpretation. Landscape metrics utilize estimation and measurements based on photo-interpretation. Results are used to infer in-wetland condition from surrounding land use intensity. Other s*tressor* metrics are based on observation and estimation/interpretation of stressor intensity. Response and other *Condition* metrics are largely based upon interpretation, except for invasive species cover, which is estimated. Although the data indicate that producer errors are minimized (as opposed to magnified) by the summing of estimated/interpreted metrics (see Table 3), respective cautions should be used when applying and interpreting RIRAM data.

To produce RIRAM indices, metrics are summed according to an empirical modification of the original metric scores from ORAM (Mack 2005). Metric scores and their relative weights have not been calibrated in any way since. Thus, metric and index scores should be treated as ordinal (rank) data, as they are throughout this document (as indicated by the application of Spearman rank rather than Pearson correlation analysis). Future calibrations could set RIRAM data on a predictive scale, which could be useful in interpreting scores (e.g. a score of 95 is always “excellent” and a score of 55 is always “poor”). However, it is unlikely that standard model calibration strategies (to increase power by removing overlapping covariates) would be helpful in enhancing this RAM’s utility, since RAM metrics may work in unison or separately, and have varying impacts, depending on the situation.

In its finished form, RIRAM will be a useful component in wetland monitoring and assessment. First, RIRAM will produce an index that can provide a central condition gradient and identify control sites for the development of reference-based landscape and intensive (e.g. IBI) models. It will provide stress/response data for studies of specific wetland impacts. It will provide baseline data that may be useful for prioritizing wetlands for protection, detecting change, and assessing wetland response to changes such as development and climate change. Finally, it will provide a defensible way to rapidly quantify and illustrate (relative) wetland condition, which will provide the State with scientific evidence needed to affect policy.

Literature Cited

Anderson, J.R. 1976. *A Land use and Land cover Classification for use with remote Sensor Data*. Geological Survey Professional Paper 964, Washington, D.C. 28 pp

Andreas, B.K., J.J. Mack, and J.S. McCormac. 2004. *Floristic Quality Assessment Index (FQAI) for vascular plants and mosses for the State of Ohio*. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, OH. 219 pp.

Bertness M.D., Ewanchuk P.J., Silliman B.R. 2002. *Anthropogenic modification of New England salt marsh landscapes*. PNAS 99:1395–98

Cowardin, L.M, V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. Office of Biological Services, Fish and Wildlife Service, U.S Dept. of the Interior. Washington, D.C. 131 pp.

DEM (RI Department of Environmental Management). 2006. *Rapid assessment of wetland condition: testing existing RAMs in Rhode Island*- Unpublished draft report. Rhode Island Department of Environmental Management Office of Water Resources, Providence, RI. 12 pp.

DEM (RI Department of Environmental Management). 2005. *State of Rhode Island and Providence Plantations water monitoring strategy, 2005-2010.* Rhode Island Department of Environmental Management Office of Water Resources, Providence, RI. 102 pp.

Enser, R. W. and J. A. Lundgren. 2006. *Natural communities of Rhode Island*. A joint project of the Rhode Island Dept. of Environmental Management Natural Heritage Program and The Nature Conservancy of Rhode Island. Web published by R.I. Natural History Survey, Kingston, RI. Available [on line] at: www.rinhs.org. 44 pp.

Fennessy, M.S., A.D. Jacobs, and M.E. Kentula. 2004. *Review of rapid methods for assessing wetland condition*. EPA/620/R-04/009. U.S Environmental Protection Agency, Washington, D.C. 75 pp.

Golet, F.C. 1976. *Wildlife wetland evaluation model* in [J.S. Larson Ed.] Models for Assessment of Freshwater Wetlands. Publi. No. 32, Water Resources Research Center, University of Massachusetts at Amherst, Amherst, MA, pp. 13-34.

Jacobs, A.D. 2007. *Delaware rapid assessment procedure version 5.0*. Delaware Department of Natural Resources and Environmental Control, Dover, DE. 35 pp.

Kutcher, T.E. 2009. *Rapid assessment of freshwater wetland condition; development of a rapid assessment method for freshwater wetlands in Rhode Island.* Technical report prepared for the RI Department of Environmental Management, Office of Water Resources, Providence, RI. 100pp. including appendices.

Mack, John J. 2001. *Ohio rapid assessment method for wetlands, manual for using version 5.0*. Ohio EPA Technical Bulletin Wetland/2001-1-1. Ohio Environmental Protection Agency, Division of Surface Water, 401 Wetland Ecology Unit, Columbus, Ohio. 64 pp.

Mehrhoff, L. J., J. A. Silander, Jr., S. A. Leicht, E. S. Mosher and N. M. Tabak. 2007. *IPANE: Invasive plant atlas of New England*. Department of Ecology & Evolutionary Biology, University of Connecticut, Storrs, CT, USA. Available [on-line] at http://www.ipane.org

Micacchion, Mick. 2004. *Integrated Wetland Assessment Program. Part 7: Amphibian Index of Biotic Integrity (AmphIBI) for Ohio Wetlands*. Ohio EPA Technical Report WET/2004-7. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water, Columbus, Ohio.

