Rapid assessment of high-ecological-value freshwater wetlands in Rhode Island

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Acronyms

EPA	U.S. Environmental Protection Agency
CRMC	Rhode Island Coastal Resources Management Council
DEM	Rhode Island Department of Environmental Management
NBNERR	Narragansett Bay National Estuarine Research Reserve
NOAA	National Oceanic and Atmospheric Administration
RIGIS	Rhode Island Geographic Information System
RINHS	Rhode Island Natural History Survey
URI	University of Rhode Island
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

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1. Introduction

Freshwater wetlands perform a number of functions that are valuable to people, including filtration of excess nutrients, toxins, and sediments from surface waters; recharge of drinking water aquifers; buffering of storm flow velocity and volume; provision of habitat for fish, shellfish, and game species; stream-flow maintenance; recreation; aesthetics; and food production (Richardson 1994). Freshwater wetlands can also perform functions that are important or critical to ecological well-being in support of numerous animals, plants, and other organisms; such wetlands could be viewed as having "ecological value". Wetland functions that benefit ecological well-being are typically collectively identified as providing "wildlife habitat" (e.g. USACE 1999), but these functions may overlap with or be the aggregate of several other recognized functions and values (Leeson et al. 2018). Wetland function, ecological value, and value for people are strongly linked, as many wetland functions, such as water quality maintenance, stream support, and food production benefit both people and wildlife (Novitski et al. 1996). Additionally, ecological well-being supports plants, animals, and ecosystems that in turn are valued by people for recreation, food production, aesthetics, and quality of life. Therefore, maintaining or promoting wetland ecological value benefits people, communities, wildlife, and ecosystems broadly, and the State of Rhode Island has recognized the importance of wetland ecological value in law and policy.

DEM has recently administered the development of draft criteria and protocol for identifying wetlands of exceptional ecological value to support watershed planning and ecosystem conservation (Leeson et al. 2018; C. Murphy, personal communication). The protocol recommends a set of attributes that may separately or additively indicate ecological value in freshwater wetlands, and further suggests that wetlands possessing outstanding or multiple attributes indicating ecological value could be categorized as wetlands of "high ecological value" (hereafter, HEV). The attributes indicating HEV wetlands are conceptually broad and include general characteristics, such as size and landscape context, vegetation and geomorphic diversity, and landscape setting, as well as specific attributes such as vegetation or geomorphic type. Spatial data for some of the HEV attributes are readily available, while data for other attributes are not. Some attributes can be remotely-sensed, whereas others can only be assessed in the field (Table 1). The protocol therefore suggests compiling available geospatial data using a geographic information system (GIS) and subsequently conducting site visits to determine the presence of other HEV attributes.

This report details a demonstration of the HEV wetland protocol. The goals of the demonstration are to (1) test the methods of the HEV protocol for effectiveness and utility, (2) improve our understanding of the condition of HEV freshwater wetlands across Rhode Island, and (3) begin to compile information on these valuable resources to support planning, conservation, and management. A GIS geospatial shapefile dataset named "RI_HEV_Wetland_Sample_2018" is available to match data collected with locations and imagery of sites.

Table 1. Attributes indicating high ecological value in freshwater wetlands and the availability of supporting data; from Leeson et al. (2018)

Indicator	Short Name	GIS data available and useful	GIS data require analysis to be usable	GIS data are Outdated, Incomplete, or Unavailable	Sources
1	Unfragmented Landscape (>250 acres)	✓			Kutcher 2017
2	Large Size (>20 acres)		✓		RIGIS ECC 2011
3	Rare Species	✓		I	DEM-RINHS, EO data
4	Wetland Type Diversity		✓	I O	RIGIS Wetlands 1993, RIGIS ECC 2011
5	Geomorphic Diversity	✓			www.edc.uri.edu/elu
6	Tidal Freshwater		✓	U	
7	Shrub Swamp	✓			RIGIS ECC 2011
8	Emergent Wetlands	✓			RIGIS ECC 2011
9	Seeps, Springs, Headwaters		✓	U	
10	Old Growth Forest			U	
11	Beaver Impoundments			U	
12	Vernal Pool Clusters		✓	I	DEM, unpublished data
13	Isolated Wetlands in Upland		✓	I	RIGIS ECC 2011
14	Coastal Plain Pondshore			I	
15	White Cedar Swamps			O I	RIGIS Wetlands 1993
16	Open Peatlands			O I	RIGIS ECC 2011
17	Limestone Wetlands		✓		RIGIS ECC 2011
18	Isolated Urban Wetlands		✓		RIGIS LULC 2011
19	Coldwater Steam Buffers		✓		RIGIS ECC 2011, RIGIS Cold Water Fishing 2013
20	Unconsolidated Shores			U	
21	Aquatic Beds			U	

2. Methods

2.1 Geospatial analysis and site selection

A GIS was used to compile all readily-available HEV attribute data, as well as incomplete data and other data requiring only simple analysis to become useful for indicating HEV wetlands (Table 1). Specifically, (1, refer to Table 1) unfragmented landscape was displayed using an "Unfragmented Wetlands" shapefile from an earlier related study (Kutcher 2018); (2) large size (>25 acres), (4) wetland diversity, and presence of (7) shrub swamp, (8) emergent wetlands, (15) white cedar swamps, (16) open peatlands, and (19) isolated urban wetlands were determined by inspecting contiguous wetland units from the RIGIS (2011) Ecological Community Classification (ECC) dataset; support of (3) rare species was determined using the Element Occurrence point dataset (RINHS and DEM 2017); and (20) cold water stream buffer was determined using the RIGIS (2013) Cold Water Fishing dataset overlaying the ECC data. All other attributes were determined in the field after sites were selected, and therefore were not used in the site selection process.

Study sites were selected by visually inspecting a GIS electronic map displaying the above-referenced datasets overlaying RIGIS (2014) high-resolution leaf-off true-color imagery. Wetland study site bounds were determined using GIS photo-interpretation and rules established in the RIRAM User's

Guide (Kutcher 2011), whereby study sites were delineated based primarily on contiguity of wetland vegetation cover and basin morphology. Sites comprised vegetated wetlands bounded by upland, manmade structures, deepwater, or a shift in basin morphology (broad versus linear and narrow), and typically contained multiple wetland community types. Sites were selected that, according to the GIS data, contained multiple HEV attributes, were potentially accessible for field survey (determined by overlaying property bounds and visually inspecting the aerial imagery for access feasibility), and were evenly distributed both spatially and across land-use settings in Rhode Island. The aim was to survey and assess a diverse and fairly representative sample of HEV freshwater wetlands in Rhode Island to inform the study goals listed above. Anticipating access impediments to some of the sites, 24 wetlands were initially selected, from which 20 were field-surveyed and assessed as study sites.

2.2 Site assessments

The study sites were assessed using a version of RIRAM V2 enhanced to allow for the standardized collection of data indicating WHEV status and climate response (Kutcher 2017; App. 1). The version additionally contains a checklist of HEV indicator attributes that can be determined in the field or through remote interpretation of aerial imagery, as well as conservation status; otherwise, the version remains consistent with prior RIRAM versions in process and content, and compatible for cross-study analysis.

RIRAM is a rapid assessment method (EPA Level 2) that characterizes the setting and condition of a freshwater wetland by scoring and aggregating perceived prevalence and impact of human disturbances and wetland response to disturbance, both within the wetland boundaries and in the surround uplands. RIRAM uses a field datasheet (App. 1) and recent aerial photography to estimate and document wetland characteristics and classification information, surrounding landscape and buffer stresses, within-wetland disturbances, and the condition of wetland attributes that contribute to function. Only metrics that evaluate relative condition are scored; sections related to wetland size, type, position, diversity, etc. are not scored. RIRAM scores can theoretically range from 1 to 100, where scores approaching 1 would indicate a nearly or completely-destroyed wetland and a score of 100 indicates no detected human disturbances within or surrounding (to 500') the wetland.

The enhanced RIRAM datasheet (App. 1) was used to conduct RIRAM according to the RIRAM User's Guide (Kutcher 2011). Sites were accessed on foot or by canoe when necessary. The perimeter and interior sections of each wetland were observed to detect stress and response as necessary to complete the RIRAM datasheet. A field map, comprising recent leaf-off aerial photography of each wetland study site and the surrounding landscape out to 500 or more feet, a photo-interpreted wetland boundary, delineations of surrounding upland zones extending outward 100' and 500' of the wetland boundary, and a scale bar, was produced before field work and used in the field to navigate and to estimate landscape and certain within-wetland metrics (App. 2).

2.3 Analysis

Data collected were compiled using Microsoft Excel software, and statistical analysis was conducted using WinSTAT® software (2006, R. Fitch Software). Correlations between RIRAM metric values were tested using Spearman rank analysis to address ordinal data generated by RIRAM and to account for any skews or gaps inherent in the study sample. Box-and-whisker analysis was used to evaluate HEV wetlands against 52 reference freshwater wetlands from an earlier study (Kutcher and Bried 2014), wherein reference sites were classified as least-disturbed (below the 25th percentile), intermediately-disturbed (between 25th-75th percentiles), and most-disturbed (above the 75th percentile) according to percentiles of RIRAM index values. Non-parametric analogs for T-test and ANOVA were used as appropriate to discriminate index and metric scores between HEV and Reference wetlands and among other grouping variables.

3. Results

3.1 Study site characteristics

The wetland study sites were distributed across Rhode Island (Fig 1) and ranged in size from 3.9 to 77 acres (*n*=20, $\bar{x}$=29 acres). Most wetlands (17 of 20) were further than 1000 feet from the coast and above 20 feet in elevation (15) (App. 3). Surface water was identified as a main source of water for 15 of the sites, and water regimes were distributed mostly among seasonally flooded (12 sites), permanently saturated (12), semi-permanently flooded (7), and permanently flooded (7). All (20) sites had a scrub-shrub wetland class present, and a majority of sites had forested (18), emergent (18), or aquatic bed (12) classes present. All (20) sites were determined to be part of a significant habitat complex or corridor and most (17) sites were classified as important for supporting species of greatest conservation need according to the first RI State Wildlife Action Plan (DEM 2005). Only 1 site was assessed as being vulnerable to the threats associated with sea level rise, but 3 headwater wetlands were noted as potentially being susceptible to precipitation shifts linked to climate change. Fifteen sites were protected by a conservation easement or ownership in their entirety or nearly so (>75% by area); the remainder of sites had conserved area of less than 50%, with 2 sites being entirely unprotected by a conservation mechanism beyond state and federal regulation.

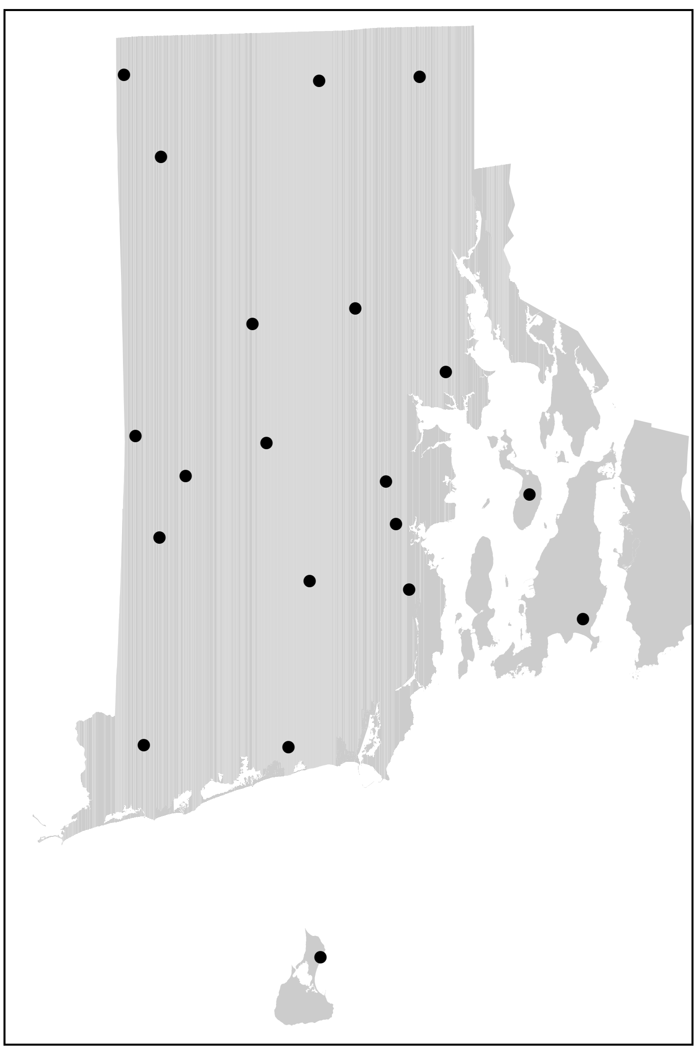

Figure 1. Distribution of 20 HEV wetland study sites across Rhode Island

3.2 HEV attributes

There was representation from all but two HEV attributes (according to Leeson et al. 2018) in the study sample (Fig. 2). The number of HEV attributes identified per site ranged from 2 to 12 (median= 7). Some HEV attributes were associated with increased numbers of other HEV attributes. HEV sites having aquatic bed habitat had a higher number of HEV attributes (not counting aquatic bed) than sites without aquatic beds (Kruskal-Wallace, n=10, Z=-3.0, P<0.01); similarly, sites with semi-permanently-flooded hydrology (n=8) or beaver impoundments (n=6) had a higher number of other HEV attributes than those without (Z=-2.5, P=0.01 and Z=2.1, P=0.04, respectively) (Fig. 3). HEV attributes qualitatively associated with multiple other HEV attributes (Kruskal Wallace 0.05<P<0.10) were diverse wetlands (n=16) and wetlands containing bogs/fens (n=9) or deep emergent marsh (n=9). Attributes related to specific sites are documented in the supplementary GIS shapefile "RI_HEV_Wetlands_ 2018".

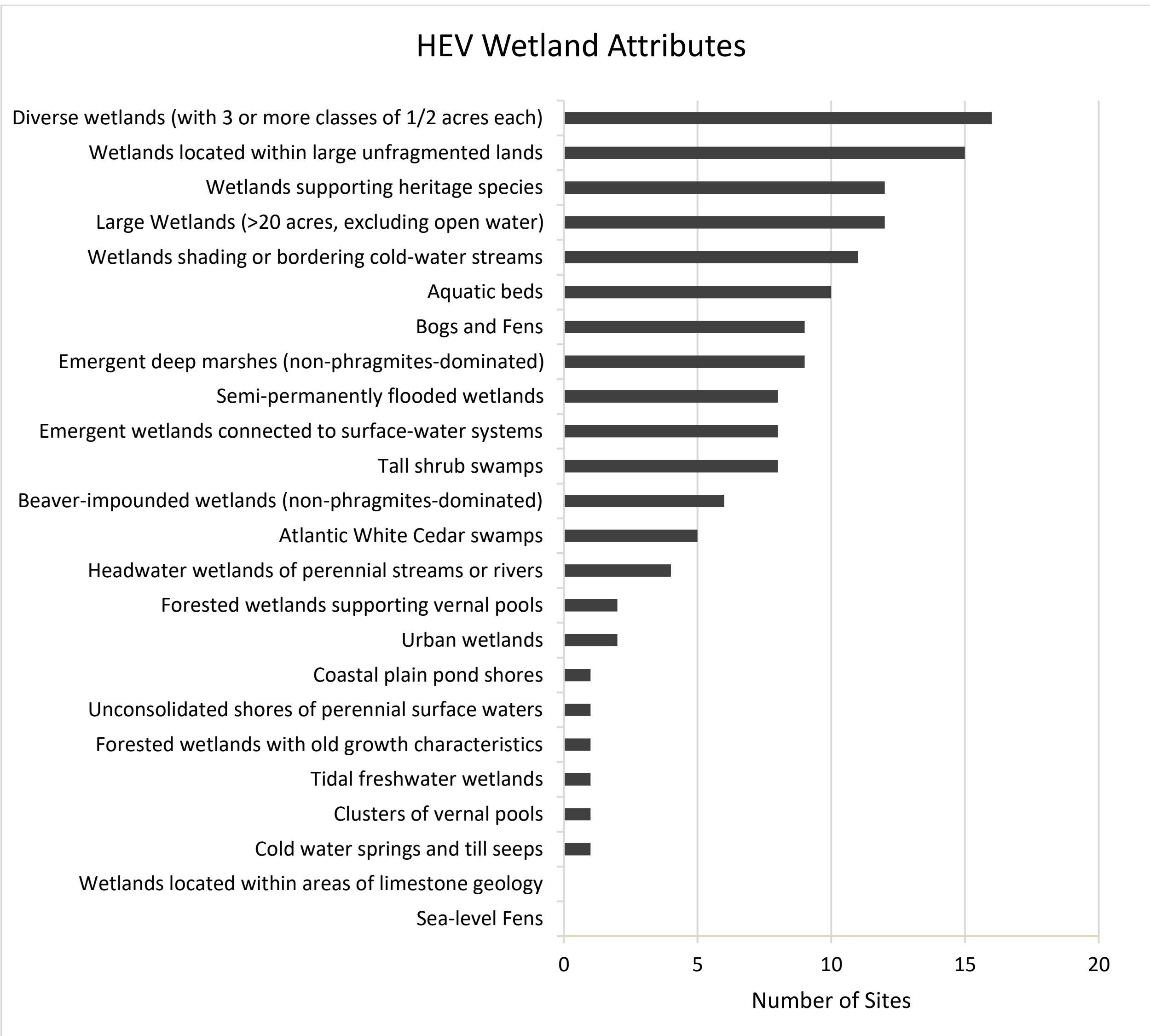

Figure 2. Representation of HEV wetland attributes across 20 freshwater wetlands in Rhode Island

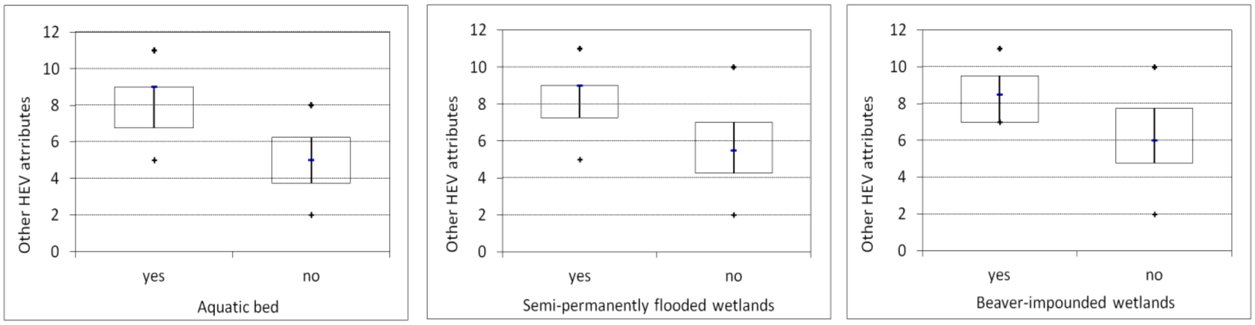

Figure 3. Box plots depicting the number of additional HEV attributes associated with specific attributes at 20 freshwater wetlands in Rhode Island; boxes represent interquartile ranges, crosses represent minimum and maximum values, and dashes represent median values

3.3 Landscape and within-wetland stress

Half (10) of the HEV wetland sites had less than 5% encroachment of cultural land use (by area) within a surrounding 100 foot buffer zone, whereas 6 sites had greater than 50% encroachment. Raised roads (5 sites) were the predominant stressor in the buffer zone. Sewered and un-sewered (3 sites combined) residential development, pasture/hay fields (3), and commercial development (3) were also common stressors identified in the buffer zone. Raised roads (10 sites) were also the primary stress identified in the surrounding landscape out to 500 feet, followed by combined residential development (9). Both landscape and buffer integrity were correlated with multiple RIRAM metrics assessing wetland functional integrity (components of the *Observed Indicators* metric), with aggregate within-wetland stress, and with several individual within-wetland stressors (Table 2).

Twelve sites were assessed as being impounded to some degree, mostly stemming from historic agricultural roads, current public roads, and historic mill dams (App. 3). Four of these wetlands were evidently created from a downstream impoundment, whereas the remaining sites were evaluated as having localized or minor hydrological effects stemming from downstream impoundment. Impoundment (mainly from roads) was also noted upstream of 4 sites, each of which was assessed as potentially affecting water flow velocity, but not water regime. Sources of nutrients were noted at 7 sites, of which 3 were assessed as being moderately-impacted by nutrients and 2 as strongly-impacted. Two sites showed evidence of moderate impacts from sediment loading and 2 showed signs of impact from road salts. Filling was observed at 14 sites, mainly localized fill for raised roads associated with public transportation (6) and historic agriculture (5). Stressors related to specific sites are documented in the supplementary GIS shapefile “RI_HEV_Wetlands_2018”.

