NWCA 2016 Vegetation Metrics

Vegetation Multimetric Index (VMMI) & Nonnative Plant Indicator (NNPI)

Vegetation Metrics

VMMI: A total of 426 metrics based on all species or only native species were considered as potential descriptors of wetland **condition**.

NNPI: A total of 130 metrics based on only nonnative plants, including alien and cryptogenic species, were viewed as indicators of wetland **stress**.

STEPS

1. Define anthropogenic disturbance gradients by identifying least- and most-disturbed sites
2. Consider sample sizes and species composition variability across wetland types and regions to determine potential scale
3. Calculate candidate vegetation metrics
4. Evaluate candidate vegetation metrics for use in VMMI and NNPI development

Four VMMIs were selected for use in estimating wetland area in good, fair, and poor condition, representing the following subpopulations of wetland groups (the below definitions were adapted from FGDC 2013):

Estuarine Herbaceous (EH)

EH consist of deepwater tidal habitat semiclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Vegetation is characterized by erect, rooted, and herbaceous hydrophytes.

Estuarine Woody (EW)

EW consist of deepwater tidal habitat semiclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Vegetation is characterized by woody species.

Inland Herbaceous (PRLH)

This includes all nontidal wetlands dominated by persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt.

Inland Woody (PRLW)

This includes all nontidal wetlands dominated by trees and shrubs, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt.

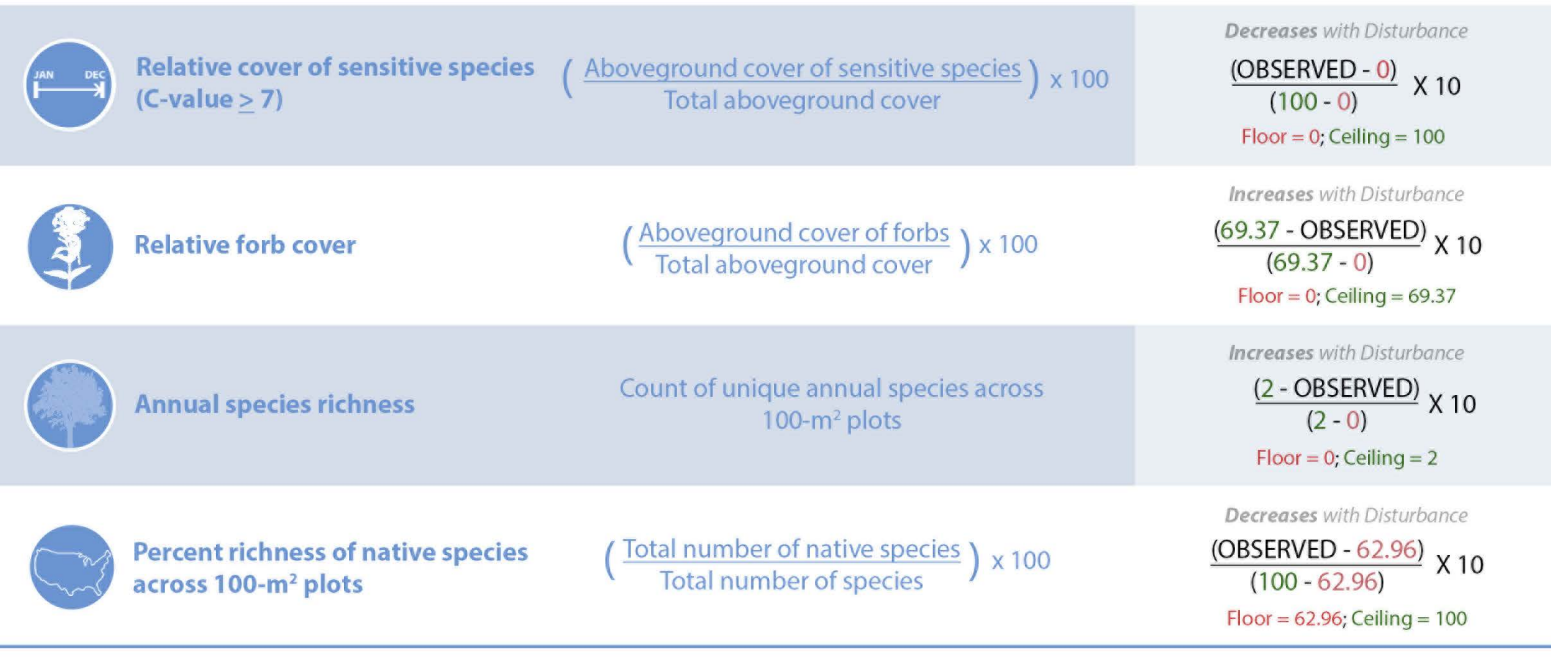
There are **THREE** sets of equations used to devise a VMMI score for each wetland site: (1) a formula for calculating each metric (raw metric score), (2) a formula for calculating an individual metric score on a continuous 0-10 scale (final metric score), and (3) an equation for determining the VMMI score on a continuous 0-100 scale, which utilizes the final metric scores. "_SC" refers to the final score of the given metric. To calculate the final metric score, metrics were scored based on the interpolation of metric values between the 5[th] (floor) and 95[th] (ceiling) percentiles for calibration sites.