Miller, N.A., F.C. Golet, and P.V. August. 2001. *Options for mapping Rhode Island's wetlands: Reccomendations based on user needs and technical, logistical, and fiscal consideration*. Final Report prepared for RI Department of Environmental Management Office of Water Resources and USEPA, Region 1. University of Rhode Island Department of Natural Resources Science, Kingston, RI

Mitchell, J.C., F.C. Golet, D.E. Skidds and P.W.C Paton. 2007. *Prioritizing non-regulatory protection of vernal pools in the Queen's River watershed, Rhode Island*. Final Research Report. Prepared for RI Department of Rnvironmental Management Office of Water Resources and U.S. Environmental Protection Agency Region1.

NEIWPCC and DEM. 2006 (New England Interstate Water Pollution Control Commission and RI Department of Environmental Management). *RI Freshwater wetlands monitoring and assessment plan.* Unpublished report. Rhode Island Department of Environmental Management Office of Water Resources, Providence, RI. 58 pp.

Paton, P. 2007. *Assessing the effects of human disturbance on New England isolated wetlands using a 3-tiered rapid assessment protocol*. Quality assurance project plan (QAPP). USEPA Region 1. Boston, MA. 19 pp.

RIGIS. 2007. *Rhode Island Geographic Information System Data*. Available [on-line] at: http://www.edc.uri.edu/rigis/

USACOE. 1993 *The Highway Methodology workbook*. US Army Corps of Engineers New England Division. 28pp.

USEPA. 2006. *Application of elements of a state water monitoring and assessment program for wetlands.* Wetlands Division, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency. Available [on line] at: http://www.epa.gov/owow/wetlands/monitor/. 12 pp.

USFWS. 2007. *U.S. Fish and Wildlife Service Rhode Island Spatial Data*. Available [on-line] at: http://www.fws.gov/data/statdata/ridata.html

Appendix 1

Original RIRAM v.1 Field Datasheet as Recommended by Kutcher (2009)

Background Information

Investigator(s):	
Date:	
Affiliation:	
Address:	
Phone Number:	
Email:	
Name of Wetland:	
Site Code:	
Town:	
Property/Easement Owner:	
Access Directions:	
HGM Class(es):	
NWI Class(es):	Dominance Type(s):
RINHP Community Type(s):	
Lat/Long:	
HUC 12 Name:	
HUC 10 Name:	
HUC 8 Name:	
Assessment Unit Size (acres):	
Photos Taken:	

Site Number: **Raters:** **Date:**

I. WETLAND ATTRIBUTES

1. Wetland Area

max 6 pts.

Select one

- ☐ >50 acres
- ☐ 25 to 50 acres
- ☐ 10 to <25 acres
- ☐ 3.0 to <10 acres
- ☐ 0.3 to <3.0 acres
- ☐ 0.1 to <0.3 acres
- ☐ <0.1 acres

2. Hydrologic Characteristics and Functions

max 16 pts.

2a. Sources of groundwater. Select all that apply.

- ☐ Groundwater
- ☐ Precipitation
- ☐ Seasonal/intermittent surface water
- ☐ Perennial surface water

2b. Connectivity. Select all that apply.

- ☐ 100 year flood plain
- ☐ Between stream/lake and human use
- ☐ Part of a wetland or upland complex
- ☐ Part of a riparian or upland corridor

2c. Maximum water depth. Select one.

- ☐ > 0.7m
- ☐ 0.4 to 0.7m
- ☐ <0.4m

2d. Duration of water. Select one or double check.

- ☐ Semi- to permanently inundated
- ☐ Semi- to permanently saturated
- ☐ Seasonally inundated
- ☐ Seasonally saturated in the upper 30cm
- ☐ Regularly inundated/saturated (tidal)

3. Habitat Characteristics and Functions

max 20 pts.

3a. Wetland vegetation components

Rate all present using 0 to 3 scales at right.

- ☐ Aquatic bed
- ☐ Emergent
- ☐ Shrub
- ☐ Forest
- ☐ Mudflats
- ☐ Open water
- ☐ Sphagnum

3b. Horizontal interspersion

Select one.

- ☐ High
- ☐ Moderately high
- ☐ Moderate
- ☐ Moderately Low
- ☐ Low
- ☐ None

3c. Microtopography

Rate all present using 0 to 3 scale at right.

- ☐ Vegetated hummucks/tussucks
- ☐ Coarse woody debris >15cm
- ☐ Standing dead >25cm dbh
- ☐ Amphibian breeding pools

Vegetation Community Cover Scale Apply to metric 3a

0	Absent, or comprises <0.1ha **and** <30% contiguous aerial cover
1	Present and either comprises a small part of the wetland's vegetation and is of moderate quality, or comprises a significant part but is of low quality
2	Present and either comprises a significant part of the wetland's vegetation and is of moderate quality, or comprises a small part and is of high quality
3	Present and comprises a significant part or more of the wetland's vegetation and is of high quality

Mudflat and Open Water Cover Scale Apply to metric 3a

0	Absent, or comprises <0.1ha **and** <30% continuous aerial cover
1	Low 0.1 to 1ha, or <0.1ha **and** comprises >30% continuous aerial cover
2	Moderate 1 to 4ha
3	High 4ha

Microtopography Cover Scale Apply to metric 3c

0	Absent
1	Present in very small amounts or in moderate amounts of marginal quality
2	Present in moderate amounts, but not of the highest quality, or in smaller amounts of the highest quality
3	Present in moderate or greater amounts and of the highest quality

4. Special Wetlands

max 10 pts.

Check all that apply.