Roads were assessed as the most common primary stressor associated with in-wetland stress, accounting for 21% of HEV within-wetland stresses, overall (App. 3). Another 13% of all stresses were attributed to raised trails, such as historic farm paths. Nonpoint and sheet runoff (combined) accounted for 21% of assessed stresses, and dams accounted for 12%. Public transportation and historic agriculture were identified as general land uses responsible for the bulk of the in-wetland stress among the HEV wetlands, accounting for 42% and 20% of assessed stresses, respectively. Public utilities were responsible for another 12% of stresses, whereas private residential and commercial development each accounted for 8%.

Table 2. Spearman rank correlation coefficients (r_s) and probability values (*P*) indicating relationships among measures of landscape integrity, wetland stress, and wetland integrity according to RIRAM individual and aggregate metrics for 20 HEV wetlands

	Buffer Integrity (100')		Landscape Integrity (500')	
	r_s	*P*	r_s	*P*
C. WETLAND STRESS	0.66	<0.01	0.76	<0.01
c.3 Impoundment	-0.09	0.71	-0.07	0.78
c.4 Draining or diversion of water	-0.58	0.01	-0.45	0.04
c.5 Fluvial inputs	-0.67	<0.01	-0.86	<0.01
c.6 Filling and dumping	-0.69	<0.01	-0.49	0.03
c.7 Excavation / substrate disturbance	-0.31	0.18	-0.31	0.18
c.8 Vegetation or detritus removal	-0.59	0.01	-0.54	0.01
c.9 Invasive species cover	-0.58	0.01	-0.62	<0.01
D. OBSERVED INDICATORS	0.68	<0.01	0.82	<0.01
d. Hydrologic Integrity	0.63	<0.01	0.62	<0.01
d. Water and Soil Quality	0.76	<0.01	0.72	<0.01
d. Habitat Structure	0.66	<0.01	0.78	<0.01
d. Vegetation Composition	0.52	0.02	0.60	<0.01
d. Habitat Connectivity	0.73	<0.01	0.76	<0.01

3.4 Invasive Species

Invasive species, according to the Invasive Plant Atlas of New England (available: http://www.eddmaps.org/ipane), were detected 17 of the 20 sites. The number of invasive species detected per site ranged from 0 to 12 (median = 2). *Phragmites australis* (11 sites), *Rosa multiflora* (8), *Solanum dulcamara* (6), *Frangula alnus* (6), and *Celastrus orbiculatus* (overhanging from uplands of 6 sites) were the most commonly-found species (App. 3). Invasive species total aerial cover was >50% at 2 sites, 26-50% at 2 sites, and ≤25% among remaining sites. *Phragmites* was the only invasive species that singularly had moderate (26-50%) or high (51-75%) cover at a site, but this was limited to one site in each category. Both invasive species cover and the number detected (i.e. richness) were correlated with several landscape and within-wetland stress metrics, and with the aggregate RIRAM Index (Table 3).

Table 3. Spearman rank correlation coefficients (r_s) and probability values (*P*) indicating relationships among invasive species and wetland stressors according to RIRAM individual and aggregate metrics for 20 HEV wetlands

RIRAM Metric	Invasive Species Cover		Invasive Species Richness	
	r_s	*P*	r_s	*P*
B. LANDSCAPE STRESS	-0.64	<0.01	-0.76	<0.01
b.1 Integrity of buffers	-0.58	0.01	-0.69	<0.01
b.2 Surrounding land use	-0.62	<0.01	-0.73	<0.01
C. WETLAND STRESS (minus c.9 Invasive species)	-0.92	<0.01	-0.72	<0.01
c.3 Impoundment	0.23	0.33	0.22	0.34
c.4 Draining or diversion of water	0.08	0.74	0.53	0.02
c.5 Fluvial inputs	0.59	0.01	0.56	0.01
c.6 Filling and dumping	0.49	0.03	0.75	<0.01
c.7 Excavation / substrate disturbance	0.62	<0.01	0.32	0.17
c.8 Vegetation or detritus removal	0.50	0.02	0.62	<0.01
RIRAM INDEX (minus c.9 Invasive species)	-0.87	<0.01	-0.73	<0.01

3.5 Condition of HEV Wetlands

RIRAM scores for HEV wetlands ranged from 60.4 to 100 (n=20, $\overline{x}$=84.5), whereas the mean value of Reference scores was 79.0. The range of scores was nearly the same between the groups (62.1 to 100 for Reference wetlands). There was no indication that HEV wetlands were different in condition from Reference wetlands overall (*n*=51) (Mann-Whitney *U*-test, *Z*=1.46, *P*=0.15), according to RIRAM Index scores. Headwater HEV wetlands, and HEV wetlands not classified as diverse, were similar in condition (Mann-Whitney, *P*>0.05) to the Least-Disturbed (LD) (upper quartile) Reference wetlands according to the RIRAM Index (Fig. 4, designation A). Unfragmented and large wetlands, and those containing rare species, beaver impoundments, or aquatic beds had lower RIRAM Index scores (Mann-Whitney, *P*<0.05) than the LD Reference wetlands, but higher scores (Mann-Whitney, *P*<0.05) than the intermediately-disturbed (ID) (inter-quartile range) Reference wetlands (Fig. 4, designation B). All other HEV wetland categorizations by HEV attribute analyzed* were similar to the ID Reference wetlands (Mann-Whitney, *P*>0.05) (Fig. 4, designation C); *these included HEV wetlands supporting diverse vegetation habitats (3 or more NWI classes), coldwater streams, open peatlands (bogs or fens), tall shrub swamps, Atlantic cedar swamps, or deep emergent habitat, among others.

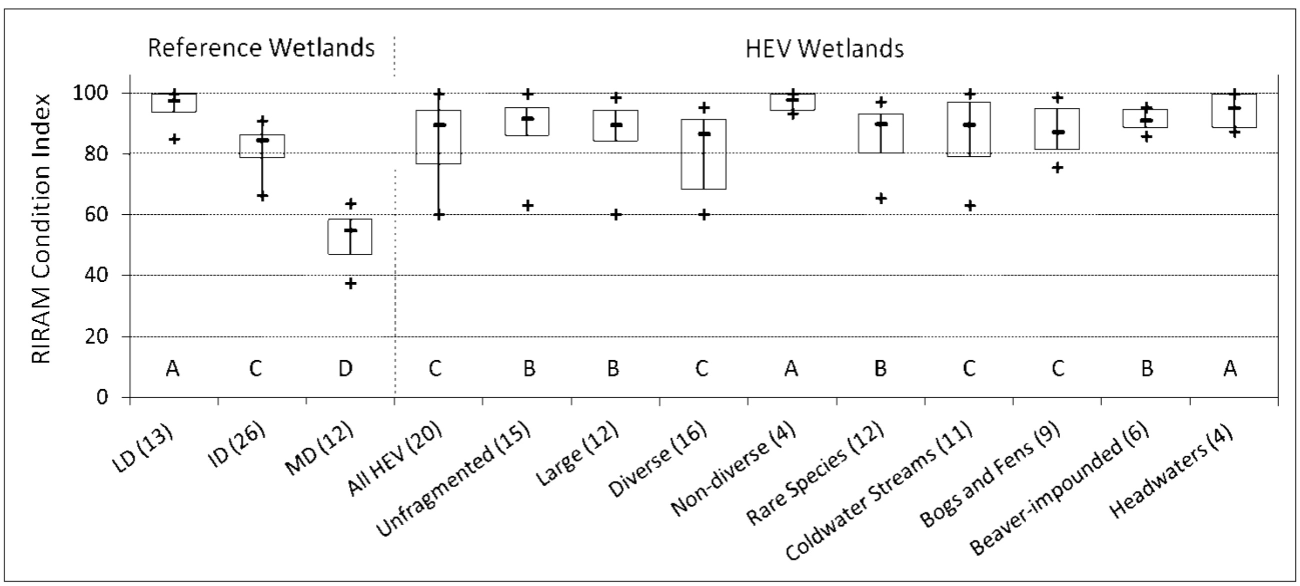

Figure 4. Box plots depicting distributions of RIRAM Index scores for 51 Reference wetlands (Kutcher and Bried 2014) and 20 HEV wetlands categorized by HEV attribute; boxes represent interquartile ranges, crosses represent minimum and maximum values, and dashes represent median values; LD = least disturbed, ID = intermediately disturbed, and MD = most disturbed condition categories; parenthetic values indicate the number of wetlands in each category; alphabetic designations indicate significantly different groupings of RIRAM index scores, where A > B > C > D

4. Discussion

4.1 HEV wetland identification protocol

The HEV identification process, which aimed to identify wetlands having multiple HEV attributes according to accessible GIS data, produced a diverse study sample of wetlands. The study wetlands were evenly distributed across Rhode Island and contained broad representation across NWI vegetated habitat classes and water regimes, indicating that vegetated wetlands of many types, settings, and attributes may individually or collectively contribute to ecological value, as defined by Leeson et al. (2018).

The use of accessible GIS data may have unavoidably biased the sample toward wetlands having those accessible HEV attributes and away from HEV wetlands having attributes needing field identification. The process produced a study sample of relatively large wetlands, having a mean area of 29 acres versus a mean area of 6.2 acres for the Reference set (Kutcher and Bried 2014). Large wetland size was a target of the site selection process (an area of 20 acres or more was considered an HEV attribute), but other factors may have also contributed to this outcome. For example, wetlands containing more than 3 NWI vegetation classes (per Cowardin et al. 1979) were targeted in the site selection process, and a diversity of habitat types is more likely to occur in larger wetlands according to species-area theory (Cain 1938, Kallimanis et al. 2008). This theory would also predict that large wetlands should be more likely to contain specific HEV wetland types, but surprisingly, large HEV wetlands were not significantly associated with a higher incidence of other HEV attributes in this study. The HEV attributes that were correlated with higher incidence of other attributes (i.e., aquatic bed, beaver-impounded, semi-permanently flooded) signify deep wetland habitats associated with shallow surface waters, suggesting that long-hydroperiod wetlands may hold multiple ecological functions and may therefore have broader ecological value than wetlands with shorter water regimes. This may be related to their support of aquatic species in addition to terrestrial species (Leeson et al. 2018).

Although it remains unclear whether the HEV study wetland sample is representative of HEV wetlands statewide or is more of an artifact of the site selection process, the sample had broad representation of HEV attributes and certainly represented some of the most commonly-occurring HEV attributes. For example, unfragmented wetlands make up an estimated 59% of wetland area in Rhode Island (Kutcher 2017) and comprised 75% of the wetlands in the HEV sample. Likewise, diverse wetlands are fairly common in the state and were well-represented in the HEV sample. The sample also contained strong representation of wetlands with attributes known to be uncommon in Rhode Island, such as bogs and fens, which comprise only about 0.1% of wetland palustrine area in the state, as derived from the RIECC dataset (RIGIS 2014). In general, the HEV attributes with missing or low representation in the HEV sample are also uncommon in Rhode Island, such as coastal plain pond-shores, sea-level fens, and wetlands in limestone geology.

Putting the characteristics and condition of HEV wetlands in context with each other and with other wetlands along a condition gradient (the Reference wetlands) may help to inform better management of natural resources in the state because it can provide insight into the locations, settings, characteristics, and condition of these valuable resources. The accompanying GIS shapefile “RI_HEV_Wetlands_2018” produced by this project will incorporate these ecologically-valuable wetlands into Rhode Island's geospatial database of assessed wetlands, which will enhance the database's use in wetland management and state planning.

4.2 HEV wetland condition

HEV wetlands were not in significantly better condition than Reference wetlands overall, but only two HEV wetlands fell within the range of most-disturbed (MD) Reference wetlands, and several HEV characteristics were associated with low disturbance and high wetland integrity. Most intuitively, unfragmented wetlands were in better condition than the majority of Reference wetlands according to RIRAM. Unfragmented wetlands, by definition, are not split by human development and should therefore be less susceptible to many human disturbances than HEV wetlands occurring in more developed landscapes. RIRAM Index scores corroborate this premise, indicating that HEV wetlands classified as unfragmented are less susceptible to stress and degradation than fragmented wetlands and freshwater wetlands in general. Unfragmented wetlands are more likely to support amphibians, sensitive birds, and mammals (Knutson et al. 1999, Xu et al. 2018, Foreman and Alexander 1992, respectively), suggesting that higher RIRAM scores may be associated with increased ecological value.

Similar to unfragmented wetlands, large (>20 acres) HEV wetlands were in better condition than 75% of Reference wetlands according to RIRAM Index scores (Fig. 4). Because RIRAM weights many of its metrics by proportion, perimeter stresses acting upon large wetlands can affect the RIRAM score proportionately less than they do on smaller wetlands. Several stressors are more likely to occur near the perimeters of wetlands, including fill, vegetation disturbances, substrate disturbances, invasive species, and effects of fluvial inputs such as sediments and road salts. In this way, large wetlands may effectively buffer themselves, which may have contributed to the higher RIRAM scores compared with Reference scores, evident in Figure 4.

Headwater wetlands, beaver-impounded wetlands, wetlands with aquatic beds, and wetlands containing documented heritage species of state concern were also associated with lower than average disturbance and above average condition in this study. Beavers have large home ranges (1 to 2 animals per square mile) and their habitat suitability is limited by roads, railways, and land-clearing (Allen et al. 1983 and references therein), indicating that beavers may prefer or require unfragmented landscapes. Additionally, the same stressors that limit beaver habitat suitability and their construction of ecologically-valuable impoundment wetlands would lower RIRAM Condition Index scores, suggesting that RIRAM may act as a predictor of ecological value in these cases. Similarly, the Rhode Island Wildlife Action Plan (RIDEM 2015) lists major threats to the survival of heritage species in Rhode Island to include roads and railways, commercial and residential development, industrial and agricultural effluents, manmade dams, invasive species, habitat alteration, and other stresses identified and scored in RIRAM. Findings of this study support the premise that heritage species are threatened by such disturbances, as they were associated with low-disturbance wetlands, and further suggest the utility of RIRAM for indicating ecological value.

The condition of HEV wetlands overall was strongly influenced by the condition of the buffer and surrounding landscape. Study findings indicate that landscape and in-wetland stresses are positively correlated, suggesting that wetlands surrounded by human land uses are more prone to human stress, likely due to the proximity of human uses that can affect condition (such as impounding structures and land uses that cause runoff into the wetland) and nearby access to the wetland interior leading to increased direct in-wetland activities (Table 2). The correlation between landscape and wetland stresses was evident even as the average HEV study wetland was relatively large and should therefore be partly buffered from perimeter stresses, suggesting that even large wetlands are affected by buffer and landscape stress. Landscape stresses also strongly influenced multiple factors of wetland integrity according to RIRAM Observed Indicators metrics. Because these factors (hydrologic integrity, water and soil quality, habitat structure, vegetative composition, and habitat connectivity) are intended to directly reflect ecological integrity, their correlation with landscape condition may suggest that degradation of surrounding landscapes poses a threat to wetland ecological value.

Roads were the most influential stressor on HEV wetland condition, as well as for the Reference wetlands and for wetlands assessed in earlier studies of freshwater wetlands in Rhode Island (Kutcher 2011, Kutcher 2012, Kutcher 2018). Roads are widely known to disrupt natural environments, have dire direct and indirect impacts on numerous animal species, are a main cause of habitat fragmentation, and affect 15-20% of all land area in the U.S. (Foreman and Alexander 1992, Spellerberg 1998). Roads directly destroy habitats; can affect soils, surface water and runoff patterns; can be a main vector for toxins, salts, and invasive species; and are associated with a variety of human uses that affect ecological condition (Trombulak and Frissell 2000). Roads and raised trails were associated with 34% of all stressors assessed across the HEV wetlands and with 22% of stressors assessed in the Reference wetlands (derived from Kutcher 2011). This suggests that of all current human land uses in Rhode Island, roads may pose the highest threat to wetland ecological value.

Invasive species may pose another major threat to HEV wetlands. Invasive species were detected at the majority (17 of 20) of HEV wetlands and can affect wetland ecological integrity in several ways. Wetlands are particularly susceptible to invasive plant species because they are landscape sinks that gather seeds, detritus, and nutrients from the surrounding landscape (Zedler and Kercher 2010). Invasive species can degrade habitat and ecological value through changing attributes such as habitat structure, species composition and biodiversity, nutrient cycling, food availability, and connectivity (Wilcove et al. 1998, Ehrenfeld 2003, Benoit and Askins 1999, Meyerson et al. 2000). Both invasive species cover and richness were highly correlated with aggregate wetland stress and landscape stress, indicating that they are facilitated by a range of human disturbances among HEV wetlands. Invasive species *richness* was most closely related to filling, dumping, and vegetation removal, suggesting the introduction of species through fill and property or roadside maintenance, both commonly-cited vectors (Christen and Matlack 2009). In contrast, invasive species *cover* was most closely associated with substrate disturbances and nutrient inputs, both of which are well-documented as promoting the growth of invasive species in wetlands (Chambers et al. 1999, Gedan and Bertness 2010). These findings suggest that multiple human activities can promote the establishment and expansion of invasive species in freshwater wetlands.

Most of the HEV wetlands contained 3 or more NWI vegetation classes, but some of the highest-integrity wetlands, according to the RIRAM Index scores, were the less-diverse wetlands. This may suggest that human disturbance can increase wetland habitat diversity. Ecological theory predicts that habitats become more diverse with intermediate disturbance (Connell 1978), which is supported by prior studies of wetlands in Rhode Island (Kutcher and Forrester 2017). Three of the four non-diverse HEV wetlands in the sample were dominated by large, unfragmented red maple swamps, the most advanced seral stage for seasonally- and temporarily-flooded depressions in the region (Golet et al.

2003), indicating that they have not been recently disturbed. This finding could suggest that certain human disturbances (such as, perhaps, partial impoundment or canopy cutting) may increase habitat diversity and thus improve this aspect of ecological value, although further study would be needed to substantiate the idea.

4.3 Implications for management

The State of Rhode Island is committed to expanding and conserving natural open space in Rhode Island. Currently, the state owns and manages 87,305 acres of conservation land (derived from RIGIS State Conservation Areas 2018), much of which is unfragmented (Kutcher 2017), and administers matching grant funding for the purchase of conservation property. Prior studies have found that wetlands on state lands are in better condition than those on properties conserved by private organizations, and that wetlands on state lands designated for conservation are in better condition than those on lands designated for human use (Kutcher 2012), indicating that conservation and management of properties by the state has been effective in promoting ecological condition. The findings of this study support those indications and further suggest that these conservation efforts may in turn promote ecological value, largely through assembling large parcels of unfragmented natural lands.

DEM has been developing regulations to reflect the intent of recent amendments to the Rhode Island Wetlands Act (R.I. Gen. Laws § 2-1-18 et seq.). The amendments broaden the authority of DEM to regulate wetlands and their buffers up to 100-200 feet from the biological wetland edge. Findings of this study indicate that conservation of natural areas of land out to 500 feet from the wetland edge is important for wetland condition and the conservation of wetland ecological value across wetland types, sizes, and settings, suggesting that maximizing natural buffer zones around even large wetlands is important for their ecological health.

This study reinforces prior findings that roads can have multiple detrimental impacts on wetlands through direct fill, hydrological change, introduction of invasive species, fragmentation of species range, and other factors. Findings from this study indicate that even large wetlands and wetlands located on parcels of unfragmented land can be negatively affected by roads in the surrounding landscape. Roads are also a main vector for invasive species, which are pervasive, even among HEV wetlands, and can have broad detrimental effects on ecosystem health. The potential physical and ecological effects on adjacent, upstream, and downstream wetlands should therefore be carefully considered in any road construction or maintenance projects. Such effects may exceed the 200-foot jurisdiction of DEM and may therefore need to be considered on a broader scale.

4.4 Conclusion

Recently-developed protocols using available GIS data can identify a diverse set of ecologically-valuable wetlands. This demonstration study produced an HEV study sample of relatively large wetlands, the majority of which were located on unfragmented lands. Deeper wetlands with longer hydroperiods tended to be associated with a greater number of HEV attributes than dryer wetlands, perhaps due to their support of both terrestrial and aquatic species. When grouped by HEV attributes, several of the HEV wetlands were, on average, in better condition than average wetlands from earlier studies. It is unclear how often wetland condition is a constraint of high ecological value, but findings of this study suggest that wetland condition is at least partly responsible for several aspects of ecological value.