VMMI - EH

$$\left(\text{XRCOV\_HTOL\_SC} + \text{XRCOV\_MONOCOTS\_NAT\_SC} + \text{XRCOV\_SEN\_SC} + \text{XRCOV\_FORB\_SC} + \text{N\_ANNUAL\_SC} + \text{PCTN\_NATSPP\_SC}\right) \times \frac{10}{6}$$

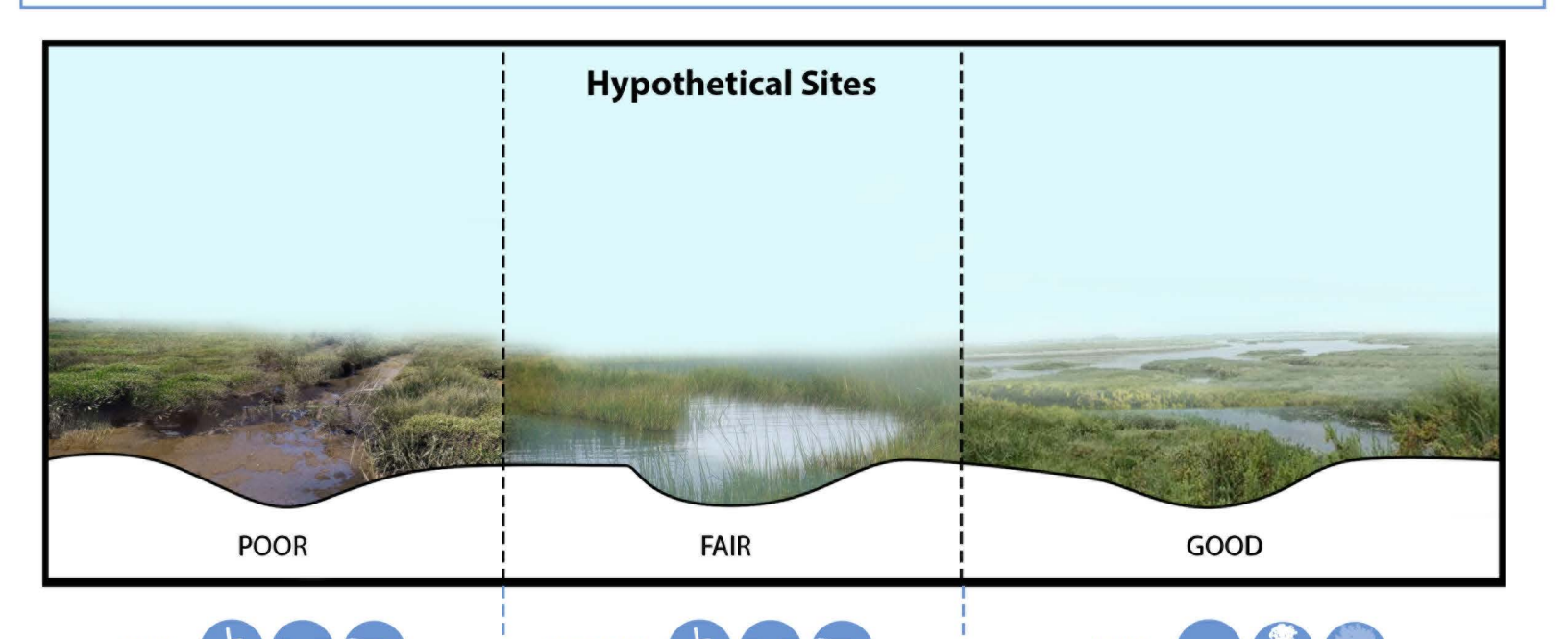
METRIC NAME	RAW METRIC SCORE (OBSERVED)	FINAL METRIC SCORE (METRIC ABBREVIATION_SC)
Relative cover of highly tolerant species (C-value ≤ 2)	(Aboveground cover of tolerant species / Total aboveground cover) x 100	Increases with Disturbance: (84.57 - OBSERVED) / (84.57 - 0) X 10; Floor = 0; Ceiling = 84.57
Relative cover of native monocots	(Aboveground cover of native monocots / Total aboveground cover) x 100	Decreases with Disturbance: (OBSERVED - 0.29) / (100 - 0.29) X 10; Floor = 0.29; Ceiling = 100
Relative cover of sensitive species (C-value ≥ 7)	(Aboveground cover of sensitive species / Total aboveground cover) x 100	Decreases with Disturbance: (OBSERVED - 0) / (100 - 0) X 10; Floor = 0; Ceiling = 100
Relative forb cover	(Aboveground cover of forbs / Total aboveground cover) x 100	Increases with Disturbance: (69.37 - OBSERVED) / (69.37 - 0) X 10; Floor = 0; Ceiling = 69.37
Annual species richness	Count of unique annual species across 100-m² plots	Increases with Disturbance: (2 - OBSERVED) / (2 - 0) X 10; Floor = 0; Ceiling = 2
Percent richness of native species across 100-m² plots	(Total number of native species / Total number of species) x 100	Decreases with Disturbance: (OBSERVED - 62.96) / (100 - 62.96) X 10; Floor = 62.96; Ceiling = 100