- ☐ Bog
- ☐ Fen
- ☐ Old growth forest
- ☐ Atlantic white cedar swamp
- ☐ Coastal plain pondshore
- ☐ Interdunal swale
- ☐ Mature forested wetland
- ☐ Vernal pool present
- ☐ Known occurrence of state/federal threatened or endangered species
- ☐ Significant migratory songbird or waterfowl habitat or use
- ☐ Other_____

Site Number: **Raters:** **Date:**

II. STRESSOR METRICS

Stressor Total

5. Upland buffers and surrounding land use

max 14 pts.

5a. Estimate % cultural cover within 50m buffer. Select one.

- <1% (7)
- 1 to 10% (5)
- 10-25% (3)
- 25-75% (1)
- >75% (0)

5b. Land Use Intensity weighted average within 100m buffer.
Estimate proportion of each class to the nearest tenth and multiply.

- Very Low (7) × 7 =
- Low (5) × 5 =
- Moderately High (3) × 3 =
- High (1) × 1 =

Sum weighted values for 5b score:

5c. Check all significant 100m buffer stressors that apply. Do **not** score.

- Commercial or industrial development or construction
- Residential development or construction
- Land fill or waste disposal
- Channelized streams or ditches
- Raised road beds
- Row crops, turf, or nursery plants
- Poultry or livestock operations
- Orchards, hay fields or pasture
- Piers or docks
- Golf course
- Sand and gravel operation

Very Low:	Natural areas
Low:	Recovering natural lands, passive recreation, low trails/dirt roads
Mod High:	Residential, pasture/hay, mowed areas, raised roads to 2-lane
High:	Urban, impervious cover, row crops, turf, paved roads > 2-lane

6. Hydrologic Stressors (within wetland)

max 7 pts.
min 0 pts.

Rate all evident disturbances observed on 0 to 3 scale below and sum. **Subtract total from 7.**
Also apply this metric to metric 9a.

- stormwater inputs
- other point source
- stream channelization
- road bed/railroad track
- beaver dam removal
- filling/grading
- groundwater withdrawal area
- ditch
- tile
- dike
- weir
- dredging
- other_____

Total
7 minus total

7. Habitat Stressors (within wetland)

max 7 pts.
min 0 pts.

Rate all evident disturbances observed on 0 to 3 scale below and sum. **Subtract total from 7.**
Also apply this metric to metric 10a.

- mowing
- grazing
- clear cutting
- selective cutting
- woody debris removal
- toxic pollutants
- substrate disturbance
- filling/raised roads
- Shrub/sapling removal
- herbaceous or aquatic bed removal
- sedimentation
- dredging
- farming
- nutrient enrichment
- other_____

Total
7 minus total

Rating Scale for metrics 6 and 7 above
0 - Not noted
U - Noted, but unknown effects on hydrology / habitats (I pt.)
1 - Minor effect on hydrology / habitats
2 - Moderate effect on hydrology / habitats
3 - Severe effect on hydrology / habitats

8. Historic Modifications

Check all evident historic disturbances. Do **not** rate these numerically. Only apply them to *Condition* metrics.
Wetlands with **only** historic disturbances should be rated as both *None or none apparent* and *Recovered* when applied to *Condition* metrics.

- Historic impoundment (>100 years). Apply to metric 9a.
- Historic draining (>100 years). Apply to metric 9a.
- Historic clear cutting/farming (>50 years). Apply to metric 10a.

Site Number: **Raters:** **Date:**

III. CONDITION METRICS

Condition Total

max 13 pts.
min 0 pts.

9. Hydrologic Condition

9a. Modifications to natural hydrologic regime. Score one or double check and average.
Refer to *Stressor Metrics* 6 and 8.

- None or none apparent (12)
- Recovered (7)
- Recovering (3)
- Recent or no recovery (1)

9b. Conditions evident due to draining. Score the uppermost attribute that applies.

- Severe root exposure >20cm (-2)
- Moderate root exposure 10 to 20cm (-1)
- Slight root exposure 3 to 10cm (0)
- Soil fissures obvious (0)
- Uncharacteristic ground cover (0)
- None noted (1)

max 17 pts.

10. Habitat Condition

10a. Habitat alteration. Score one or double check and average.
Refer to *Stressor Metrics* 7 and 8.

- None or none apparent (9)
- Recovered (6)
- Recovering (3)
- Recent or no recovery (1)

10b. Habitat development. Select one and assign score.

- Excellent (7)
- Very good (6)
- Good (5)
- Moderately good (4)
- Fair (3)
- Poor to fair (2)
- Poor (1)

10c. Total coverage of invasive plants. Refer to Appendix 1. Estimate and add or deduct points and score.

- Extensive >75% cover (-5) …….. Class 4
- Moderate 25-75% cover (-3) …….. Class 3
- Sparse 5-25% cover (-1) …….. Class 2
- Nearly absent <5% cover (0) …….. Class 1
- None noted (1)

10d. Estimate cover class of each invasive species and list by dominance within site. Do not score.