The condition of HEV wetlands, as measured by multiple indicators of ecological integrity, was strongly influenced by the condition of the immediate (100') buffer and surrounding landscape, suggesting that landscape condition may affect ecological value. Even large HEV wetlands were strongly-affected by buffer and landscape stress. Roads were associated with multiple aspects of HEV wetland stress and degradation, and of all current human land uses in Rhode Island, may be the primary threat to wetland condition. Invasive species may also pose a major threat to HEV wetlands, as multiple human activities associated with roads, development, and fragmentation can promote the establishment and expansion of invasive species in freshwater wetlands. This study suggests that wetland condition and fragmentation may in turn affect the capacity of wetlands to support beavers and other threatened wildlife species, an important ecological function of freshwater wetlands.

Collectively, the findings of this study highlight the importance of unfragmented areas of natural land for sustaining wetland ecological value, supporting the premise of Rhode Island's ongoing efforts to assemble contiguous parcels of natural land for ecological conservation. Findings also suggest that to support ecological value, regulations should maximize natural, vegetated buffers surrounding all wetlands, large and small, and aim to protect wetlands from the pervasive impacts of roads.

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Appendix 1

RIRAM Version 2.18 Wetlands of High Ecological Value Field Datasheet

RIRAM V.2.18 WHEV Investigators________________________________ Site Code______________ Date_______

Longitude (DD) ___________________________ Latitude (DD) __________________________

A. Wetland Characteristics; apply to the *current* state of the wetland. Not Scored.

1) Assessment Unit Area; select one:

- ☐ <0.25 acres
- ☐ 0.25 to <1.0 acres
- ☐ 1.0 to <3.0 acres
- ☐ 3.0 to <10 acres
- ☐ 10 to <25 acres
- ☐ 25 to 50 acres
- ☐ >50 acres

2) Position in Watershed

Distance above NAVD88 ☐ <5’ ☐ 5-10’ ☐ 10-20’ ☐ >20’

Distance to MHHW ☐ <200’ ☐ 201-500’ ☐ 501-1000’ ☐ >1000’

Within 100-year floodplain ☐ Yes ☐ No

Headwater wetland ☐ Yes ☐ No

3) Hydrologic Characteristics

Source of water; select main source:

- ☐ Precipitation
- ☐ Groundwater
- ☐ Surface water

Maximum water depth, today; select one:

- ☐ Dry
- ☐ Saturated
- ☐ <1 foot
- ☐☐ 1 to 3 feet
- ☐☐ >3 feet

Water Regime; select one or two dominant regimes:

- ☐ Permanently flooded
- ☐ Semi-permanently flooded
- ☐ Seasonally flooded
- ☐ Temporarily flooded
- ☐ Permanently saturated
- ☐ Seasonally saturated
- ☐ Regularly flooded (tidal)
- ☐ Irregularly flooded (tidal)

4) Habitat Characteristics

Habitat stratum diversity; estimate total cover of all habitat strata within unit using classes at right:

___ Trees
___ Shrubs
___ Emergent
___ Aquatic bed
___ Sphagnum
___ Surface water, today
___ Unvegetated substrate, today

Cover Classes:
0…..< 1%
1…..1-5%
2…..6-25%
3…..26-50%
4…..51-75%
5…..>75%

Microhabitat diversity; rate each present using the scale at right:

___ Vegetated hummocks or tussocks
___ Coarse woody debris
___ Standing dead trees
___ Amphibian breeding habitat

Ecological Significance Scale:
0…..None Noted
1…..Minor Feature
2…..Significant Feature
3…..Dominant Feature

5) Wetland Classification

Hydrogeomorphic Class; select main one:

- ☐ Isolated Depression
- ☐ Connected Depression
- ☐ Floodplain (riverine)
- ☐ Fringe
- ☐ Slope
- ☐ Flat

NWI Classes; select all comprising unit and indicate *Dominance Type*:

- ☐ Forested____
- ☐ Scrub-shrub____
- ☐ Emergent____
- ☐ Aquatic Bed ____
- ☐ Unconsolidated Bottom or Shore
- ☐ Rock Bottom or Shore

RI natural community types; select all present within unit: Dominant RI community:_____________________

- ☐ Intermittent stream
- ☐ Eutrophic Pond
- ☐ Coastal plain pondshore*
- ☐ Deep emergent marsh
- ☐ Shallow emergent marsh
- ☐ Freshwater tidal marsh*
- ☐ Wet meadow
- ☐ Shrub swamp
- ☐ Managed marsh
- ☐ Dwarf shrub bog / fen*
- ☐ Black spruce bog*
- ☐ Gramminoid fen*
- ☐ Coastal plain quagmire*
- ☐ Sea level fen
- ☐ Floodplain Forest*
- ☐ Red Maple Swamp
- ☐ Swamp white oak swamp
- ☐ Hemlock-hardwood swamp
- ☐ Atlantic white cedar swamp*
- ☐ Seeps, spring* ☐ Vernal pool*
- ☐ Other Type: ___________________________

6) Wetland values; select all known or observed:

- ☐ Within 100-year flood plain
- ☐ Between stream or lake and human use
- ☐ Part of a habitat complex or corridor
- ☐ Falls in aquifer recharge zone
- ☐ Feeds headwater stream
- ☐ Contains known T/E species
- ☐ Significant avian habitat
- ☐ Contains *GCN* habitat type (indicated by asterisk above)
- ☐ Educational or historic significance

7) **Vulnerability to Climate Impacts**: select all the apply: __ Borders salt marsh __ Borders lower coastal tributary __ Borders freshwater coastal pond __ Subject to coastal overwash __ Subject to salt intrusion __ Tidal fresh __ Headwater wetland __ Ephemeral pool __ Other

8) **Wetlands High Ecological Value (WHEV) Attributes**

Factors that indicate wetlands of high ecological value; select all known or observed within assessment unit:

- ☐ Wetlands located within large (>250 acres) unfragmented lands
- ☐ Large wetlands (>20 acres, excluding open water)
- ☐ Diverse wetlands (with 3 or more classes of ½ acre each)
- ☐ Wetlands supporting rare species (EO rank C or higher)
- ☐ Headwater wetlands of perennial streams or rivers
- ☐ Wetlands shading or bordering cold-water streams or rivers
- ☐ Cold water springs and till seeps
- ☐ Wetlands located within areas of limestone geology
- ☐ Urban wetlands
- ☐ Beaver-impounded wetlands (non-Phragmites-dominated)
- ☐ Clusters of vernal pools
- ☐ Forested wetlands supporting vernal pools
- ☐ Tidal freshwater wetlands
- ☐ Forested wetlands with old growth characteristics
- ☐ Tall shrub swamps
- ☐ Emergent deep marshes (non-Phragmites dominated)
- ☐ Emergent wetlands connected to surface-water systems
- ☐ Aquatic beds
- ☐ Unconsolidated shores of perennial surface waters
- ☐ Semi-permanently flooded wetlands
- ☐ Bogs and Fens
- ☐ Atlantic White Cedar swamps
- ☐ Coastal Plain Pond Shores

9) **Conservation Status**; select closest estimate for each section

Proportion of unit conserved;
Estimate to the nearest tenth; circle one:

.1 .2 .3 .4 .5 .6 .7 .8 .9 .10

Fee Ownership; select all that apply

- ☐ Private
- ☐ NGO
- ☐ Municipal
- ☐ State
- ☐ Federal
- ☐ Multiple
- ☐ Unknown

Conservation type: select one or both

- ☐ Conservation Easement
- ☐ Fee Owner
- ☐ Unknown

Public Access

- ☐ Yes
- ☐ No
- ☐ Unknown

B. Landscape Stresses. Sum metrics 1 and 2

1) Degradation of Buffers

[ ] Estimate % cultural cover within 100-foot buffer. Select one.

- ☐ <5% (10)
- ☐ 6 to 25% (7)
- ☐ 26-50% (4)
- ☐ 51-75% (1)
- ☐ >75% (0)

2) Intensity of Surrounding Land Use

[ ] Land Use Intensity weighted average within 500-foot buffer.
Estimate proportion of each class to the nearest tenth and multiply.

	Proportion	Score	Weighted Value
Very Low	______	× 10 =	______
Low	______	× 7 =	______
Moderately High	______	× 4 =	______
High	______	× 1 =	______

Sum weighted values for score = ______

Associated Stressors: Check all that apply

B1	B2	
☐	☐	Commercial or industrial development
☐	☐	Unsewered Residential development
☐	☐	Sewered Residential development
☐	☐	New construction
☐	☐	Landfill or waste disposal
☐	☐	Channelized streams or ditches
☐	☐	Raised road beds
☐	☐	Foot paths / trails
☐	☐	Row crops, turf, or nursery plants
☐	☐	Poultry or livestock operations
☐	☐	Orchards, hay fields, or pasture
☐	☐	Piers, docks, or boat ramps
☐	☐	Golf courses / recreational development
☐	☐	Sand and gravel operations
☐	☐	Railroad bed
☐	☐	Power lines
☐	☐	Other ____________________________

Very Low.......Natural areas, open water
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 land cover, new construction, row crops, turf crops, mining operations, paved roads > 2-lane

Sum of Metrics 1 and 2 = [ ] **B. Landscape Stress Score**

C. Wetland Stresses. Sum metrics 3 to 9 and subtract from 70.

3) Impoundment.

[ ] Sum a and b (Max = 10)

a. Increase in depth or hydroperiod. Select one and multiply by the proportion of the unit affected to the nearest tenth. = ________

- ☐ None (0)
- ☐ Wetland was *created* by impoundment (1)
- ☐ Change in velocity only (2)
- ☐ Change of less than one water regime (4)
- ☐ Change of one water regime (6)
- ☐ Change of two or more water regimes (8)
- ☐ Change to deepwater (10)

Proportion of unit affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

b. Artificial barrier to movement of resources through water. Select all that apply and sum. = ________

- ☐ None (0)
- ☐ Barrier to upstream movement of aquatic fauna at low water (1)
- ☐ Barrier to downstream movement of any resources at low water (1)
- ☐ Barrier to upstream or downstream movement of any resources above low water (1)

Evidence: check all that apply

- ☐ Physical barrier across flow downstream of wetland
- ☐ Abrupt and unnatural edge downstream of wetland
- ☐ Dam or restricting culvert downstream of wetland
- ☐ Deepening of wetland upstream of barrier
- ☐ Widening of wetland upstream of barrier
- ☐ Change in vegetation across barrier
- ☐ Dead or dying vegetation

Primary Associated Stressor; check one:

- ☐ Road
- ☐ Railway
- ☐ Weir / Dam
- ☐ Raised Trail
- ☐ Development Fill
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):

- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

Water Regimes

(Upland)..Temporarily Flooded...................Irregularly Flooded
Seasonally Saturated ....Seasonally Flooded........................Regularly Flooded
Permanently Saturated ....Semi-permanently Flooded
Permanently Flooded

4) Draining or diversion of water from wetland.

☐ Decrease in depth or hydroperiod. Select one and multiply by the proportion of the unit affected to the nearest tenth.

- ☐ None (0)
- ☐ Change in velocity only (3)
- ☐ Change of less than one water regime (5)
- ☐ Change of one water regime (7)
- ☐ Change of two or more water regimes or to upland (10)

Water Regimes

(Upland)....................................Temporarily Flooded.............. Irregularly Flooded
Seasonally Saturated ....Seasonally Flooded..................Regularly Flooded
Permanently Saturated ....Semi-Permanently Flooded
Permanently Flooded

Proportion of unit affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Drainage ditches or tiles evident
- ☐ Evident impoundment upstream of wetland
- ☐ Severe root exposure
- ☐ Moderate root exposure
- ☐ Soil fissures
- ☐ Uncharacteristically dry groundcover
- ☐ Dead or dying vegetation
- ☐ Change in vegetation across barrier

Primary Associated Stressor; Check one:
- ☐ Road
- ☐ Railway
- ☐ Dike
- ☐ Fill
- ☐ Drainage ditch / tile
- ☐ Within a well area
- ☐ Surface water pumps
- ☐ Current or recent drought
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Unusual climate event
- __ Undetermined

5) Anthropogenic fluvial inputs.

☐ Rank the evidence of impact for each and sum (Max = 10).

____ a. Nutrients

____ b. Sediments / Solids

____ c. Toxins / Salts

____ d. Increased flashiness

Evidence-of-Impact Ranks
0.....No evidence
1.....Sources evident, only
3.....Slight impact evident
5.....Moderate to strong impact evident

Evidence: check all that apply
- ☐ Runoff sources evident
- ☐ Point sources evident
- ☐ Excessive algae or floating vegetation
- ☐ Excessive rooted submerged or emergent vegetation
- ☐ Uncharacteristic sediments
- ☐ Obvious plumes or suspended solids
- ☐ Chemical smell
- ☐ Strangely tinted water
- ☐ Dead, dying, or patchy vegetation
- ☐ Dead fauna or stark lack of life
- ☐ Root exposure or bank erosion due to scouring
- ☐ Wide stream channel with relatively little water
- ☐ Coastal washover

Primary Associated Stressor; Check one:
- ☐ Point runoff
- ☐ Sheet runoff
- ☐ Effluent discharge
- ☐ Organic / yard waste
- ☐ Other point _______________
- ☐ Riverine (up-stream)
- ☐ Multiple / non-point
- ☐ Recent freshwater flooding event
- ☐ Recent coastal flooding event
- ☐ Channelization

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Unusual climate event
- __ Multiple / non-point
- __ Undetermined

6) Filling and dumping within wetland. Select one and multiply by the proportion of the unit affected to the nearest tenth (Max = 10).

☐ Intensity of filling
- ☐ None (0)
- ☐ Affects aesthetics only (2)
- ☐ Affects water regime, vegetation, or soil quality (6)
- ☐ Changes area to upland (10)
- ☐ Fill is above surrounding upland grade (12)

Proportion of unit (or perimeter) affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Unnaturally abrupt change in ground level
- ☐ Abrupt change in soil texture or content
- ☐ Unnaturally straight or abrupt wetland edge
- ☐ Unnatural items on or within the sediments
- ☐ Coastal washover

Primary Associated Stressor; Check one:
- ☐ Road ☐ Dam
- ☐ Raised Trail ☐ Dike
- ☐ Railway ☐ Trash
- ☐ Organic / yard waste
- ☐ Fill
- ☐ Recent FW flooding event
- ☐ Recent coastal flooding event
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Unusual climate event
- __ Undetermined

7) Excavation and other substrate disturbances within wetland. Select one and multiply by the proportion of the unit affected to the nearest tenth.

Intensity of disturbance
- ☐ None (0)
- ☐ Wetland unit was *created* by excavation (1)
- ☐ Soil quality or vegetation disturbed (4)
- ☐ Changes water regime (7)
- ☐ Excavated to deep water (10)

Proportion of unit (or perimeter) affected (circle one)
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Unnaturally abrupt lowering in ground level
- ☐ Loss of vegetation
- ☐ Unnaturally straight and abrupt wetland edge
- ☐ Direct evidence of disturbance

Primary Associated Stressor; Check one:
- ☐ Vehicle disturbance
- ☐ Plowing / cultivation
- ☐ Excavation / Grading
- ☐ Channelization / Dredging
- ☐ Ditching
- ☐ Footpaths
- ☐ Trampling
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

8) Vegetation and detritus removal within wetland. Rank extent and multiply by the estimated proportion affected for each layer; then sum (Max = 10).

Layers affected	Extent		Proportion	
☐ Aquatic Bed	______	×	________	=________
☐ Detritus	______	×	________	=________
☐ Emergent	______	×	________	=________
☐ Shrub	______	×	________	=________
☐ Canopy	______	×	________	=________

Sum =________

Proportion of unit affected
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Evidence: check all that apply
- ☐ Cut stems or stumps
- ☐ Immature vegetation strata
- ☐ Missing vegetation strata
- ☐ Mowed areas
- ☐ Browsing or grazing

Extent of removal
0.....None
2.....Partial or recovering
3.....Complete

Primary Associated Stressor; Check one:
- ☐ Power lines
- ☐ Grazing
- ☐ Cultivation
- ☐ Timber Harvest
- ☐ Development clearing
- ☐ Trails / non-raised roads
- ☐ Excavation / ditching
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Public transportation
- __ Public utilities
- __ Public recreation
- __ Undetermined

9) Invasive species within wetland.

9a. Select one class for total coverage.
- ☐ None noted (0)
- ☐ Nearly absent <5% cover (2)...........Cover Class 1
- ☐ Low 6-25% cover (4)........................Cover Class 2
- ☐ Moderate 26-50% cover (6).............Cover Class 3
- ☐ High 51-75% cover (8).......................Cover Class 4
- ☐ Extensive >75% cover (10)................Cover Class 5

9b. List and select a cover class for each invasive plant species noted.

Cover Class	Species
_____	____
_____	____
_____	____
_____	____
_____	____

Primary Abutting Stressor; Check one:
- ☐ Road
- ☐ Railway
- ☐ Raised Trail
- ☐ Footpath
- ☐ Dam / Dike
- ☐ Organic / yard waste
- ☐ Other Fill
- ☐ Drainage ditch / tile
- ☐ Stormwater input
- ☐ Clearing
- ☐ Multiple
- ☐ Other

Primary Source of Stress; indicate as current (C) or historic (H):
- __ Private / Residential
- __ Commercial
- __ Agricultural
- __ Undetermined
- __ Public transportation
- __ Public utilities
- __ Public recreation

Sum of C3 to C9 Scores = ☐ **70 Minus Sum =** ☐ **C. Wetland Stress Score**

D. Observed Wetland Indicators. Circle one score for each indicator and sum.
Refer to Sections A through C to inform scores. Consider current wetland types.