Hypothetical Sites



Examples of EH for all condition types

Final Metric Scores < 8.00 (0 = low, 10 = high)



VMMI SCORE = 36.97	VMMI SCORE = 83.00	VMMI SCORE = 94.55
XRCOV_HTOL_SC = 2.24	XRCOV_HTOL_SC = 9.21	XRCOV_HTOL_SC = 10.00
XRCOV_MONOCOTS_NAT_SC = 2.31	XRCOV_MONOCOTS_NAT_SC = 7.40	XRCOV_MONOCOTS_NAT_SC = 8.51
XRCOV_SEN_SC = 2.15	XRCOV_SEN_SC = 8.20	XRCOV_SEN_SC = 9.08
XRCOV_FORB_SC = 8.48	XRCOV_FORB_SC = 9.75	XRCOV_FORB_SC = 9.14
N_ANNUAL_SC = 0	N_ANNUAL_SC = 10	N_ANNUAL_SC = 10
PCTN_NATSPP_SC = 7.00	PCTN_NATSPP_SC = 5.24	PCTN_NATSPP_SC = 10.00

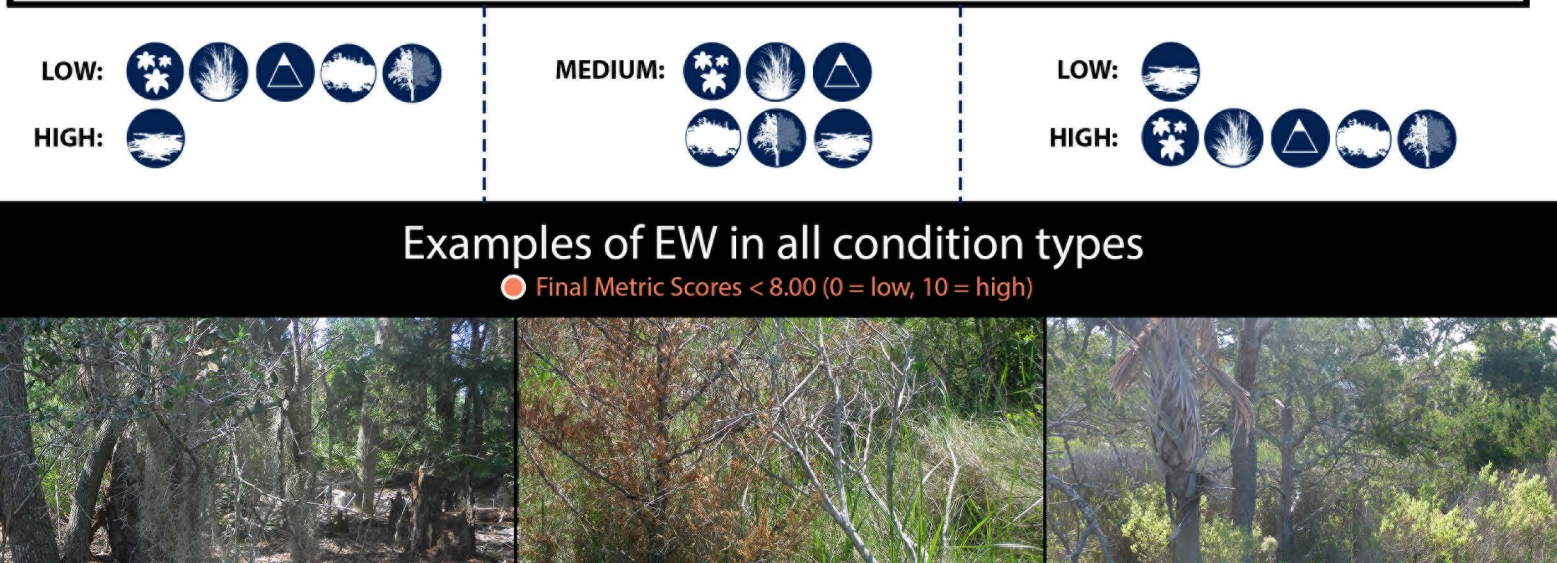
VMMI-EH Score Thresholds: 73.6, 86.4 (POOR, FAIR, GOOD)