Appendix 2

Modified RIRAM v.1 (F08) Field Datasheet Used in Year-3 (2008) Field Assessments

Background Information

Investigator(s):	
Date:	
Affiliation:	
Address:	
Phone Number:	
Email:	
Name of Wetland:	
Site Code:	
Town:	
Property/Easement Owner:	
Access Directions:	
HGM Class(es):	
NWI Class(es):	Dominance Type(s):
RINHP Community Type(s):	
Lat/Long:	
HUC 12 Name:	
HUC 10 Name:	
HUC 8 Name:	
Assessment Unit Size (acres):	
Photos Taken:	

RIRAM v. 1 Assessment Form

Site Number: **Raters:** **Date:**

I. WETLAND CHARACTERISTICS RIRAM V. F08

Stressor Total	_____	**+**
Condition Total	_____	**=**
RIRAM Total		

1. Assessment Area

Select one

- [ ] >50 acres
- [ ] 25 to 50 acres
- [ ] 10 to <25 acres
- [ ] 3.0 to <10 acres
- [ ] 0.3 to <3.0 acres
- [ ] 0.1 to <0.3 acres
- [ ] <0.1 acres

2. Hydrologic Characteristics

2a. Sources of groundwater. Select all that apply.

- [ ] Groundwater
- [ ] Precipitation
- [ ] Seasonal/intermittent surface water
- [ ] Perennial surface water

2b. Connectivity. Select all that apply.

- [ ] 100 year flood plain
- [ ] Between stream/lake and human use
- [ ] Part of a wetland or upland complex
- [ ] Part of a riparian or upland corridor

2c. Maximum water depth. Select one.

- [ ] > 0.7m
- [ ] 0.4 to 0.7m
- [ ] <0.4m

2d. Duration of water. Select one or double check.

- [ ] Semi- to permanently flooded
- [ ] Semi- to permanently saturated
- [ ] Seasonally flooded
- [ ] Temporarily flooded
- [ ] Seasonally saturated
- [ ] Regularly flooded (tidal)
- [ ] Irregularly flooded (tidal)

3. Habitat Characteristics

3a. Habitat structural diversity

Estimate cover of all habitat components present using 1 to 5 scales at right.

- [ ] Aquatic bed
- [ ] Emergent
- [ ] Shrub
- [ ] Trees
- [ ] Mudflats
- [ ] Open water
- [ ] Sphagnum

Cover Class Scale

Class 5	>75% cover
Class 4	51-75% cover
Class 3	26-50% cover
Class 2	6-25% cover
Class 1	1-5% cover
Class 0	< 1% Cover

3b. Horizontal interspersion

Select one.

- [ ] High
- [ ] Moderately high
- [ ] Moderate
- [ ] Moderately Low
- [ ] Low
- [ ] None

3c. Microtopography

Rate all present using 0 to 3 scale at right.

- [ ] Vegetated hummucks/tussucks
- [ ] Coarse woody debris >15cm
- [ ] Standing dead >25cm dbh
- [ ] Amphibian breeding pools

Microtopography Cover Scale. Apply to metric 3c

0	Absent
1	Present in very small amounts
2	Present in small to moderate amounts
3	Present in moderate or greater amounts

4. Special Wetlands

Check all that apply.

- [ ] Bog
- [ ] Fen
- [ ] Old growth forest
- [ ] Atlantic white cedar swamp
- [ ] Coastal plain pondshore
- [ ] Interdunal swale
- [ ] Mature forested wetland
- [ ] Vernal pool present
- [ ] Known occurrence of state/federal threatened or endangered species
- [ ] Significant migratory songbird or waterfowl habitat or use
- [ ] Other_____

II. STRESSOR METRICS

Stressor Total ☐

☐ max 14 pts.

5. Upland buffers and surrounding land use

5a. Estimate % cultural cover within 50m buffer. Select one.

- ☐ <5% (7)
- ☐ 6 to 25% (5)
- ☐ 26-50% (3)
- ☐ 51-75% (1)
- ☐ >75% (0)

5b. Land Use Intensity weighted average within 100m buffer.
Estimate proportion of each class to the nearest tenth and multiply.

☐ Very Low (7)	× 7 =	☐
☐ Low (5)	× 5 =	☐
☐ Moderately High (3)	× 3 =	☐
☐ High (1)	× 1 =	☐

Sum weighted values for 5b score: _____

5c. Check all significant 100m buffer stressors that apply.
Do not score.

- ☐ Commercial or industrial development or construction
- ☐ Sewered residential development or construction
- ☐ Unsewered residential development or construction
- ☐ Land fill or waste disposal
- ☐ Channelized streams or ditches
- ☐ Raised road beds or trails
- ☐ Row crops, turf, or nursery plants
- ☐ Poultry or livestock operations
- ☐ Orchards, hay fields or pasture
- ☐ Piers or docks
- ☐ Golf course
- ☐ Sand and gravel operation

Very Low: Natural areas
Low: Recovering natural lands, passive recreation, low trails/dirt roads
Mod High: Residential, pasture/hay, mowed areas, raised roads to 2-lane
High: Urban, impervious cover, new construction, row crops, turf crops, paved roads > 2-lane

☐ max 7 pts. min 0 pts.

6. Hydrologic Stressors (within or abutting wetland)

Rate the effects of all stressors observed on 0 to 3 scale at right and sum. **Subtract total from 7.**

- ☐ road bed
- ☐ railroad track
- ☐ weir / dam
- ☐ dike
- ☐ trails
- ☐ other filling / grading
- ☐ drainage ditch
- ☐ tile drain
- ☐ groundwater or surface water pumps
- ☐ stream channelization
- ☐ dredging
- ☐ stormwater inputs
- ☐ sheet runoff inputs
- ☐ other point source
- ☐ nutrient enrichment
- ☐ toxic pollutants
- ☐ other _____

_____ **Total**

_____ **7 minus total**

Rating Scale for metric 6
0 - Noted, but no evident effect on hydrology
1 - Minor effect on hydrology evident
2 - Moderate effect on hydrology evident
3 - Severe effect on hydrology evident

Evidence of hydrologic effects and stress. Check all that apply. Do not score.
Apply these to Metric 8.