Indicators	Characteristic*		Degraded		Destroyed
Hydrologic Integrity	2	1.5	1	0.5	0
Water and Soil Quality	2	1.5	1	0.5	0
Vegetation/microhabitat Structure	2	1.5	1	0.5	0
Vegetation Composition	2	1.5	1	0.5	0
Habitat Connectivity	2	1.5	1	0.5	0

SUM = ☐ **D. Observed Indicators Score**

B. Landscape Stress Score (max 20) __________ +

C. Wetland Stress Score (max 70) __________ =

B+C. Total Stress Score (max 90) ☐

D. Observed Indicators Score (max 10) __________ =

RIRAM V.2.18 WHEV Condition Index ☐

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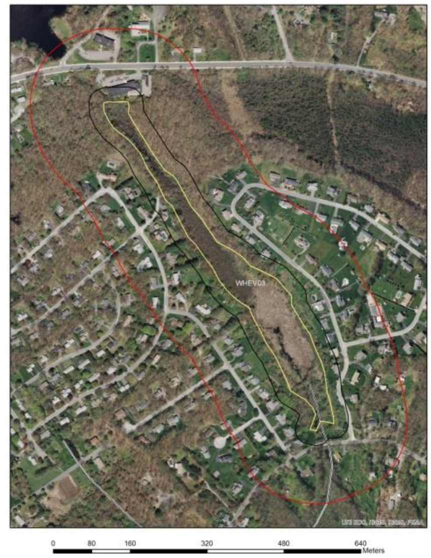
* Characteristic of wetland type in an unstressed setting

Appendix 2

Site maps of 20 HEV freshwater wetlands assessed in 2018, depicting assessment site boundaries, 100-foot buffers, and 500-foot surrounding landscape zones

WHEV01

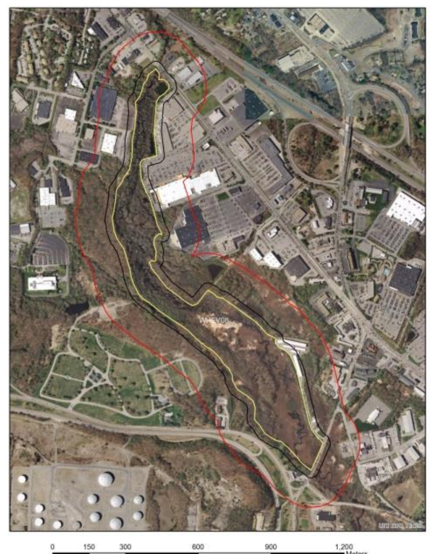
WHEV02



WHEV03

WHEV04

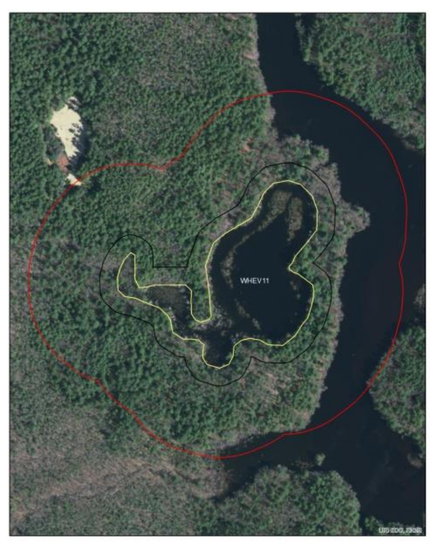
WHEV05



WHEV06

WHEV09

WHEV10



WHEV11

WHEV12

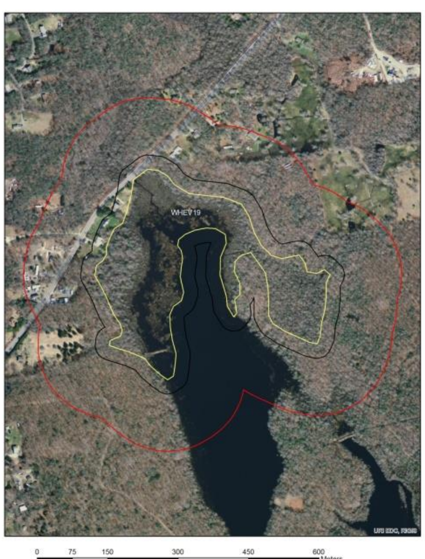
WHEV13

WHEV14

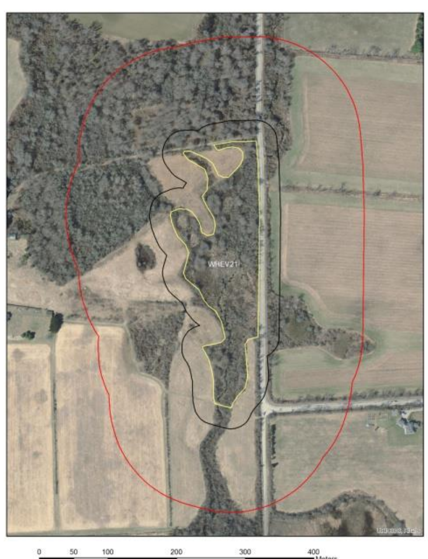
WHEV15

WHEV16

WHEV17



WHEV19



WHEV21

WHEV22

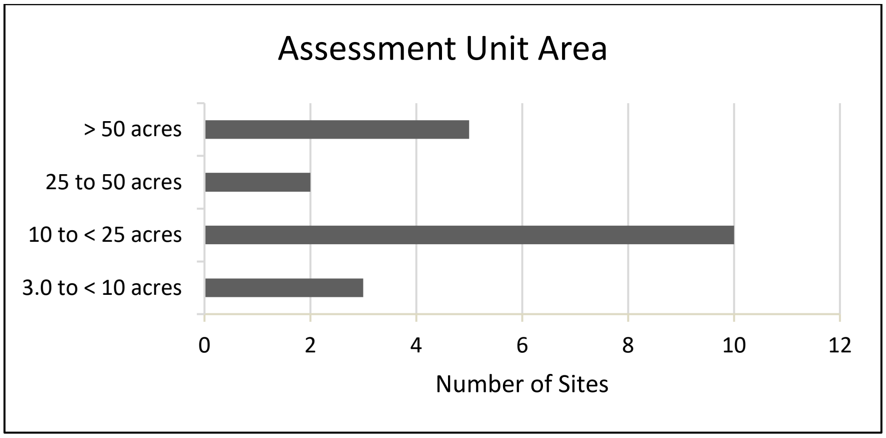
WHEV23

WHEV24

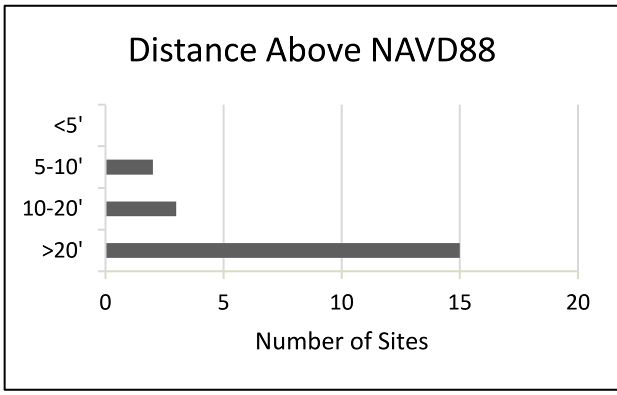
Appendix 3

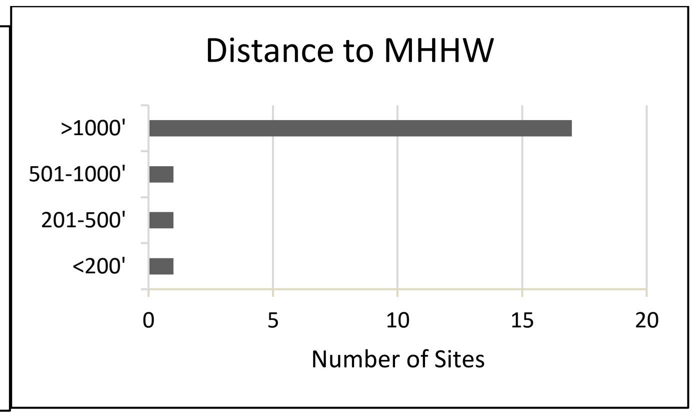
Graphs of RIRAM attributes and metric Scores at 20 HEV freshwater wetlands assessed 2018