VMMI - EW

$$\left(\text{PCTN\_MONOCOT\_SC} + \text{XRCOV\_GRAMINOID\_SC} + \text{RIMP\_NATSPP\_SC} + \text{XCOV\_WD\_FINE\_SC} + \text{PCTN\_NATSPP\_SC} + \text{PCTN\_ISEN\_SC}\right) \times \frac{10}{6}$$

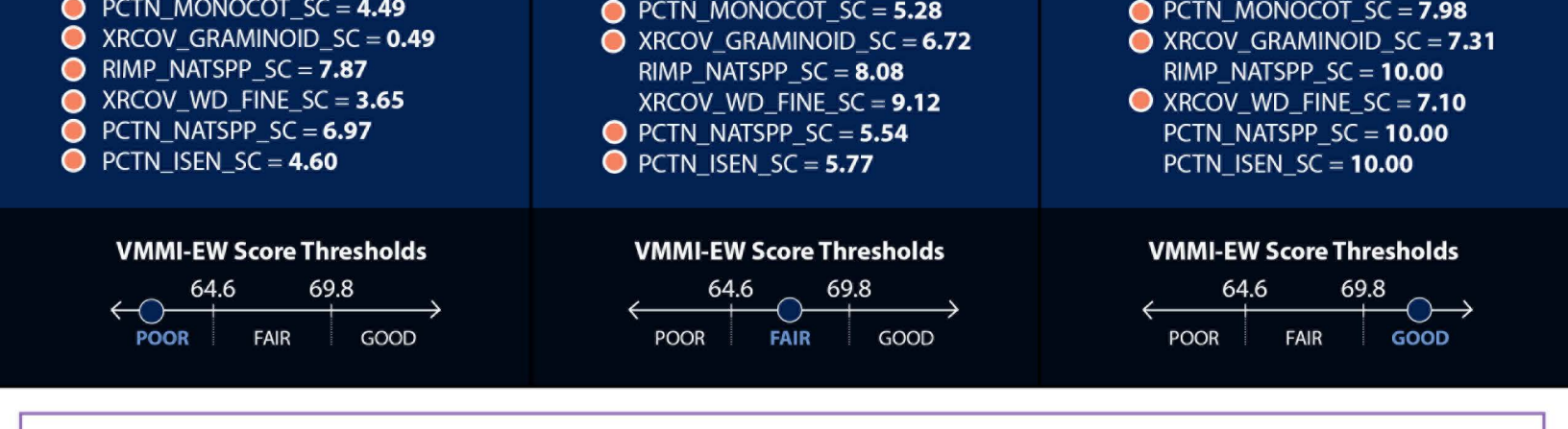
METRIC NAME	RAW METRIC SCORE (OBSERVED)	FINAL METRIC SCORE (METRIC ABBREVIATION_SC)
Monocot percent richness	(Number of monocots / Total number of species) x 100	Decreases with Disturbance: (OBSERVED - 0) / (55.68 - 0) X 10; Floor = 0; Ceiling = 55.68
Mean relative graminoid cover	(Aboveground cover of graminoids / Total aboveground cover) x 100	Decreases with Disturbance: (OBSERVED - 0) / (90.36 - 0) X 10; Floor = 0; Ceiling = 90.36
Mean relative importance of native species	(Freq. of native species + Cover of native species) / 2	Decreases with Disturbance: (OBSERVED - 68.56) / (100 - 68.56) X 10; Floor = 68.56; Ceiling = 100
Mean cover of fine woody debris (<5-cm diameter)	Percent cover of fine woody debris across 5 plots / 5 plots	Increases with Disturbance: (13.85 - OBSERVED) / (13.85 - 0) X 10; Floor = 0; Ceiling = 13.85
Percent richness of native species across 100-m² plots	(Total number of native species / Total number of species) x 100	Decreases with Disturbance: (OBSERVED - 66.98) / (100 - 66.98) X 10; Floor = 66.98; Ceiling = 100
Percent richness of intermediate sensitivity species (C-value = 5 to 6)	(Number of intermediate sensitivity species / Total number of species) x 100	Decreases with Disturbance: (OBSERVED - 7.57) / (45.45 - 7.57) X 10; Floor = 7.57; Ceiling = 45.45