Increase in water level or hydroperiod

- ☐ Widening of wetland upstream of impoundment
- ☐ Deepening of wetland upstream of impoundment
- ☐ Abrupt wetland edge along impoundment or fill
- ☐ Dead or dying woody vegetation due to flooding
- ☐ Pioneer vegetation community present (saplings)

Decrease in water level or hydroperiod

- ☐ Flowing drainage ditch or tile
- ☐ Perched culvert or dam upstream of wetland
- ☐ Unnatural water level fluctuations obvious
- ☐ Severe root exposure (>20cm)
- ☐ Moderate root exposure (5-20cm)
- ☐ Soil fissures
- ☐ Uncharacteristic ground cover

Change in velocity or flashiness

- ☐ Excessive bank erosion or undercutting
- ☐ Root exposure due to scouring
- ☐ Floodplain erosion
- ☐ Perched culvert or dam downstream of wetland
- ☐ Perched culvert or dam upstream of wetland

Degredation of water quality

- ☐ Excessive algae or floating vascular vegetation
- ☐ Excessive submergent rooted vascular vegetation
- ☐ Rotten egg smell from sediments
- ☐ Excessively clear or strangely tinted water
- ☐ Obvious discharges, plumes, or spills
- ☐ Chemical smell
- ☐ Dead fish or larval amphibians

☐ max 7 pts. min 0 pts.

7. Direct Habitat Stressors (within or abutting wetland)

Rate the effects of all direct stressors observed on 0 to 3 scale at right and sum.. **Subtract total from 7.**
Also apply this metric to metric 9.

- ☐ mowing
- ☐ grazing / browsing
- ☐ clear cutting
- ☐ selective cutting
- ☐ woody debris removal
- ☐ substrate disturbance
- ☐ trails
- ☐ roads / railroad
- ☐ other filling
- ☐ shrub / sapling removal
- ☐ emergent or aquatic bed removal
- ☐ sedimentation
- ☐ dredging / ditching
- ☐ farming
- ☐ dumping trash
- ☐ dumping organic waste
- ☐ other_____

_____ **Total**

_____ **7 minus total**

Rating Scale for metric 6
0 - Noted, but no effect on habitats evident
1 - Minor effect on habitats evident
2 - Moderate effect on habitats evident
3 - Severe effect on habitats evident

III. CONDITION METRICS

Condition Total

8. Wetland Response to Hydrologic Alteration

max 12 pts.
min 0 pts.

8a. Check one only; refer to metric 6

- No hydrologic stressor effects evident (12). Skip to metric 9.
- Hydrologic stressor effects evident. Score 8b to 8d below and sum.

8b. Hydrologic response to hydrologic stressors
Check and sum all evident effects of stressors; refer to metric 6.

- Increase in water level or hydroperiod (1)
- Decrease in water level or hydroperiod (-1)
- Change in velocity or flashiness (0)
- Degredation of water quality (-1)

8c. Persistence of effective stressor(s). Check one and score.

- Discrete (3)
- Historic (>100 ya) but ongoing (1)
- Ongoing (0)

8d. Current wetland response to hydrologic stressors.
Circle a score for each and average.

	Unaffected		Degraded		Destroyed
Vegetation structure	8	6	4	2	0
Vegetation composition	8	6	4	2	0
Soil condition	8	6	4	2	0
Microtopography	8	6	4	2	0
Hydrologic Connectivity	8	6	4	2	0
	Affected				

Average 8d

8x. Original hydrologic modification metric.
Refer to Metric 6
Select one or double check and average.

- None or none apparent (12)
- Recovered (7)
- Recovering (3)
- Recent or no recovery (1)

8x

9. Wetland Response to Habitat Alteration

max 9 pts.
min 0 pts.

9a. Check one only; refer to metric 7

- No direct habitat stressor effects evident (9). Skip to metric 10.
- Direct habitat stressor effects evident.
  Score 9b and 9c below and sum.

9b. Persistence of effective stressor(s). Check one and score.

- Discrete (3)
- Ongoing (1)

9c. Current wetland response to direct habitat stressors.
Circle a score for each and average.

	Unaffected		Degraded		Destroyed
Vegetation structure	6	5	3	1	0
Vegetation composition	6	5	3	1	0
Soil condition	6	5	3	1	0
Microtopography	6	5	3	1	0
Habitat Connectivity	6	5	3	1	0
	Affected				

Average 9c

9x. Original habitat alteration metric.
Refer to metric 7
Select one or double check and average.

- None or none apparent (9)
- Recovered (6)
- Recovering (3)
- Recent or no recovery (1)

9x

10. Wetland State

max 13 pts.

10a. Total coverage of invasive plants. Refer to Appendix 1.
Estimate and select one class.

- Extensive >75% cover (0) …… Class 5
- High 51-75% cover (2) …… Class 4
- Moderate 26-50% cover (3)…… Class 3
- Low 6-25% cover (4) …… Class 2
- Nearly absent <5% cover (5)…… Class 1
- None noted (6)

Estimate cover class of each invasive species observed and list. Do not score.