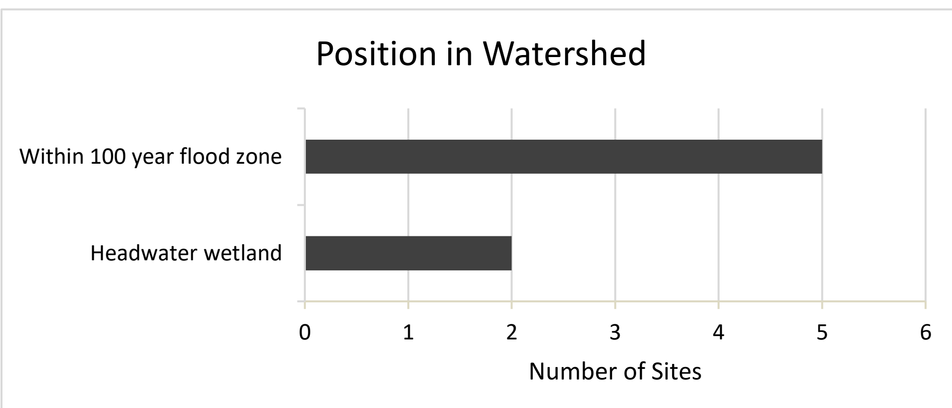
A1. Assessment Unit Area



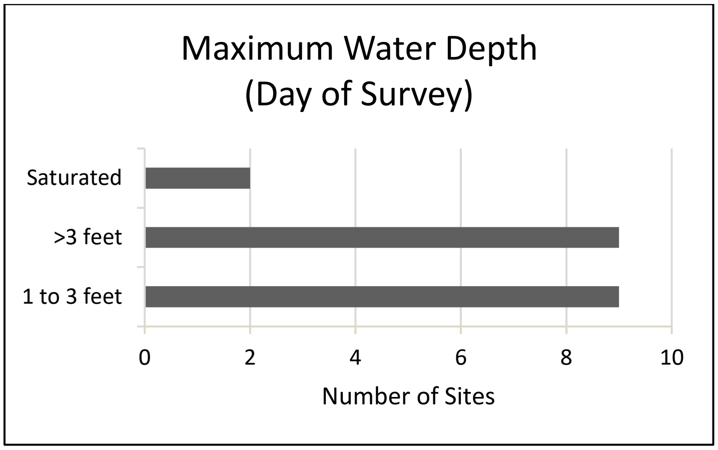
A2. Position in Watershed

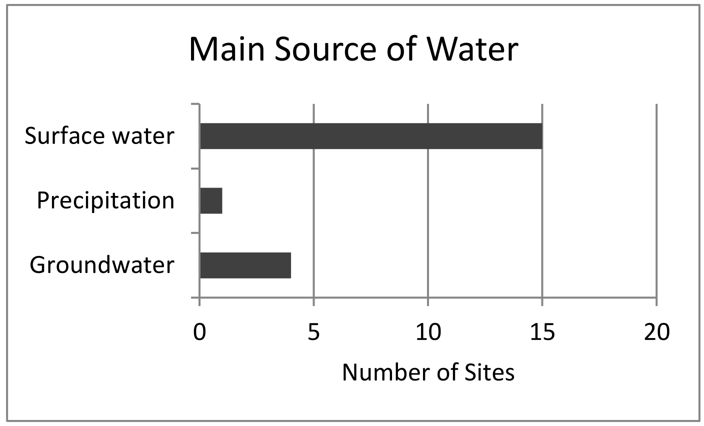


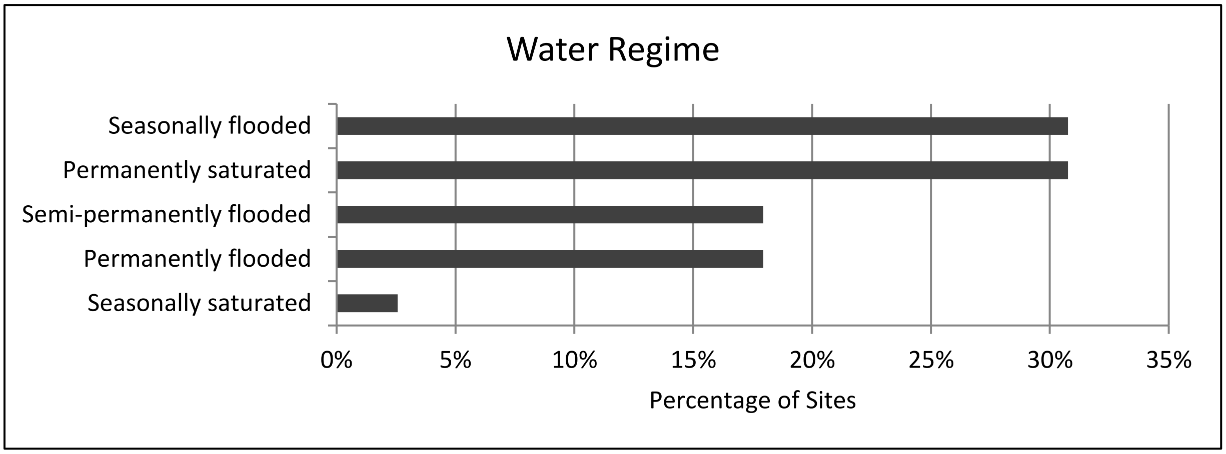




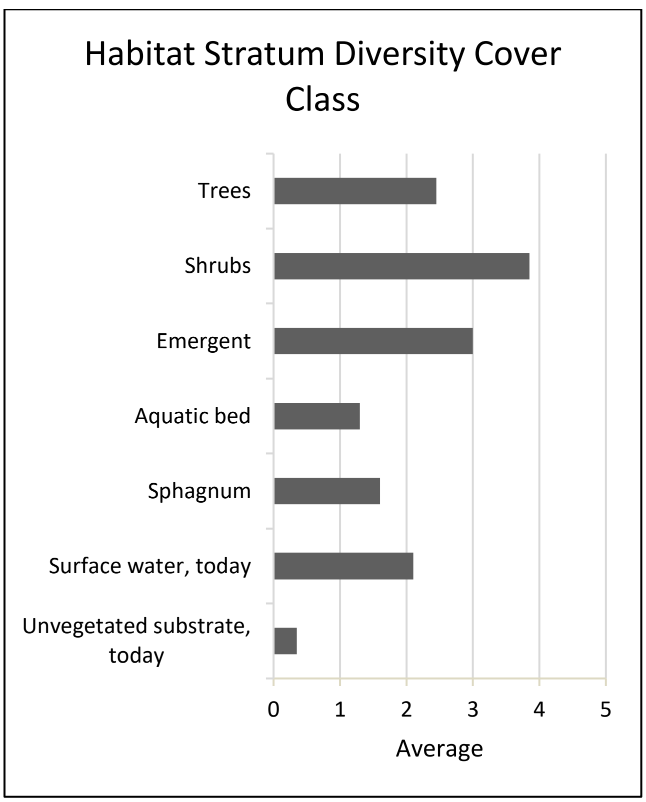
A3. Hydrologic Characteristics

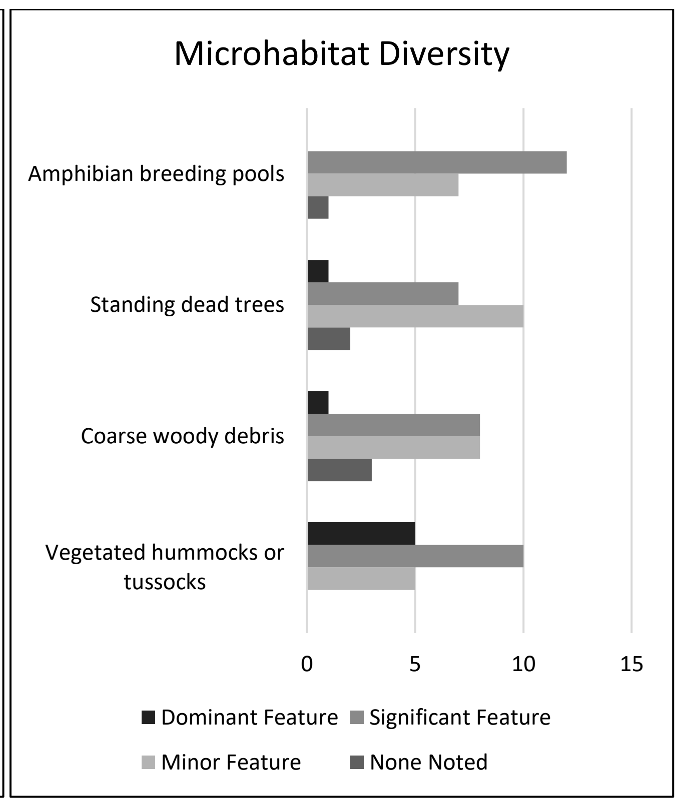




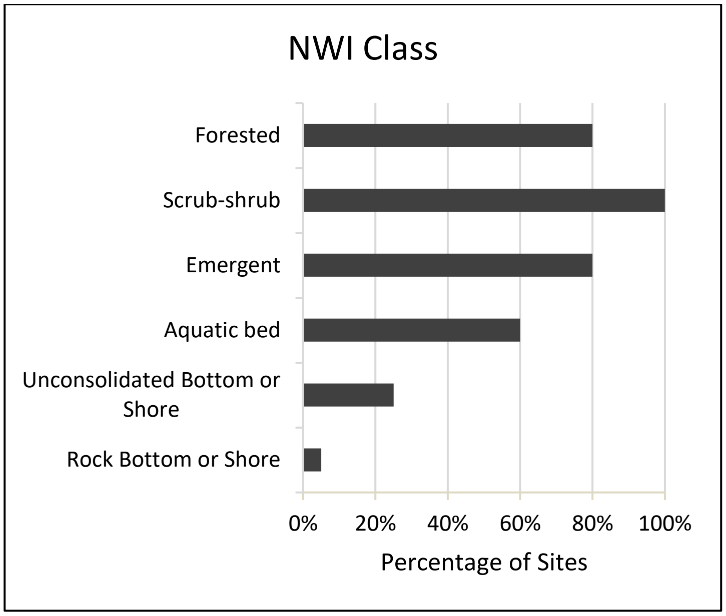


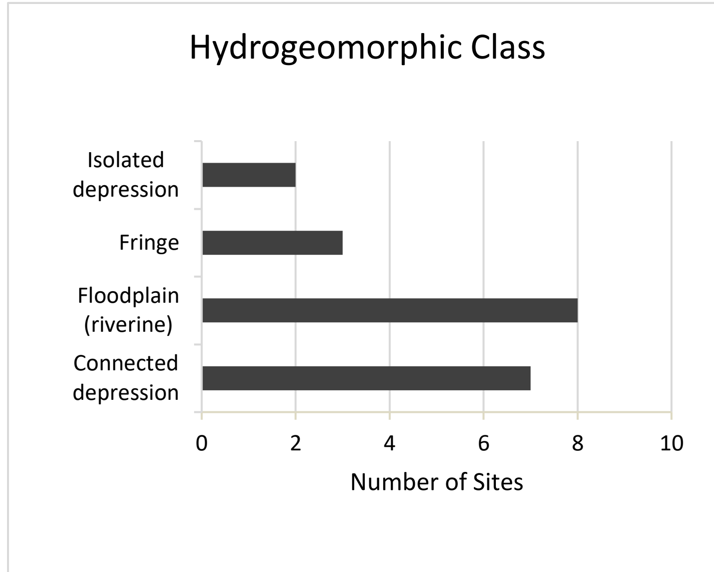
A4. Habitat Characteristics

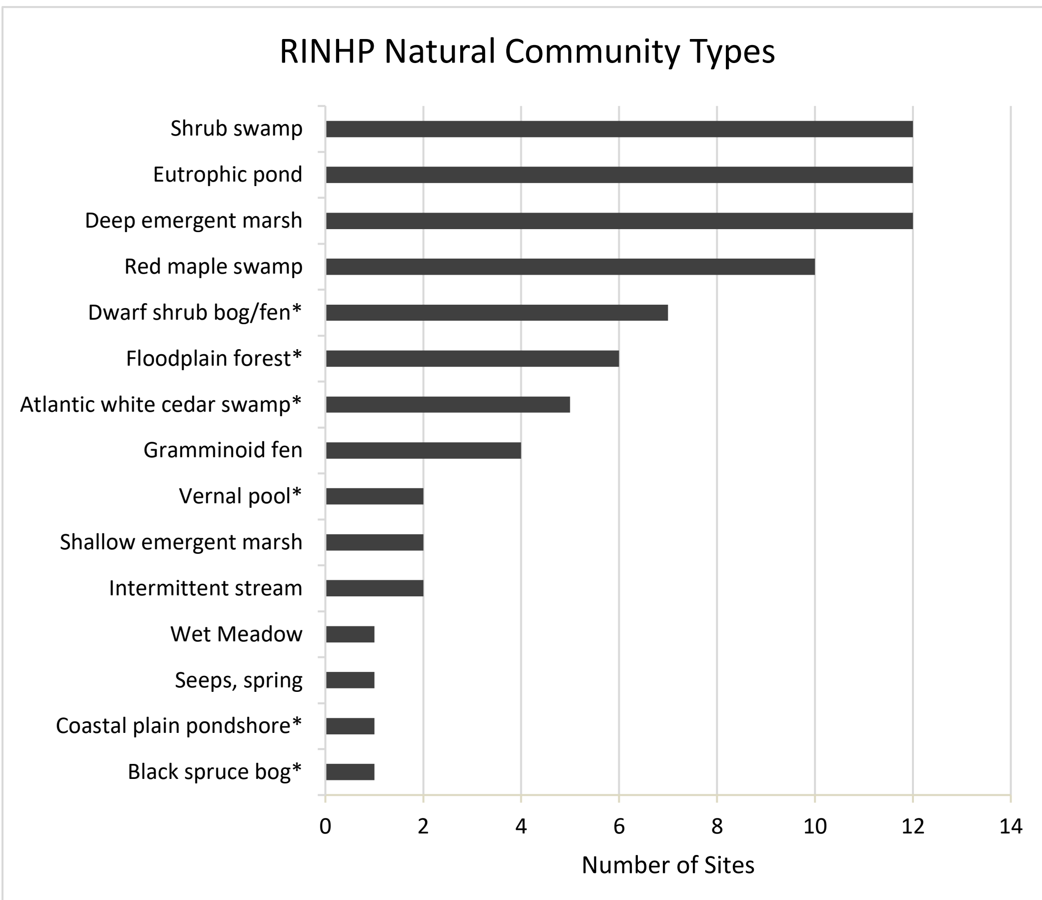




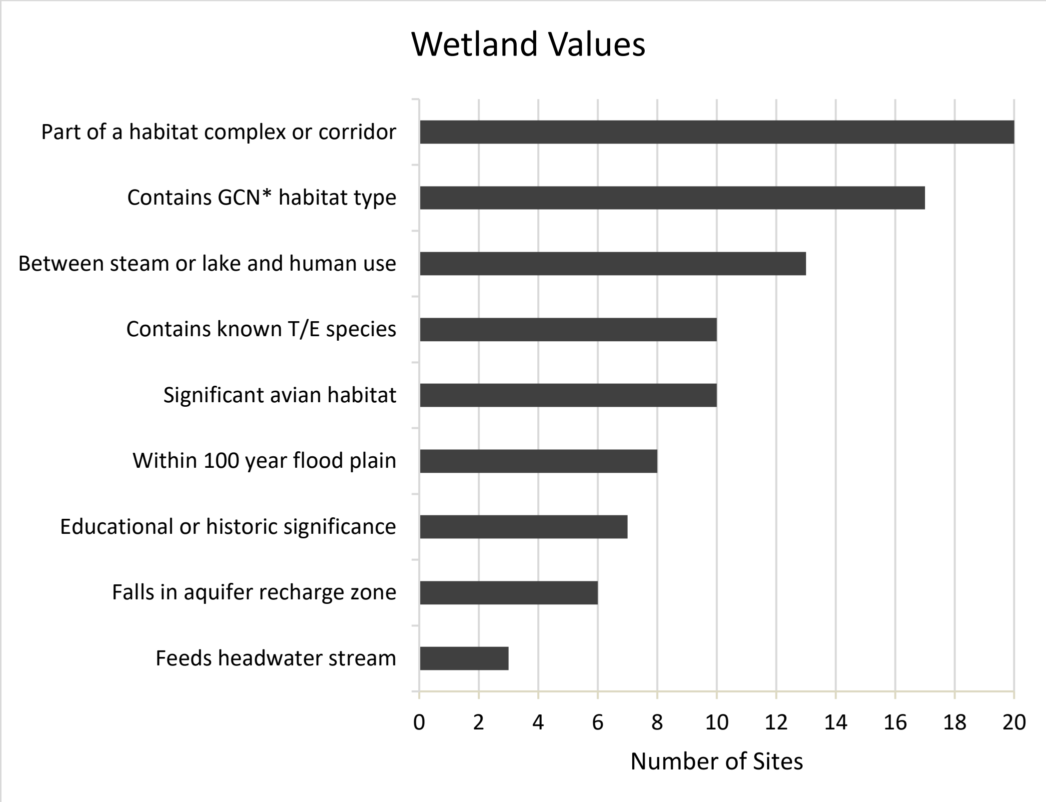
A5. Wetland Classification



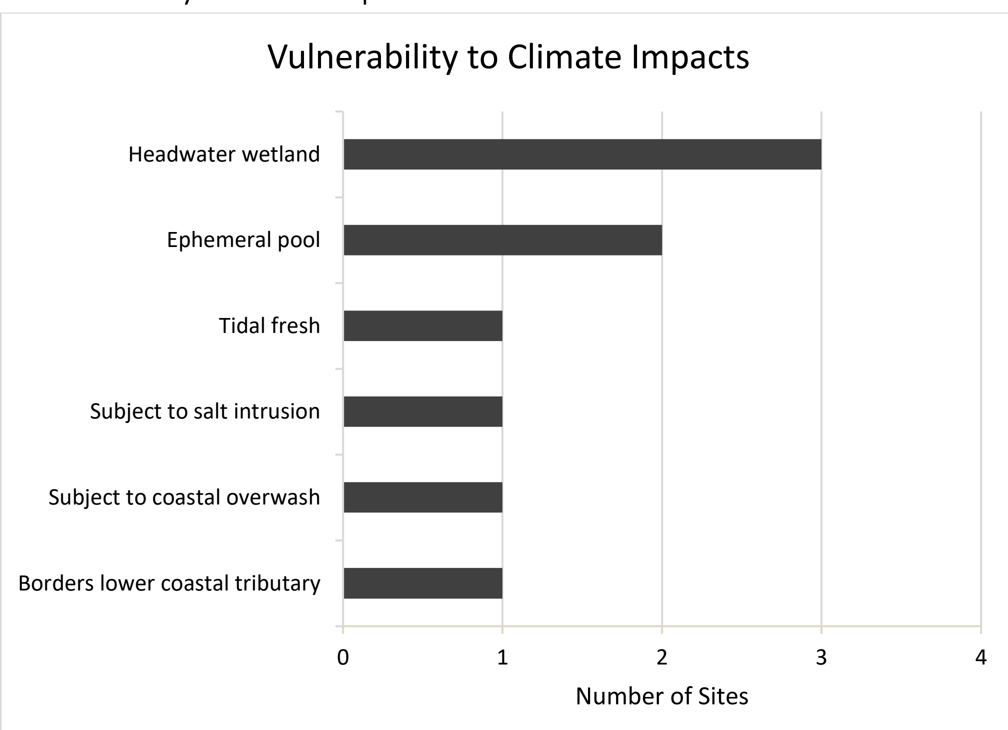




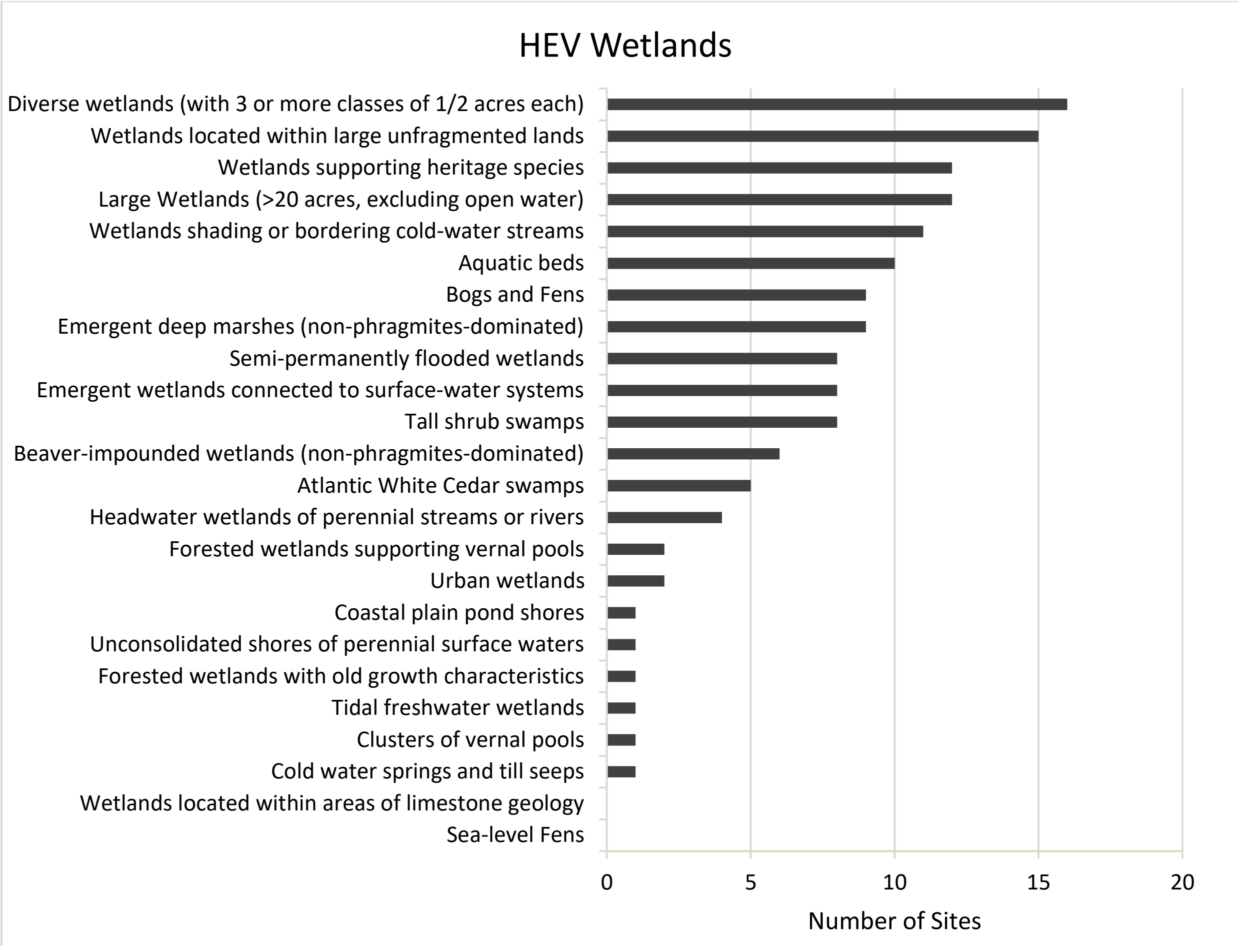
A6. Wetland Values



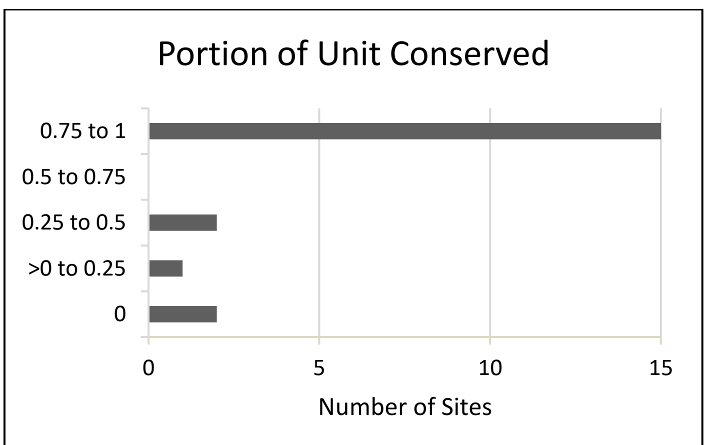
A7. Vulnerability to Climate Impacts