Hypothetical Sites



Examples of EW in all condition types

Final Metric Scores < 8.00 (0 = low, 10 = high)



VMMI SCORE = 46.78	VMMI SCORE = 67.52	VMMI SCORE = 87.32
PCTN_MONOCOT_SC = 4.49	PCTN_MONOCOT_SC = 5.28	PCTN_MONOCOT_SC = 7.98
XRCOV_GRAMINOID_SC = 0.49	XRCOV_GRAMINOID_SC = 6.72	XRCOV_GRAMINOID_SC = 7.31
RIMP_NATSPP_SC = 7.87	RIMP_NATSPP_SC = 8.08	RIMP_NATSPP_SC = 10.00
XRCOV_WD_FINE_SC = 3.65	XRCOV_WD_FINE_SC = 9.12	XRCOV_WD_FINE_SC = 7.10
PCTN_NATSPP_SC = 6.97	PCTN_NATSPP_SC = 5.54	PCTN_NATSPP_SC = 10.00
PCTN_ISEN_SC = 4.60	PCTN_ISEN_SC = 5.77	PCTN_ISEN_SC = 10.00

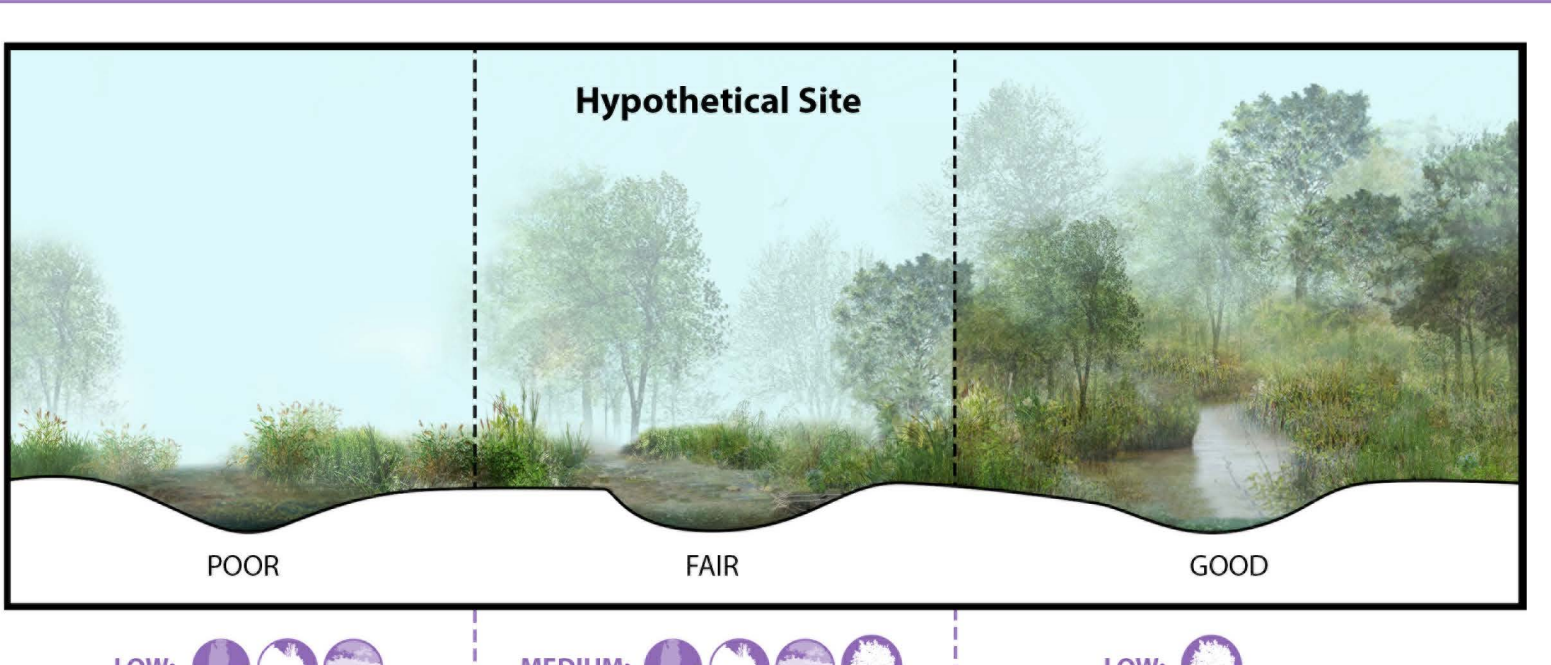
VMMI-EW Score Thresholds: 64.6, 69.8 (POOR, FAIR, GOOD)