Cover Class	Species

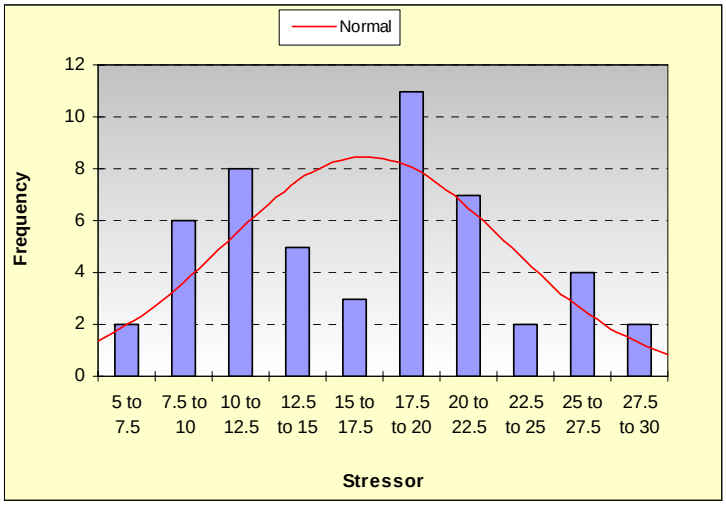
10b. Overall habitat development, considering **current** wetland type. Select one and assign score.

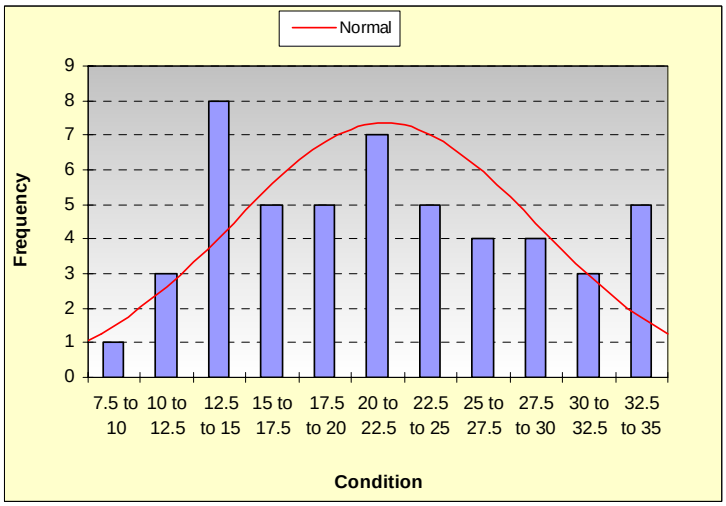
- Excellent (7)
- Very good (6)
- Good (5)
- Moderately good (4)
- Fair (3)
- Poor to fair (2)
- Poor (1)

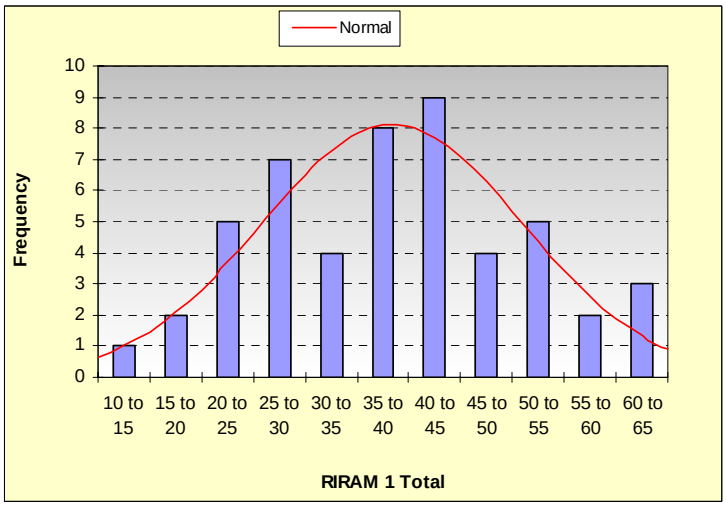
Appendix 3

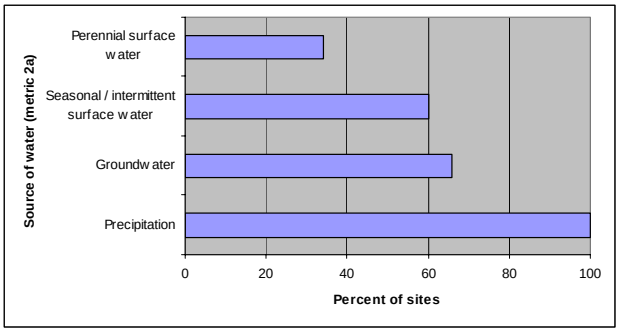
Summary of RIRAM v.1 Index and Selected Metric Data Collected in Year 3 (2008) at 50 Wetland Assessment Units located in the Hunt and Pawtuxet River Basins