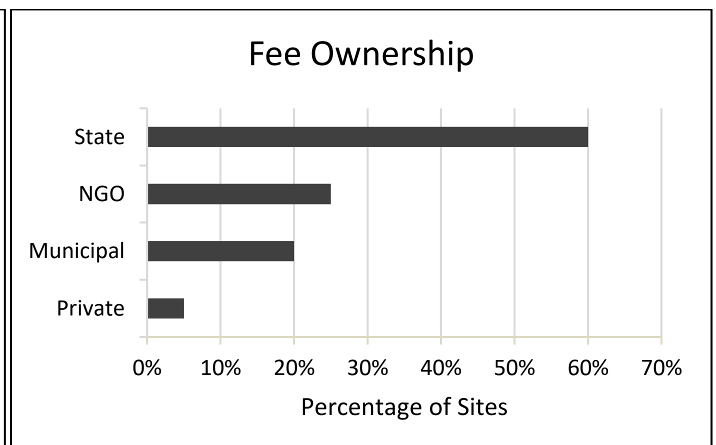


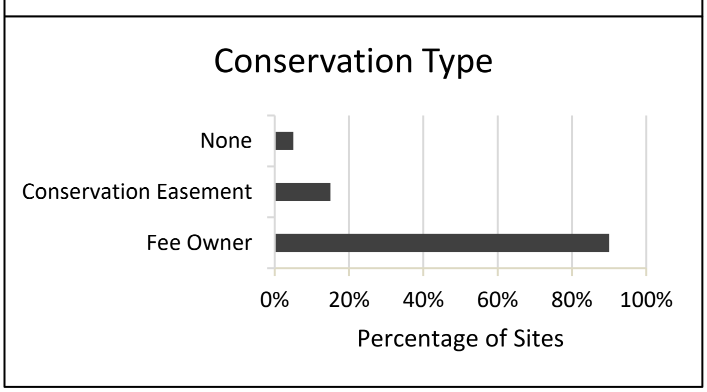
A8.WHEV Attributes

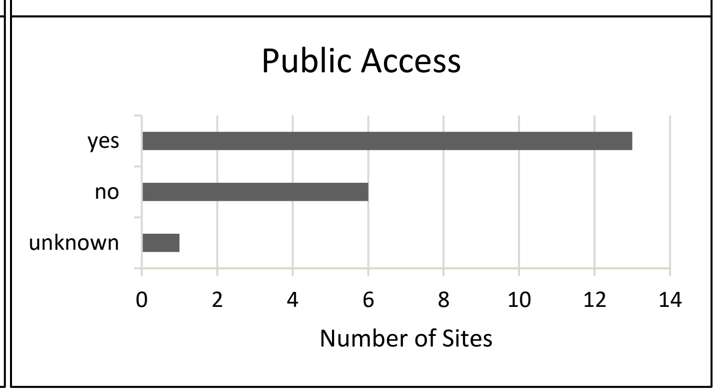


A9. Conservation Status

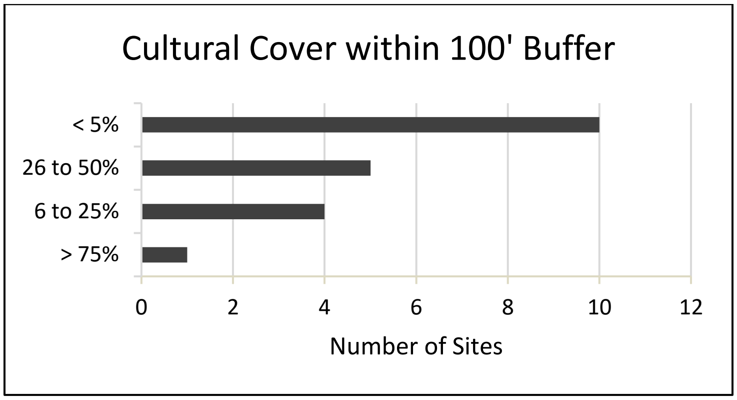




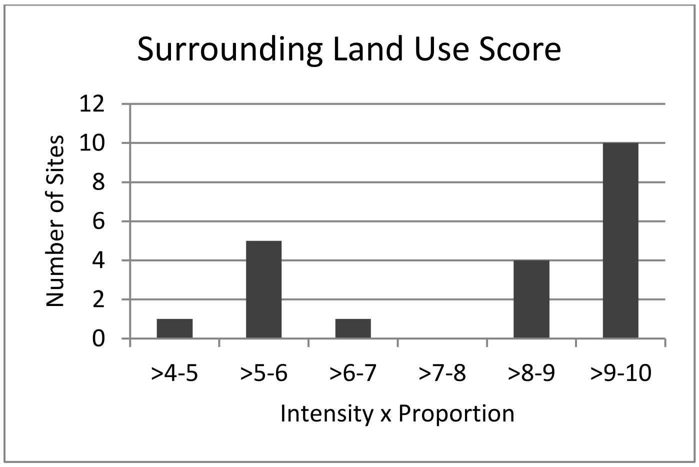


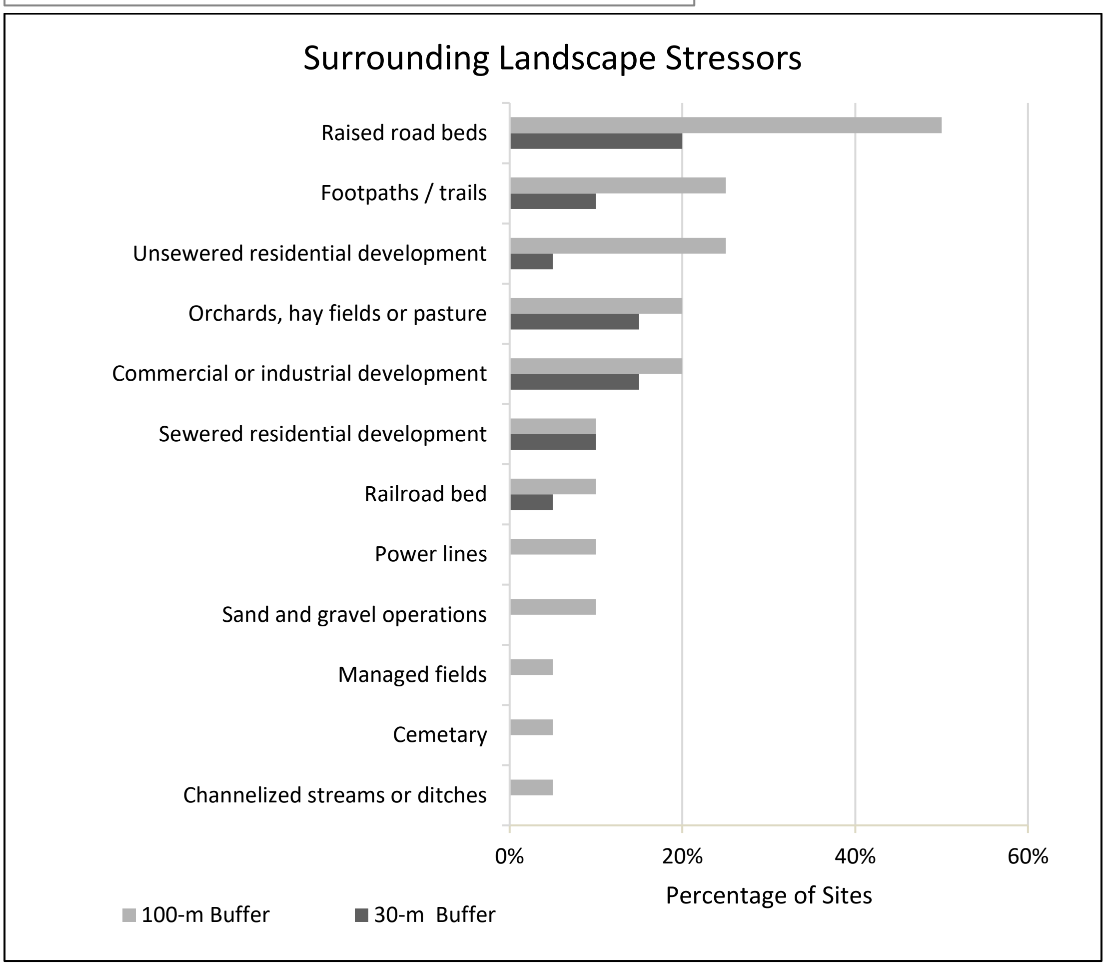


B1. Degradation of Buffers

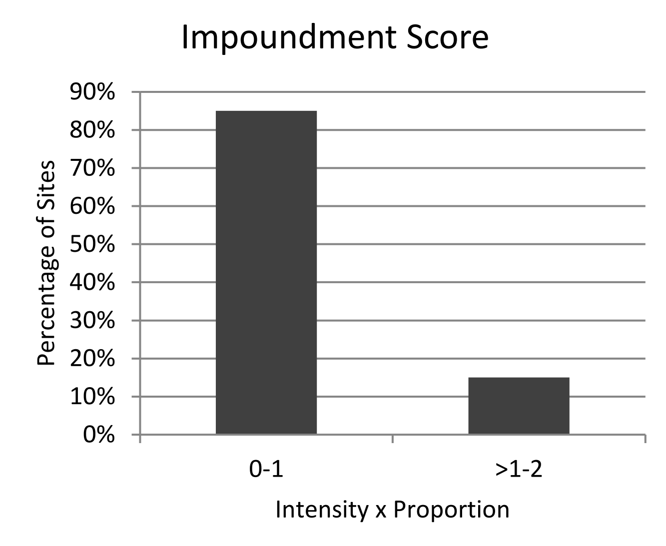


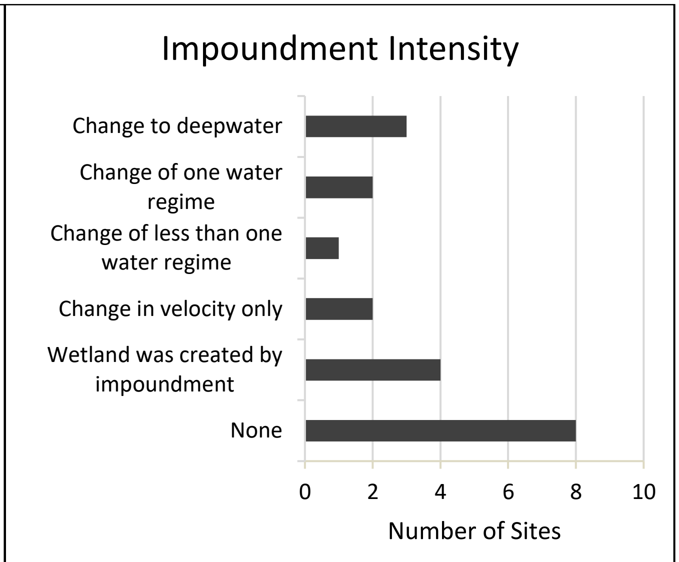
B2. Surrounding Land Use Score

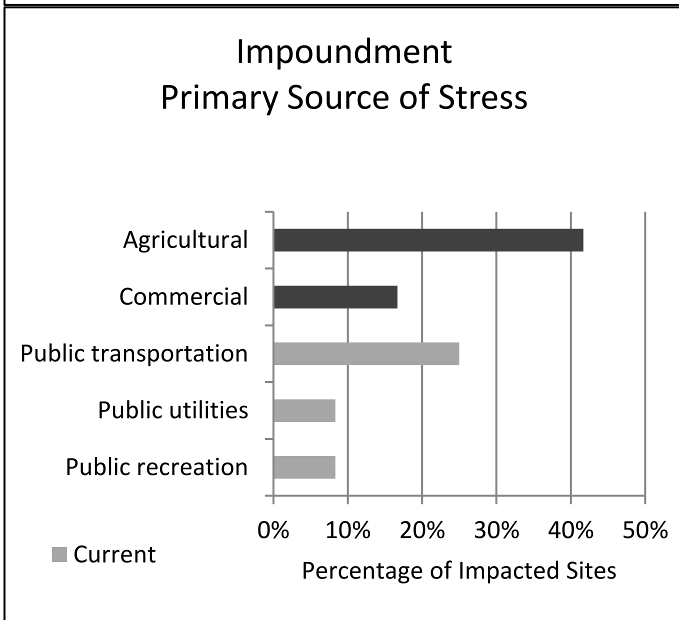


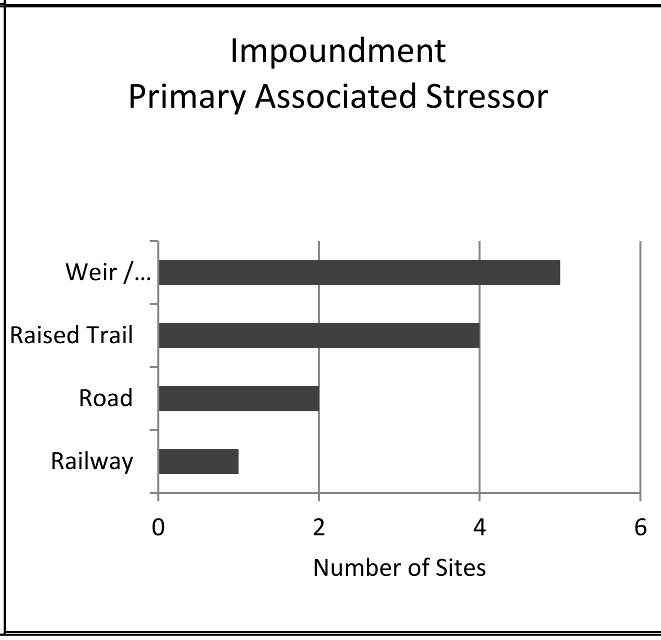


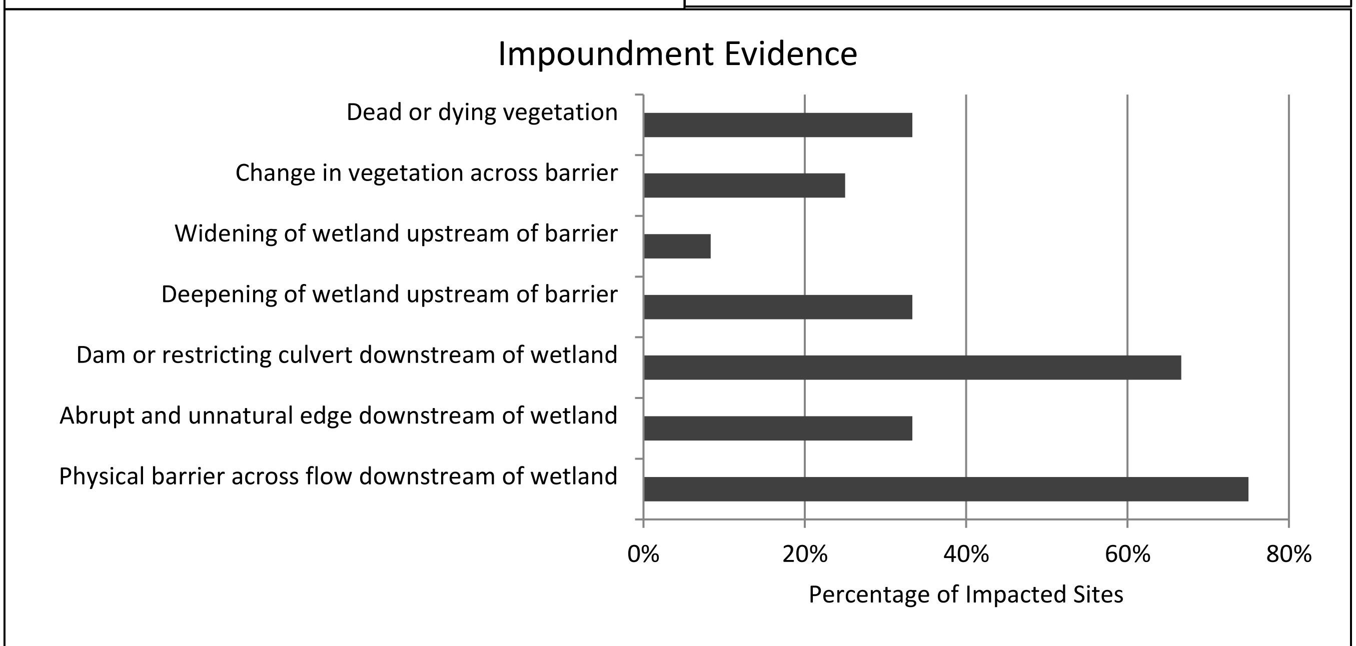
C1. Impoundment



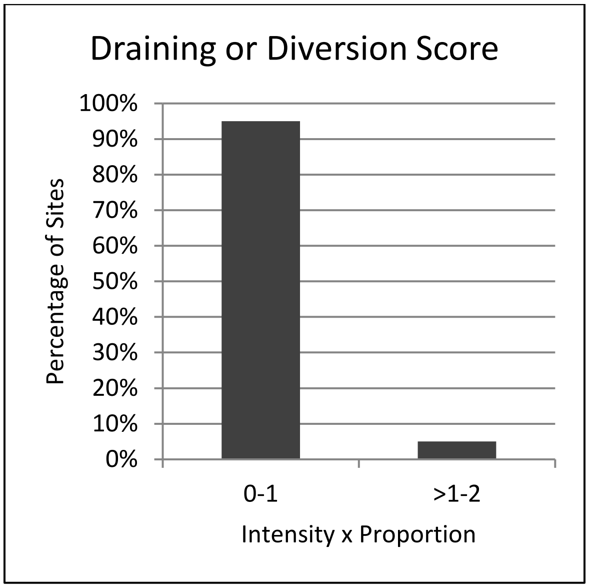


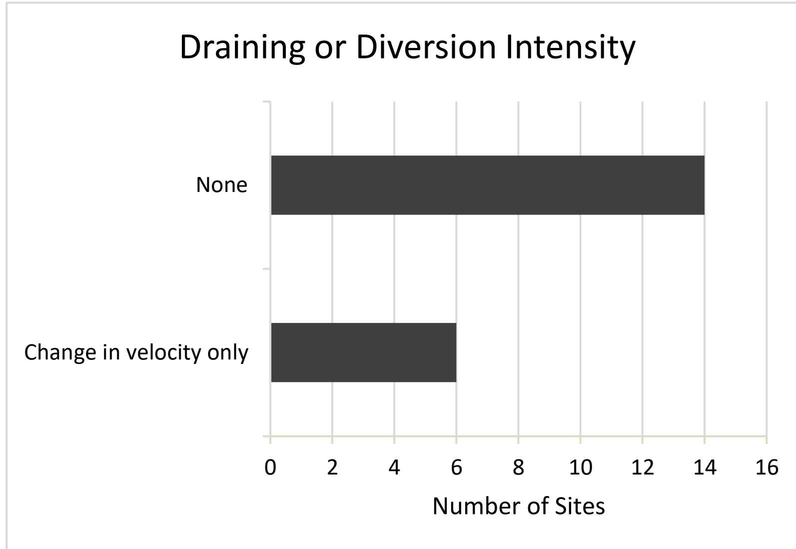


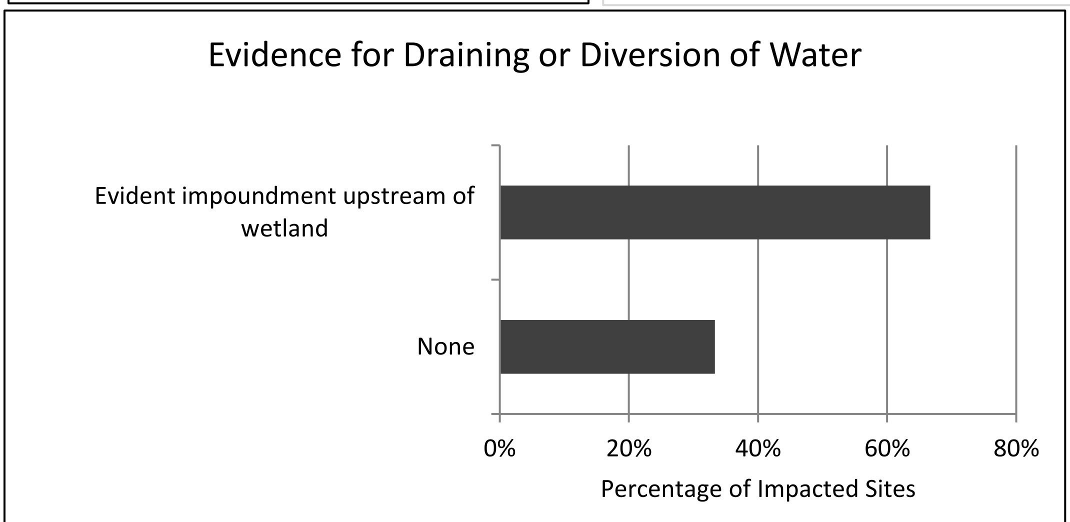


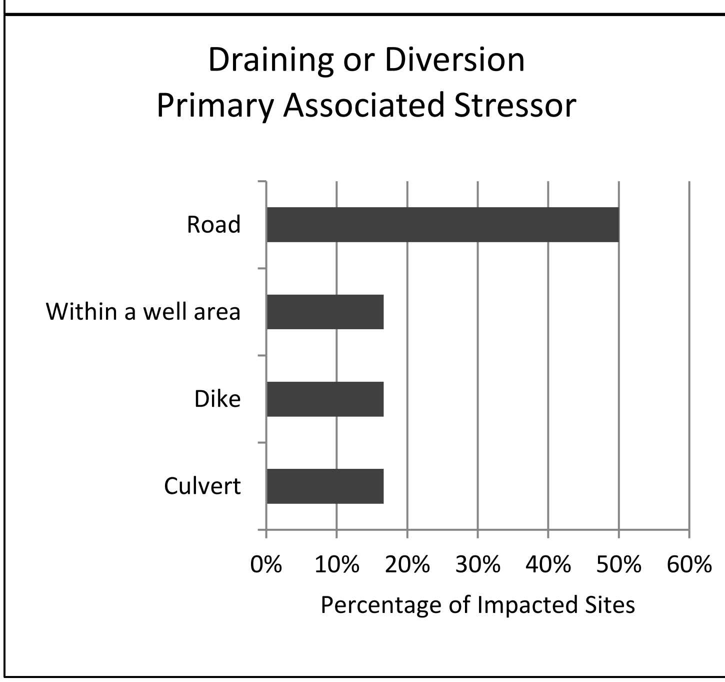