VMMI - PRLH

$$\left(\text{PCTN\_OBL\_FACW\_SC} + \text{FQAI\_ALL\_SC} + \text{XRCOV\_NATSPP\_SC} + \text{N\_TOT\_SC}\right) \times \frac{10}{4}$$

METRIC NAME	RAW METRIC SCORE (OBSERVED)	FINAL METRIC SCORE (METRIC ABBREVIATION_SC)
Percent richness (number) of obligate and facultative wetland species	(Number of obligate and facultative wetland species / Total number of species) x 100	Decreases with Disturbance: (OBSERVED - 17.21) / (100 - 17.21) X 10; Floor = 17.21; Ceiling = 100
Floristic quality assessment index (FQAI) with all species	$FQAI = \Sigma CC_i / \sqrt{N_i}$; CC_i = coefficient of conservatism for each unique species i at site j; N = number of species at site j	Decreases with Disturbance: (OBSERVED - 4.90) / (35.77 - 4.90) X 10; Floor = 4.90; Ceiling = 35.77
Mean relative cover of native species across 100-m² plots as percentage of total cover	(Aboveground cover of native species / Total aboveground cover) x 100	Decreases with Disturbance: (OBSERVED - 12.42) / (100 - 12.42) X 10; Floor = 12.42; Ceiling = 100
Number (richness) of tolerant species (C-value < 4)	Count of unique species that meet criterion across 100-m² plots	Increases with Disturbance: (41 - OBSERVED) / (41 - 3) X 10; Floor = 3; Ceiling = 41

Hypothetical Site



Examples of PRLH in all condition types

Final Metric Scores < 8.00 (0 = low, 10 = high)

VMMI SCORE = 32.20	VMMI SCORE = 66.05	VMMI SCORE = 81.22
PCTN_OBL_FACW_SC = 0.00	PCTN_OBL_FACW_SC = 9.43	PCTN_OBL_FACW_SC = 10.00
FQAI_ALL_SC = 1.84	FQAI_ALL_SC = 3.54	FQAI_ALL_SC = 5.08
XRCOV_NATSPP_SC = 6.30	XRCOV_NATSPP_SC = 5.56	XRCOV_NATSPP_SC = 9.77
N_TOT_SC = 4.74	N_TOT_SC = 7.89	N_TOT_SC = 7.63

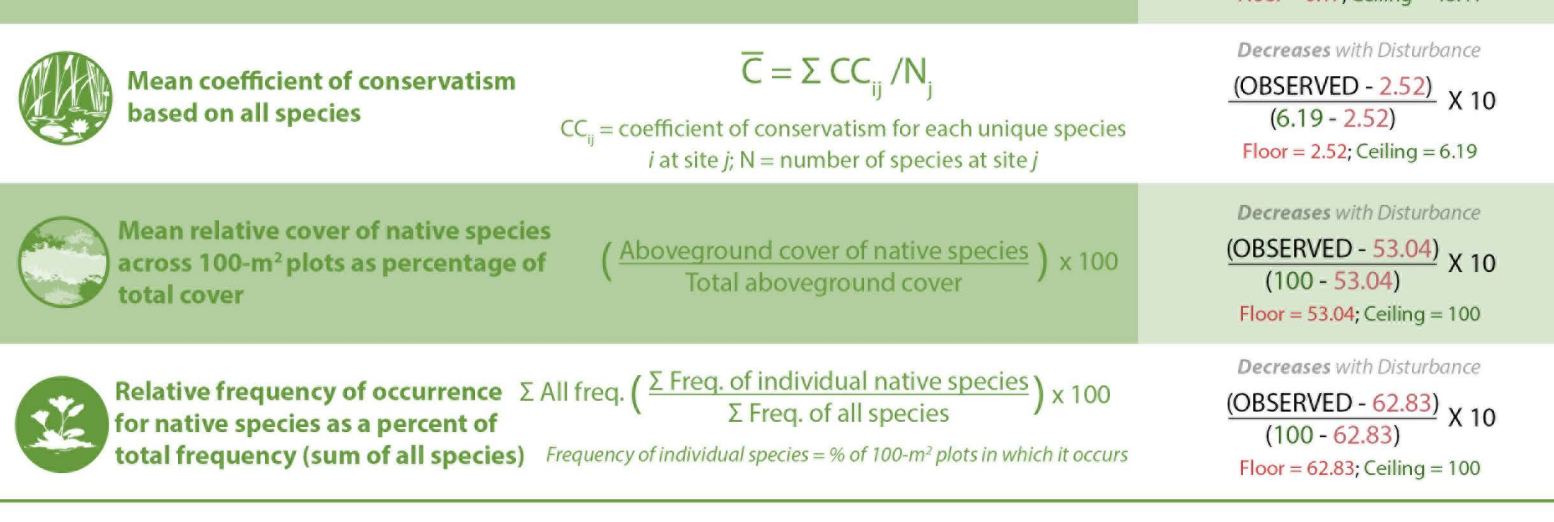
VMMI-PRLH Score Thresholds: 63.8, 74.2 (POOR, FAIR, GOOD)