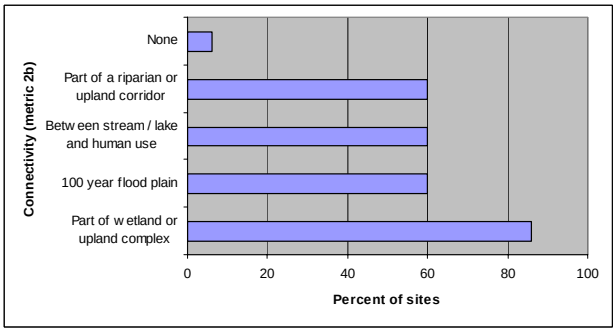
RIRAM v.1 Index Histograms

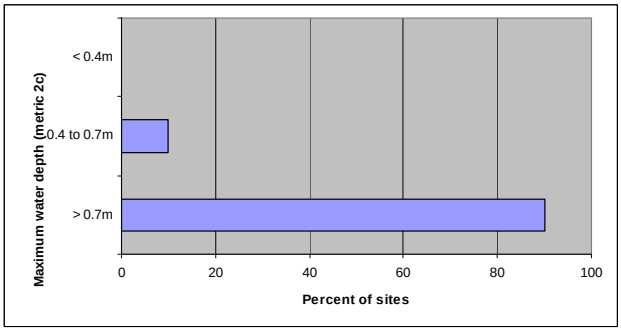


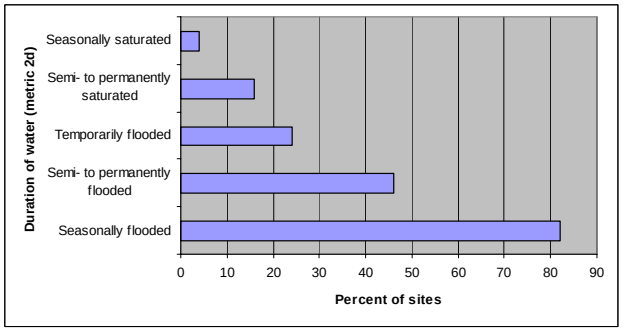


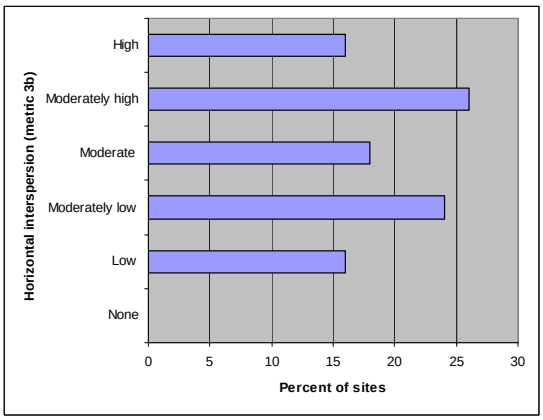


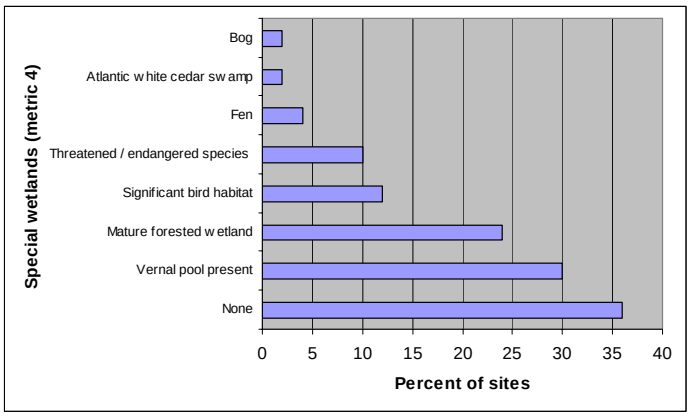

Source of water (metric 2a)
Perennial surface water
Seasonal / intermittent surface water
Groundwater
Precipitation
0
20
40
60
80
100
Percent of sites

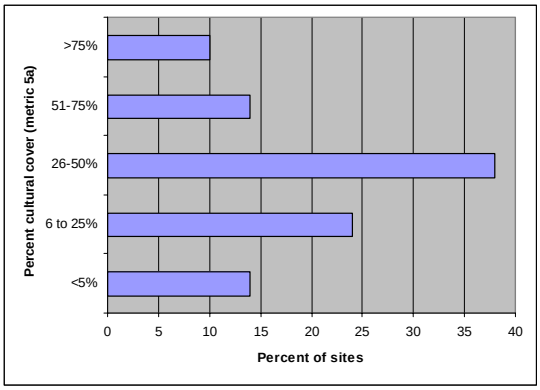

Connectivity (metric 2b)
None
Part of a riparian or upland corridor
Between stream / lake and human use
100 year flood plain
Part of wetland or upland complex
0
20
40
60
80
100
Percent of sites

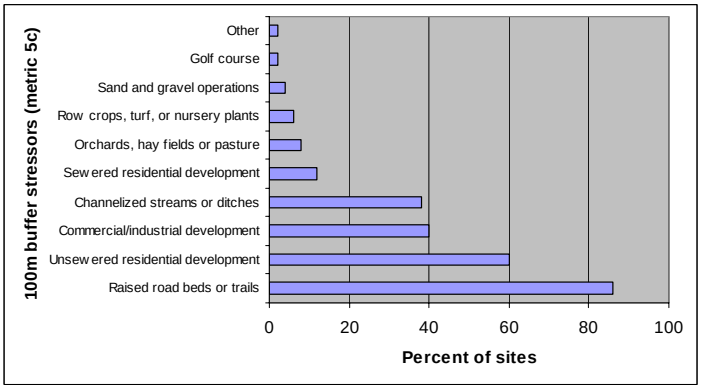

Maximum water depth (metric 2c)
< 0.4m
0.4 to 0.7m
> 0.7m
0
20
40
60
80
100
Percent of sites