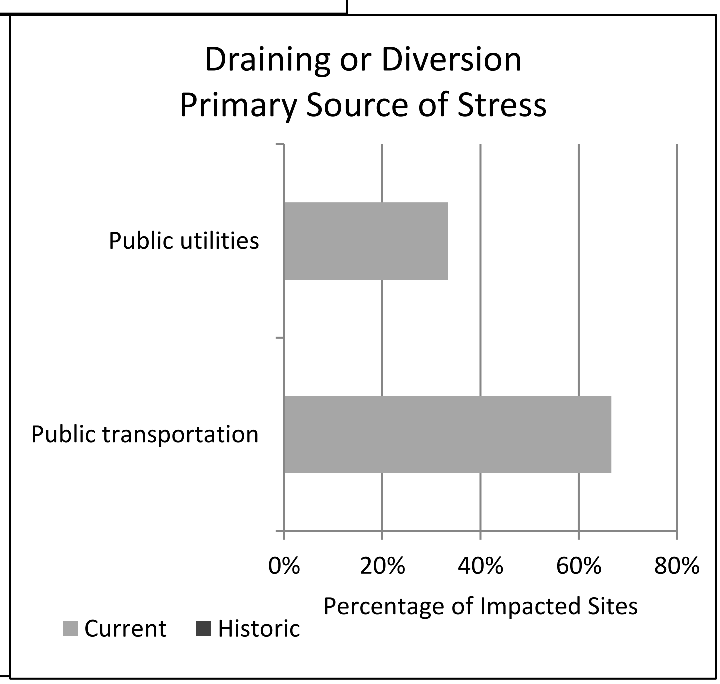
C2. Ditching and Draining



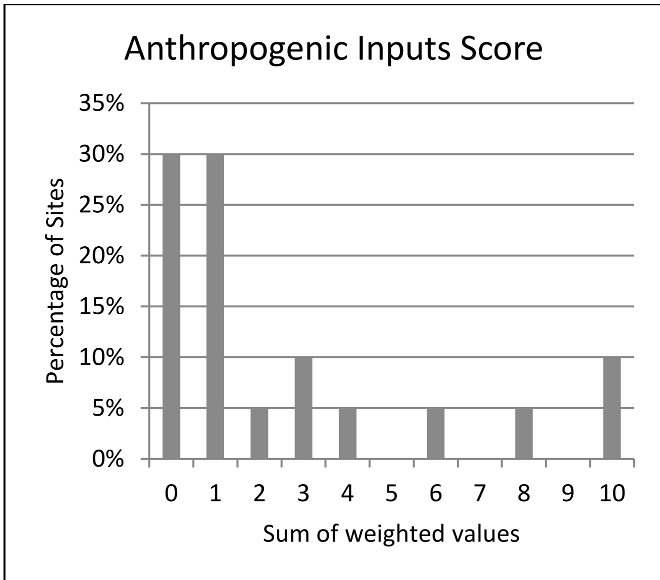


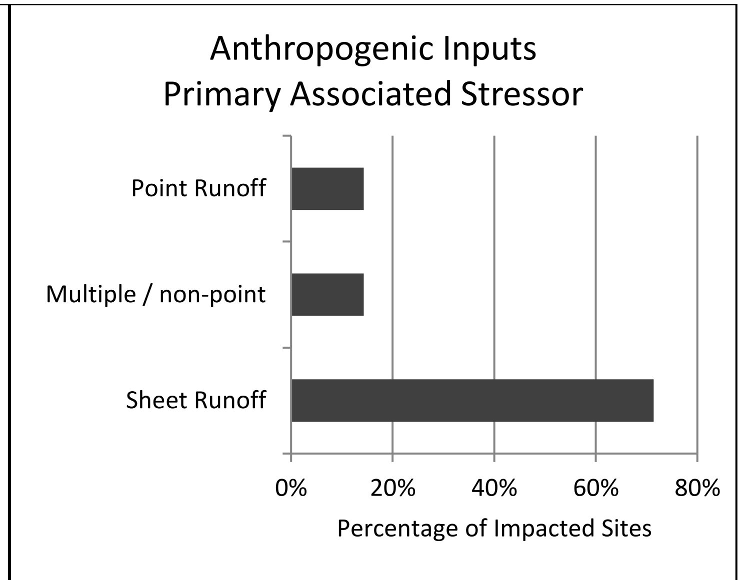


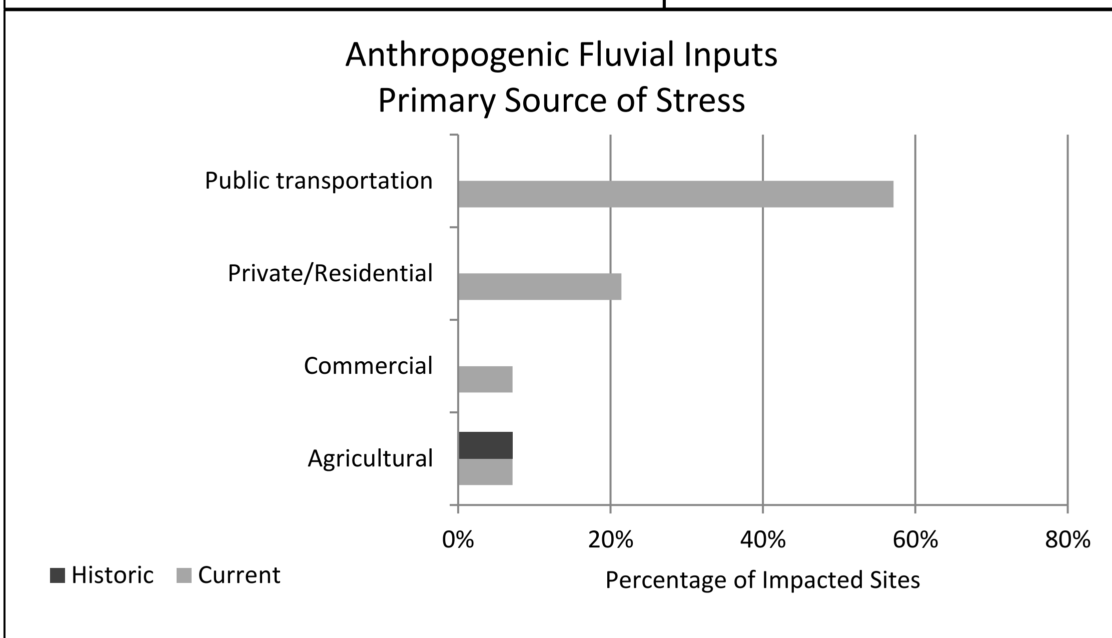


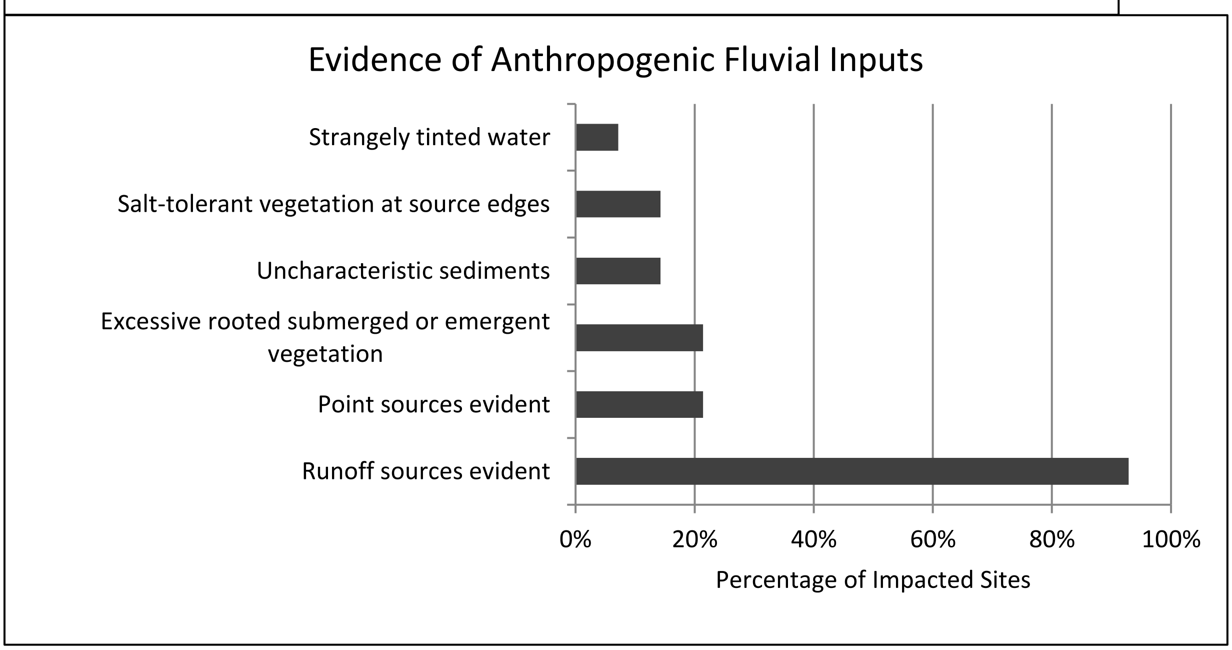


C3. Anthropogenic Fluvial Inputs

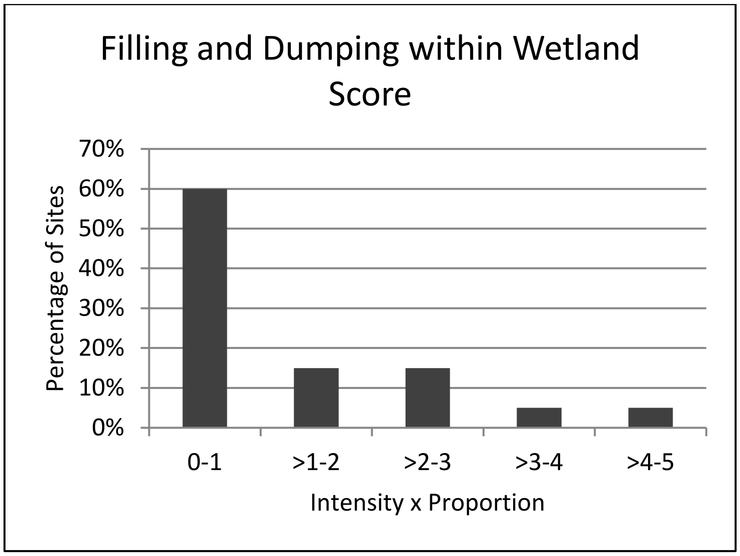


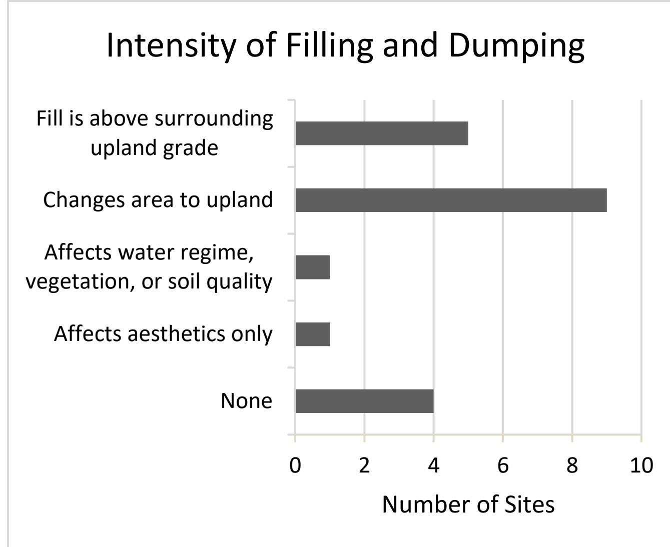


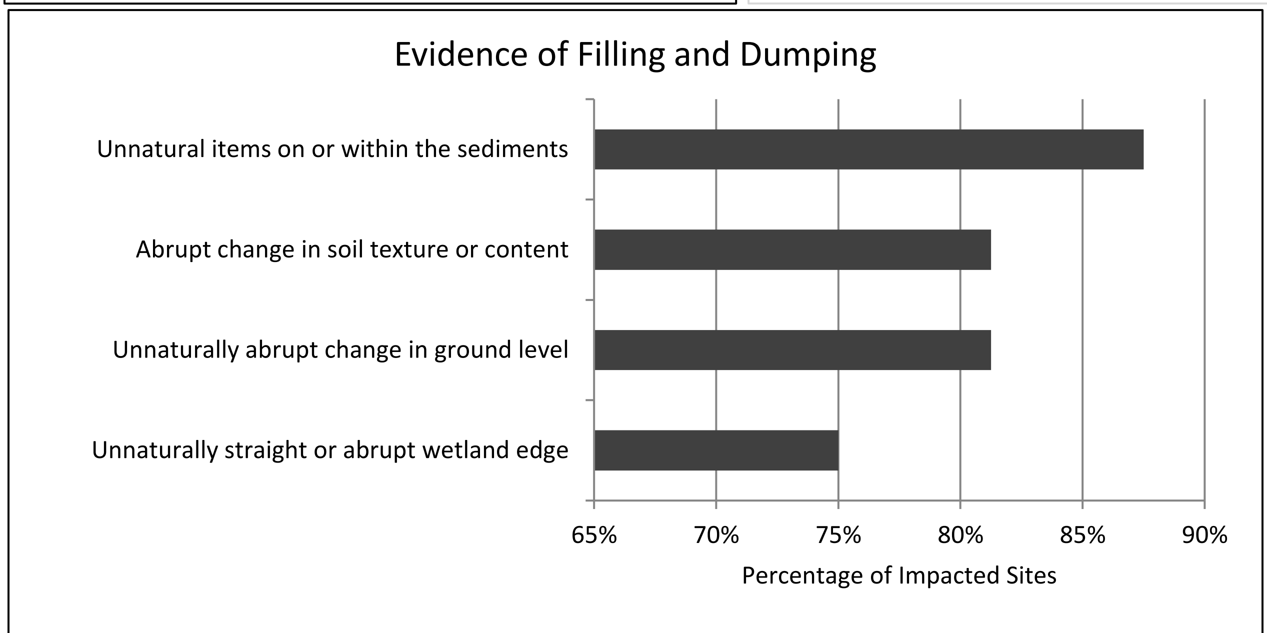


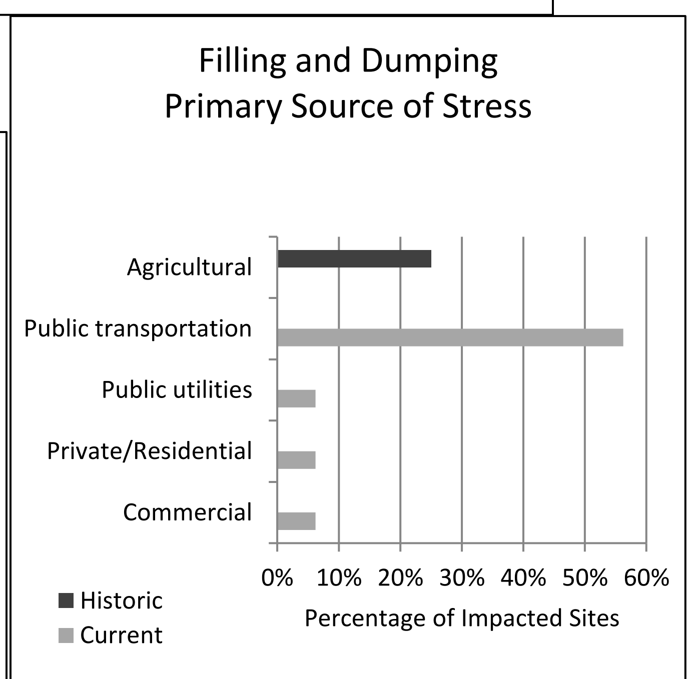


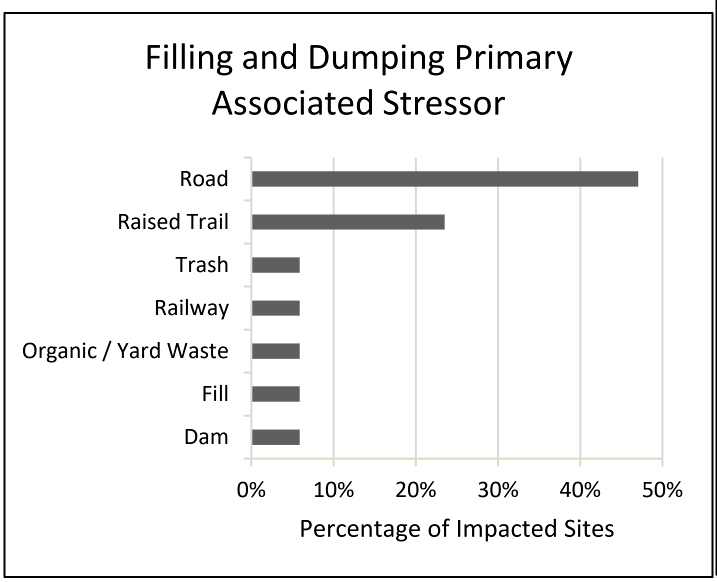
C4. Filling and Dumping



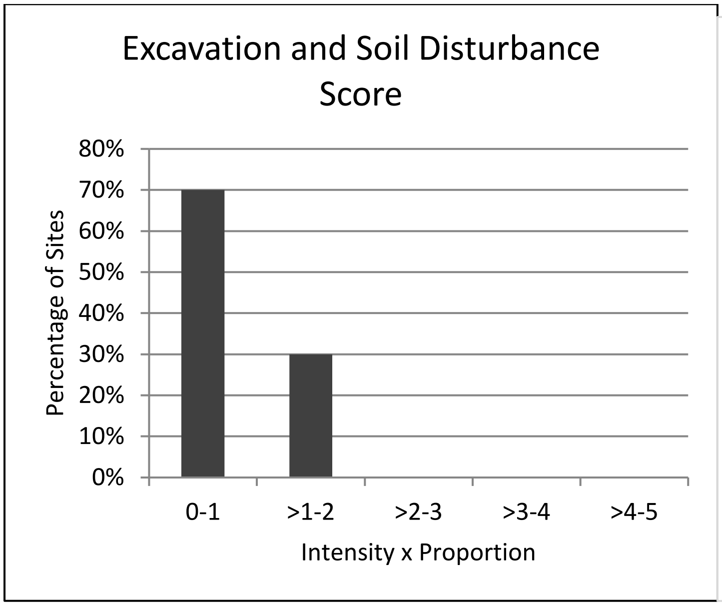


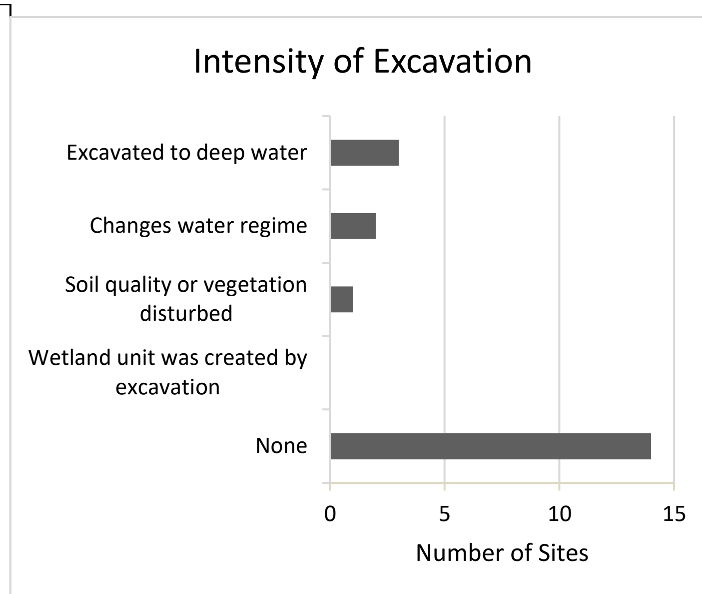


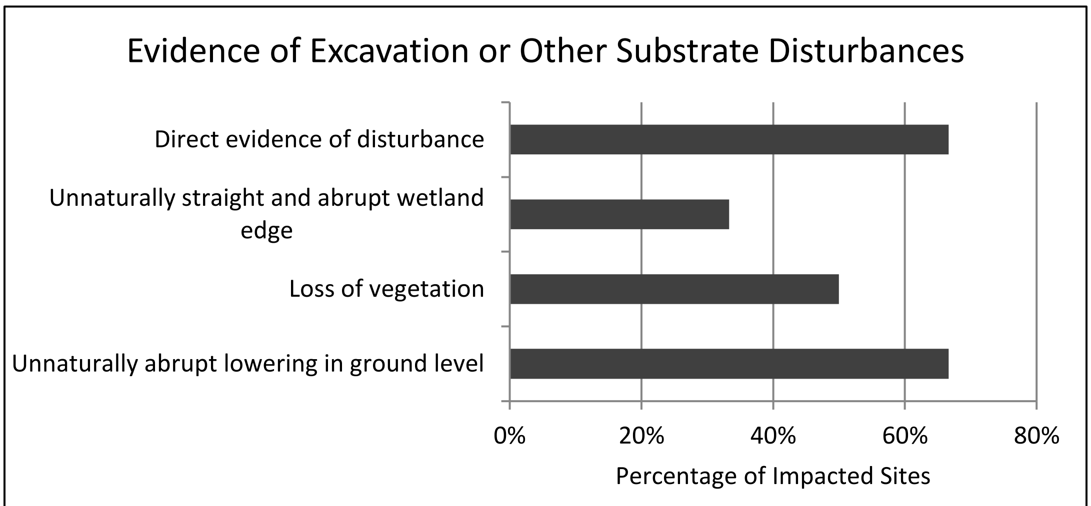


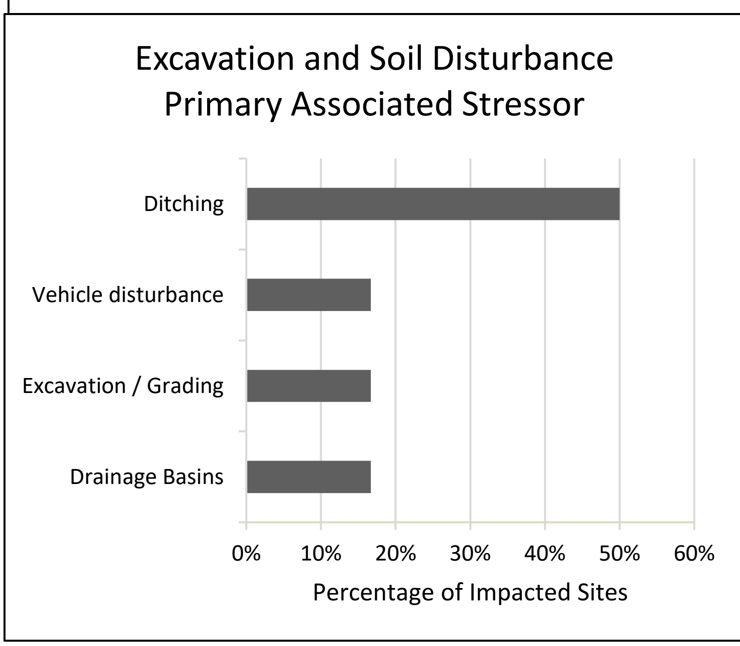


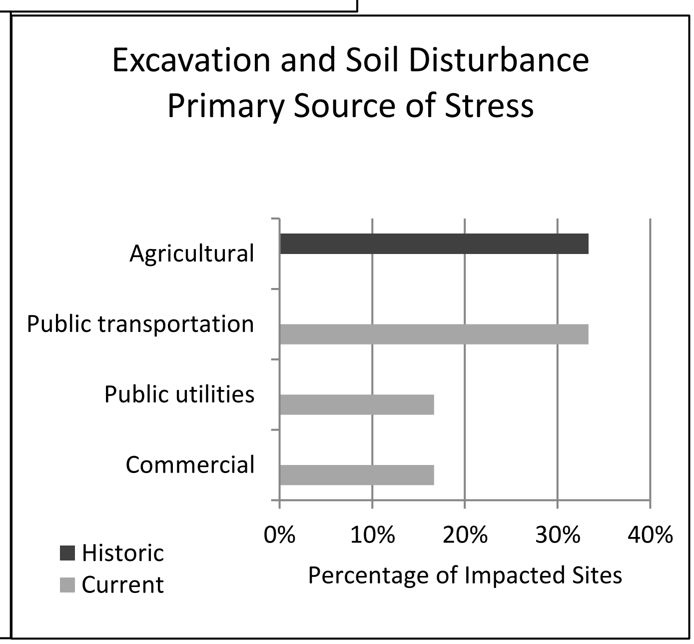
C5. Excavation and Substrate Disturbance