VMMI - PRLW

$$\left(\text{XRCOV\_MONOCOTS\_NAT\_SC} + \text{XC\_ALL\_SC} + \text{XRCOV\_NATSPP\_SC} + \text{RFREQ\_NATSPP\_SC}\right) \times \frac{10}{4}$$

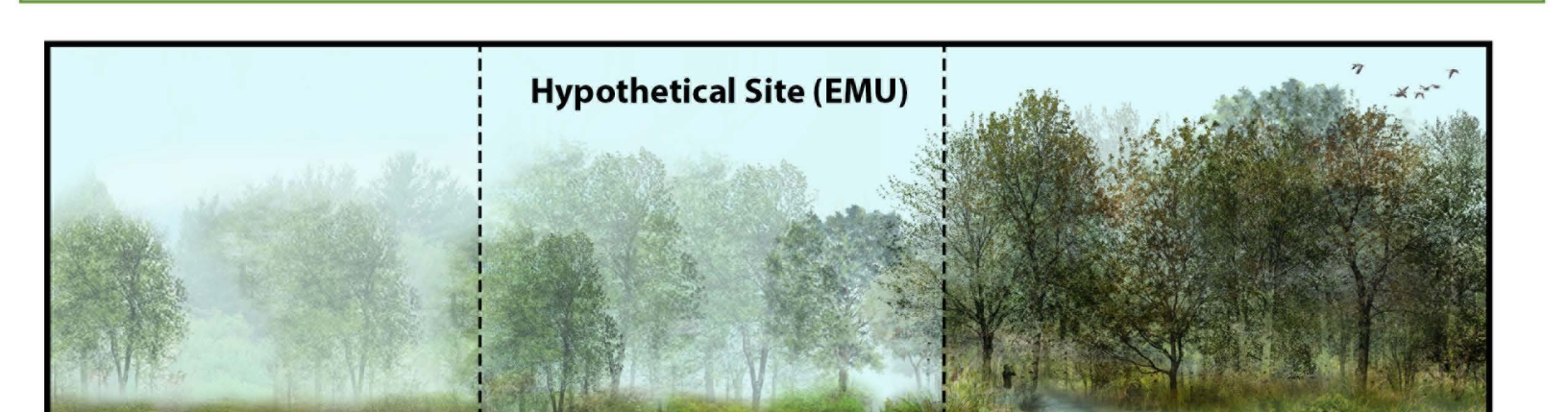
METRIC NAME	RAW METRIC SCORE (OBSERVED)	FINAL METRIC SCORE (METRIC ABBREVIATION_SC)
Relative cover of native monocots	(Aboveground cover of native monocots / Total aboveground cover) x 100	Decreases with Disturbance: (OBSERVED - 0.17) / (48.41 - 0.17) X 10; Floor = 0.17; Ceiling = 48.41
Mean coefficient of conservatism based on all species	$\overline{C} = \Sigma CC_i / N_j$; CC_i = coefficient of conservatism for each unique species i at site j; N = number of species at site j	Decreases with Disturbance: (OBSERVED - 2.52) / (6.19 - 2.52) X 10; Floor = 2.52; Ceiling = 6.19
Mean relative cover of native species across 100-m² plots as percentage of total cover	(Aboveground cover of native species / Total aboveground cover) x 100	Decreases with Disturbance: (OBSERVED - 53.04) / (100 - 53.04) X 10; Floor = 53.04; Ceiling = 100
Relative frequency of occurrence for native species as a percent of total frequency (sum of all species)	Σ All freq. (Σ Freq. of individual native species / Σ Freq. of all species) x 100; Frequency of individual species = % of 100-m² plots in which it occurs	Decreases with Disturbance: (OBSERVED - 62.83) / (100 - 62.83) X 10; Floor = 62.83; Ceiling = 100