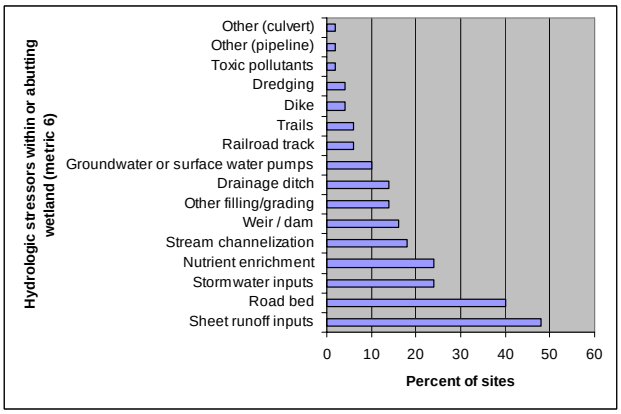

Duration of water (metric 2d)
Seasonally saturated
Semi- to permanently saturated
Temporarily flooded
Semi- to permanently flooded
Seasonally flooded
0
10
20
30
40
50
60
70
80
90
Percent of sites

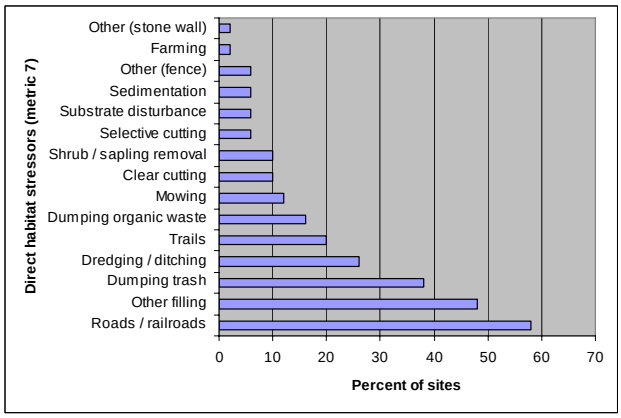

Horizontal interspersion (metric 3b)
High
Moderately high
Moderate
Moderately low
Low
None
0
5
10
15
20
25
30
Percent of sites

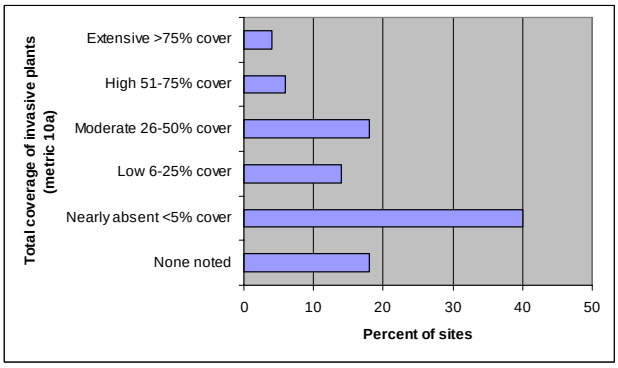

Special wetlands (metric 4)
Bog
Atlantic white cedar swamp
Fen
Threatened / endangered species
Significant bird habitat
Mature forested wetland
Vernal pool present
None
0
5
10
15
20
25
30
35
40
Percent of sites

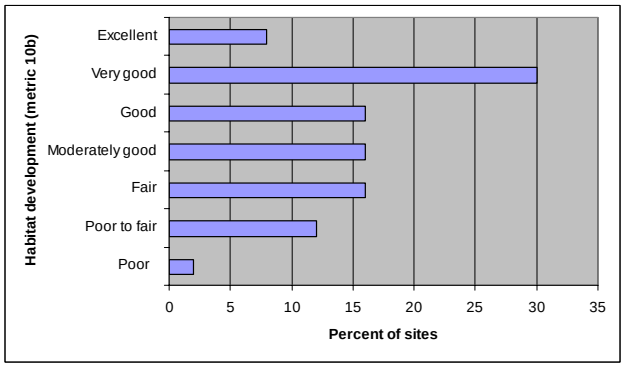

Percent cultural cover (metric 5a)
>75%
51-75%
26-50%
6 to 25%
<5%
0 5 10 15 20 25 30 35 40
Percent of sites


100m buffer stressors (metric 5c)
Other
Golf course
Sand and gravel operations
Row crops, turf, or nursery plants
Orchards, hay fields or pasture
Sewered residential development
Channelized streams or ditches
Commercial/industrial development
Unsewered residential development
Raised road beds or trails
0 20 40 60 80 100
Percent of sites


Hydrologic stressors within or abutting wetland (metric 6)
Other (culvert)
Other (pipeline)
Toxic pollutants
Dredging
Dike
Trails
Railroad track
Groundwater or surface water pumps
Drainage ditch
Other filling/grading
Weir / dam
Stream channelization
Nutrient enrichment
Stormwater inputs
Road bed
Sheet runoff inputs
0 10 20 30 40 50 60
Percent of sites


Direct habitat stressors (metric 7)
Other (stone wall)
Farming
Other (fence)
Sedimentation
Substrate disturbance
Selective cutting
Shrub / sapling removal
Clear cutting
Mowing
Dumping organic waste
Trails
Dredging / ditching
Dumping trash
Other filling
Roads / railroads
0 10 20 30 40 50 60 70
Percent of sites


Total coverage of invasive plants (metric 10a)
Extensive >75% cover
High 51-75% cover
Moderate 26-50% cover
Low 6-25% cover
Nearly absent <5% cover
None noted
0 10 20 30 40 50
Percent of sites


Habitat development (metric 10b)
Excellent
Very good
Good
Moderately good
Fair
Poor to fair
Poor
0 5 10 15 20 25 30 35
Percent of sites