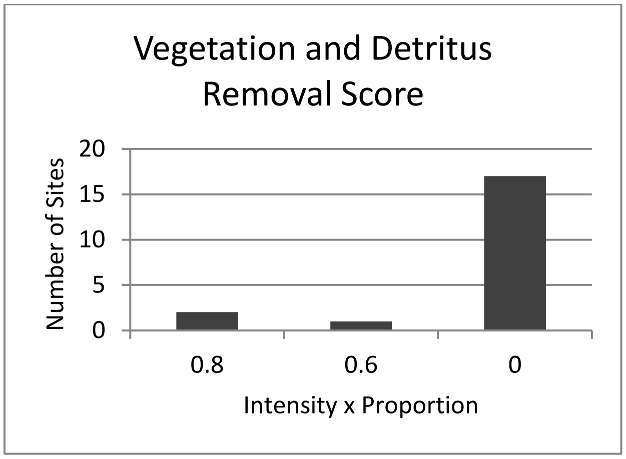


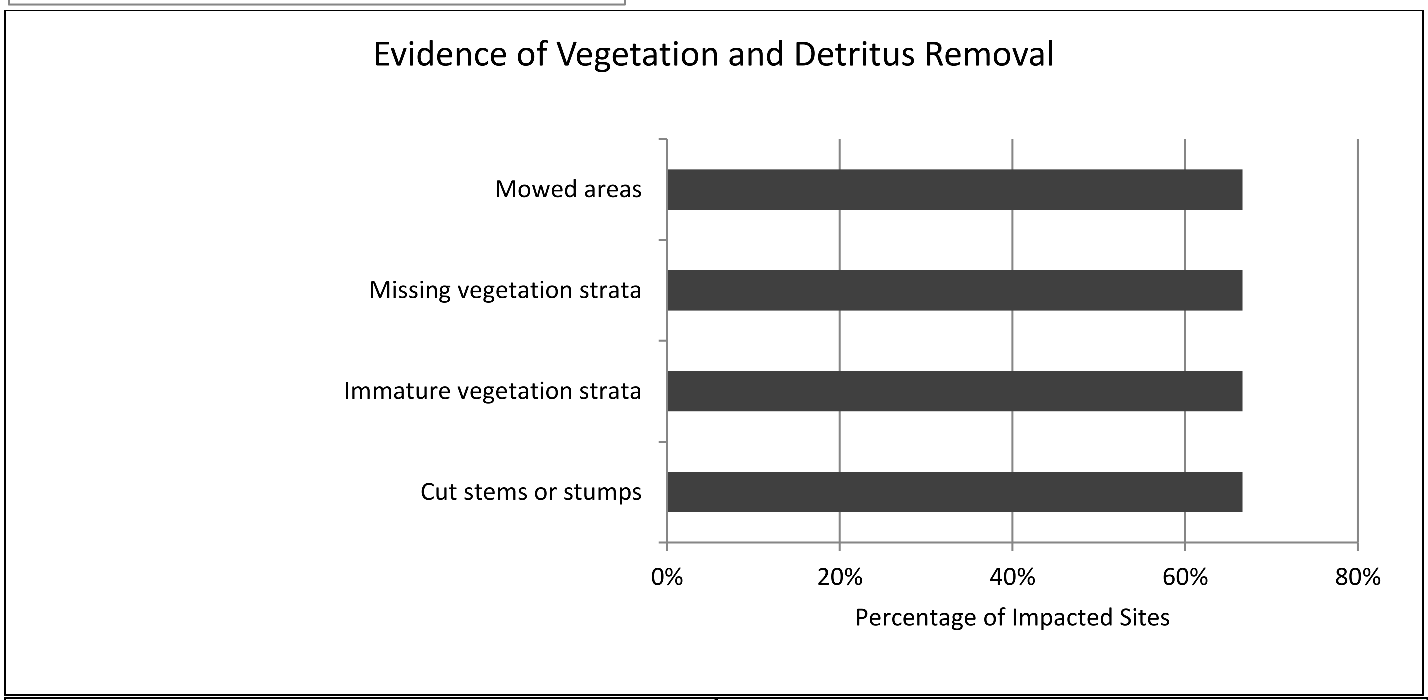


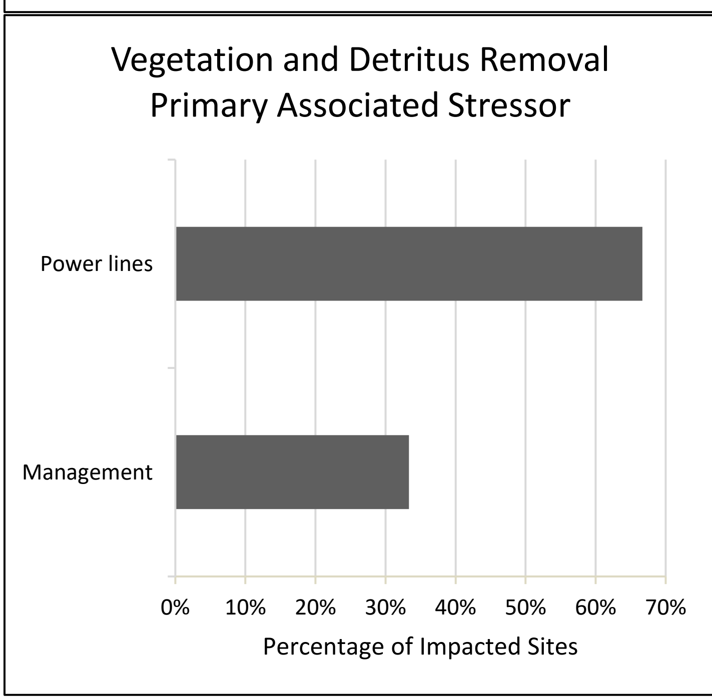


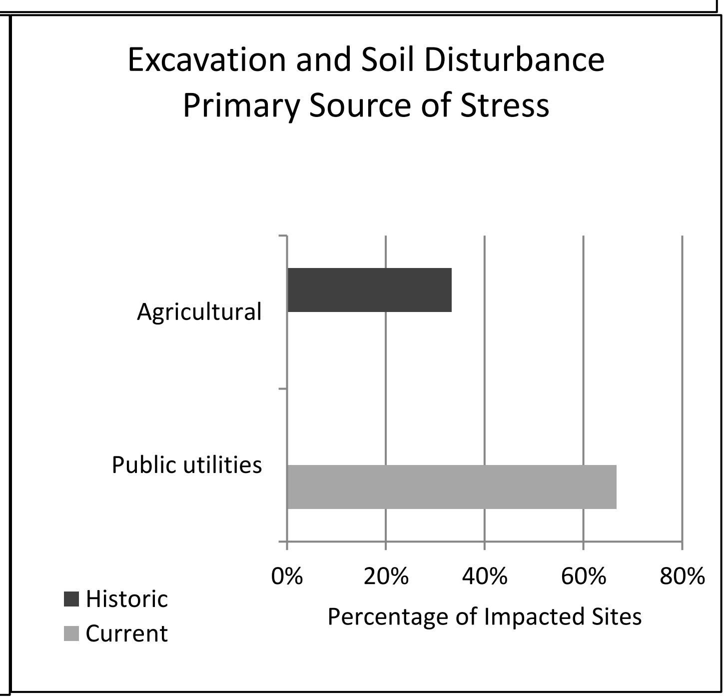


C6. Vegetation and Detritus Removal

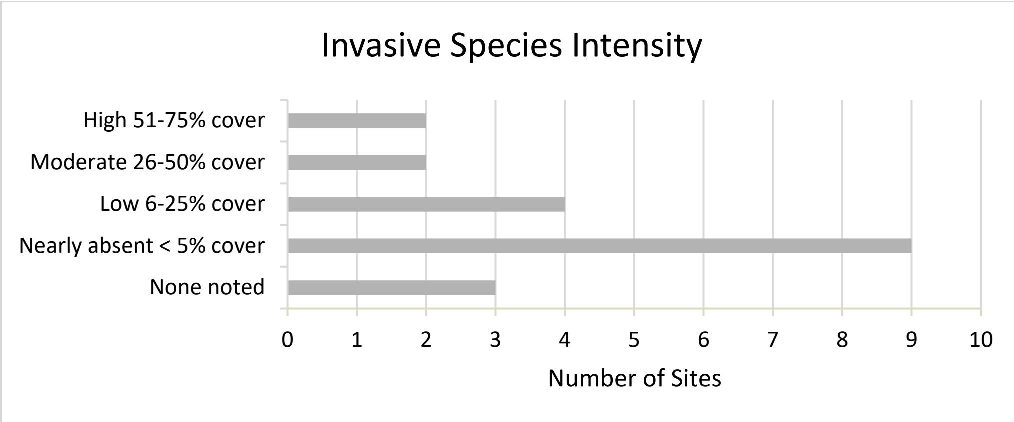


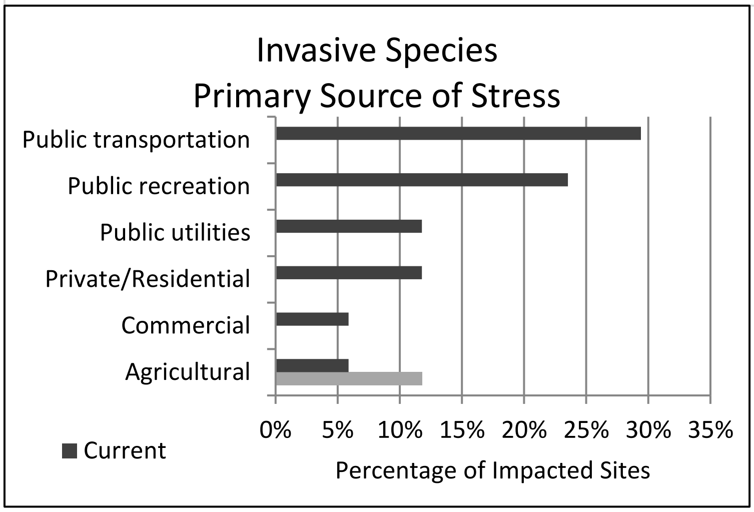


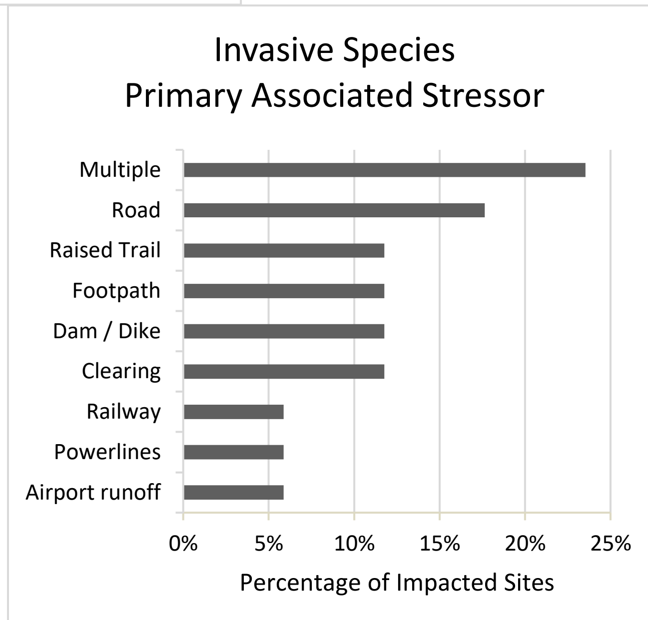


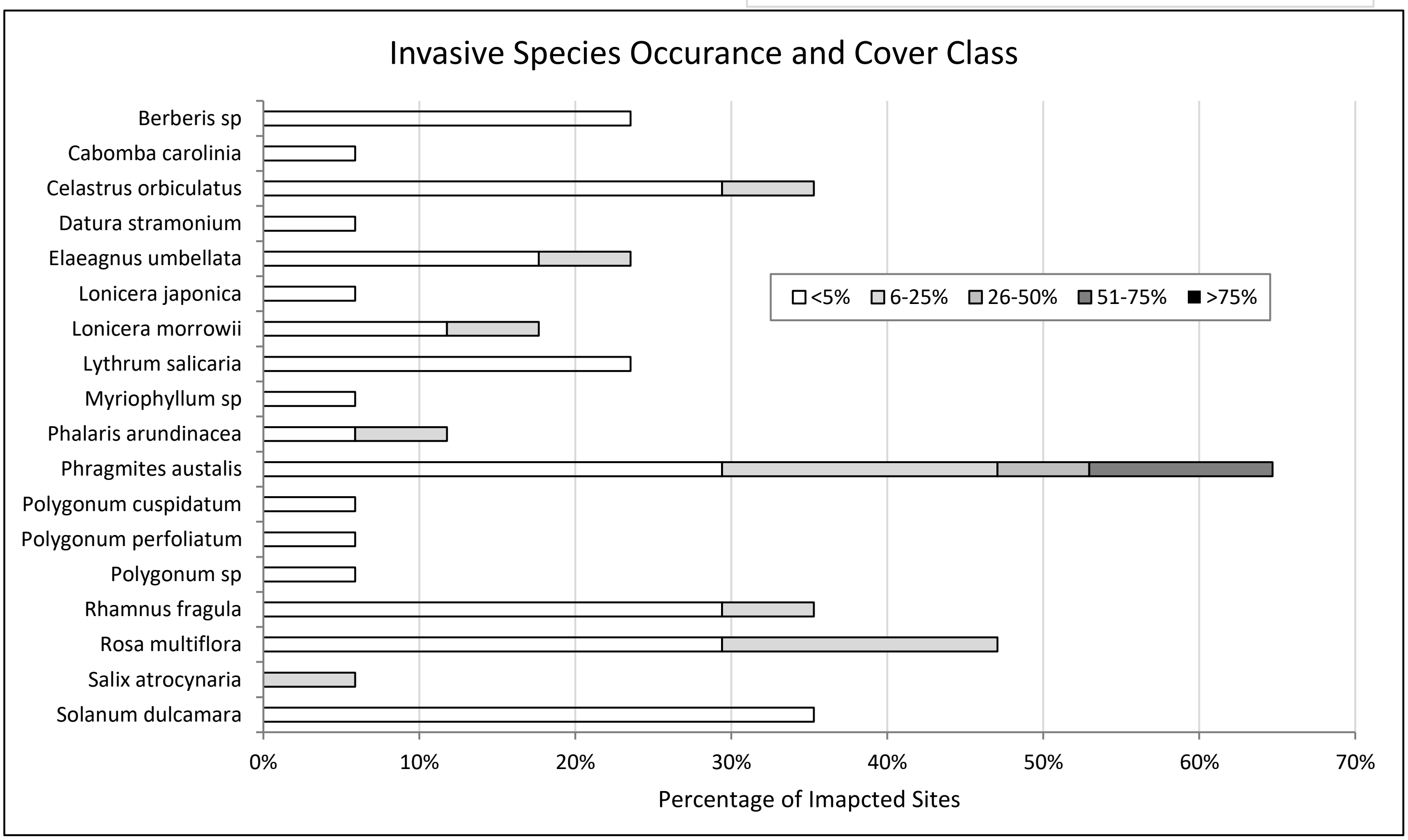


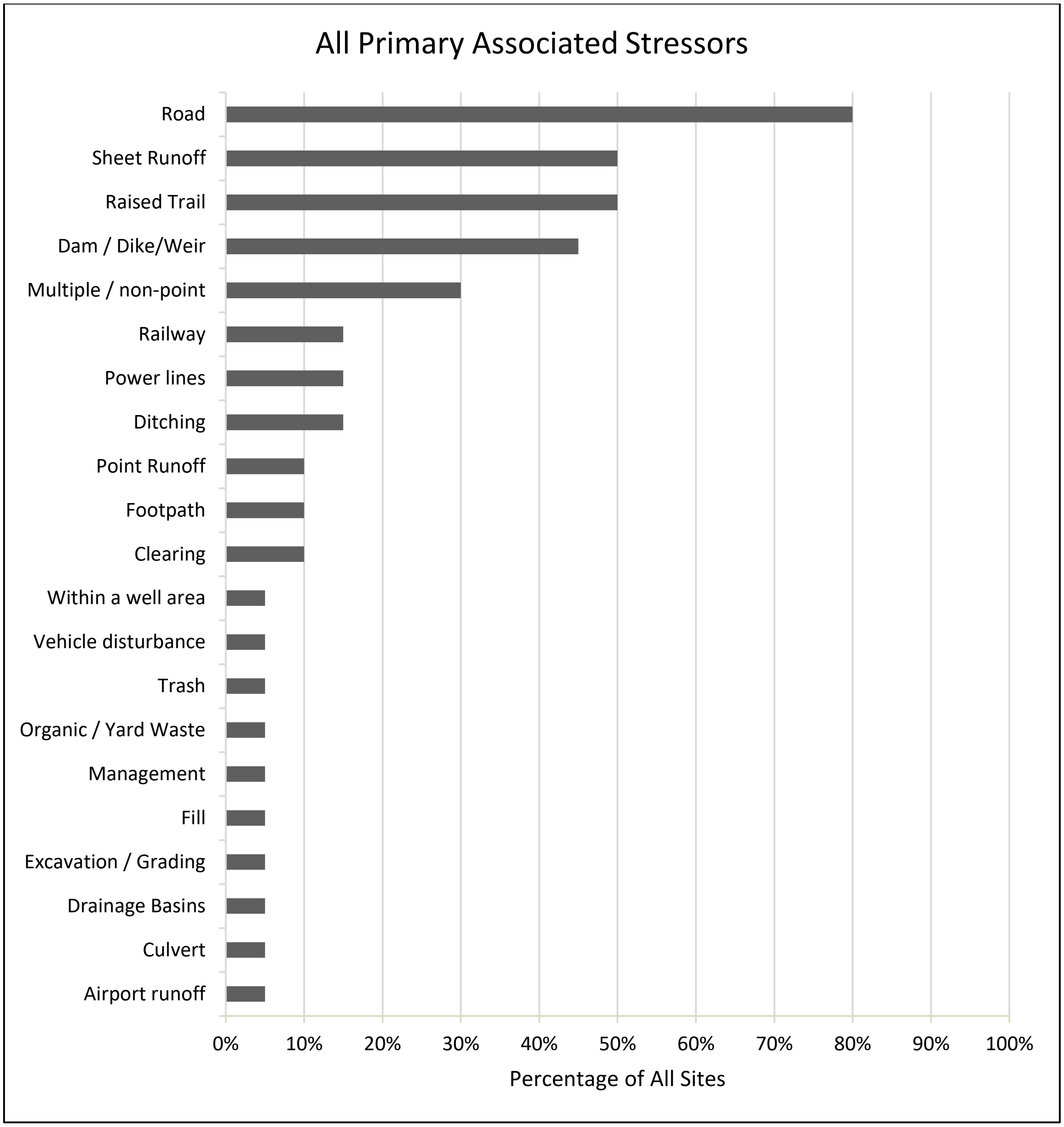
C7. Invasive Species Cover

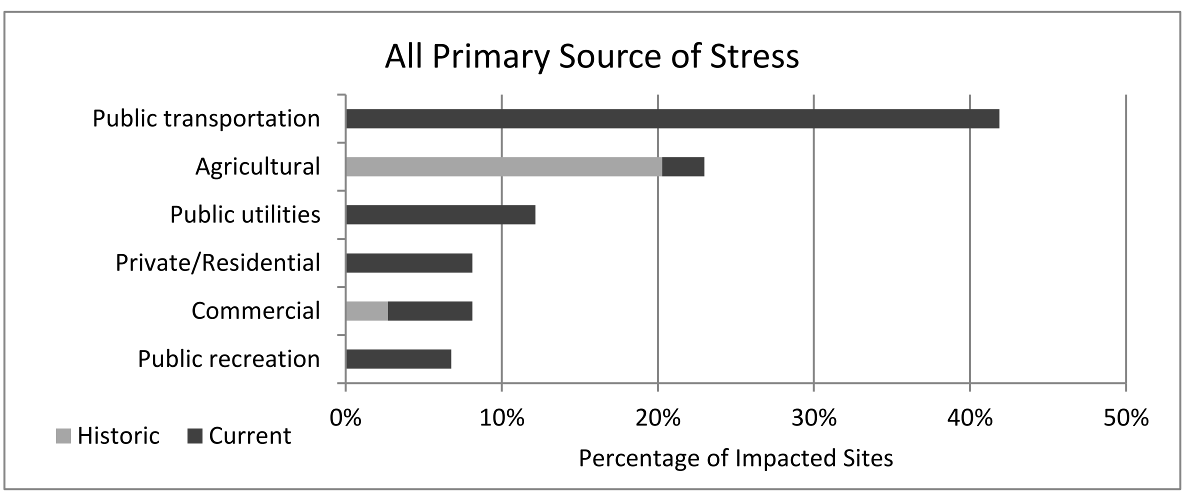


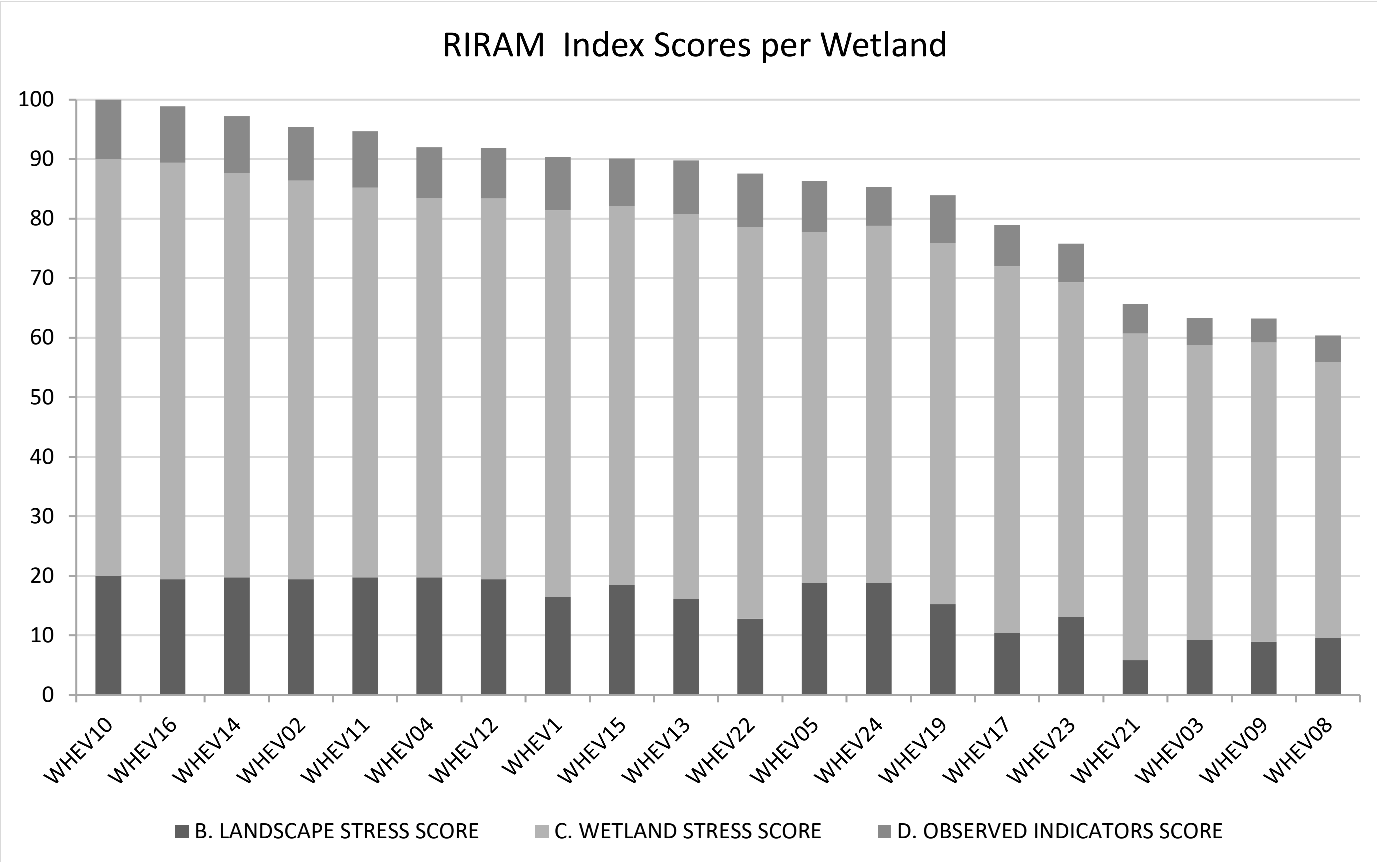







All Primary Associated Stressors
Road
Sheet Runoff
Raised Trail
Dam / Dike/Weir
Multiple / non-point
Railway
Power lines
Ditching
Point Runoff
Footpath
Clearing
Within a well area
Vehicle disturbance
Trash
Organic / Yard Waste
Management
Fill
Excavation / Grading
Drainage Basins
Culvert
Airport runoff
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percentage of All Sites


All Primary Source of Stress
Public transportation
Agricultural
Public utilities
Private/Residential
Commercial
Public recreation
0%
10%
20%
30%
40%
50%
Percentage of Impacted Sites
Historic
Current



RIRAM Index Scores per Wetland
100
90
80
70
60
50
40
30
20
10
0
WHEV10
WHEV16
WHEV14
WHEV02
WHEV11
WHEV04
WHEV12
WHEV1
WHEV15
WHEV13
WHEV22
WHEV05
WHEV24
WHEV19
WHEV17
WHEV23
WHEV21
WHEV03
WHEV09
WHEV08
B. LANDSCAPE STRESS SCORE
C. WETLAND STRESS SCORE
D. OBSERVED INDICATORS SCORE