Hypothetical Site (EMU)



Examples of PRLW in all condition types

Final Metric Scores < 8.00 (0 = low, 10 = high)



VMMI SCORE = 46.13	VMMI SCORE = 48.25	VMMI SCORE = 73.53
XRCOV_MONOCOTS_NAT_SC = 0.00	XRCOV_MONOCOTS_NAT_SC = 0.19	XRCOV_MONOCOTS_NAT_SC = 0.75
XC_ALL_SC = 6.14	XC_ALL_SC = 3.70	XC_ALL_SC = 8.66
XRCOV_NATSPP_SC = 9.18	XRCOV_NATSPP_SC = 9.95	XRCOV_NATSPP_SC = 10.00
RFREQ_NATSPP_SC = 3.13	RFREQ_NATSPP_SC = 5.46	RFREQ_NATSPP_SC = 10.00

VMMI-PRLW Score Thresholds: (EMU, ICP, WVM) 53.7, 65.5; (PLN, ARW) 43.7, 49.9 (POOR, FAIR, GOOD)

Mesic Regions: Inland Coastal Plains (ICP), Eastern Mountains & Upper Midwest (EMU), Western Valley & Mountains (WVM)
Arid Regions: Plains (PLN), Arid West (ARW)

NNPI

The NNPI was developed as a categorical descriptor of **stress** to ecological condition and was based on **three** continuous metrics that reflect different **potential impacts of nonnative plants.**

These metrics were used together in a decision matrix to assign each sampled site to a **condition category** (good, fair, poor, very poor) based on exceedance values for each of the metrics. The overall NNPI status for each site was determined by the **lowest condition category** observed across the three NNPI metrics.

NNPI METRICS

XRCOV_AC · TOTN_AC · RFREQ_AC

"_AC" refers to combined alien and cryptogenic species that together are considered nonnative by the NWCA

Relative Nonnative Cover (0-100%) reflects preemption of space and resources and is often associated with changes in plant community composition (species identity, richness, abundance) and vegetation structure (horizontal/vertical), or with alteration of ecosystem processes (e.g., hydrology, nutrient cycling, fire regime).

(Σ Absolute cover of nonnative species / Σ Absolute cover of all species) x 100

Greater **Richness of Nonnative Species** (number of unique nonnative species) increases the risk that individual nonnative taxa are or may become invasive or act as ecosystem engineers that negatively alter biotic or abiotic properties.

Number of unique nonnative species observed at a site

Increasing **Relative Nonnative Frequency** (0-100%) across a site reflects increasing numbers of loci from which nonnatives could compete with native species, expand in cover, or spread to new locations.

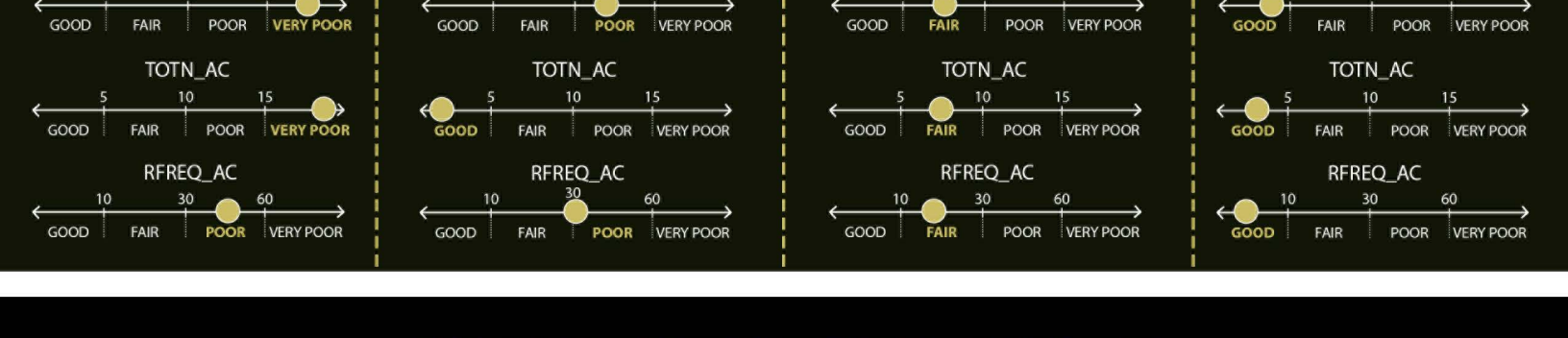
(Σ Frequency of nonnative species / Σ Frequencies of all species) x 100

where for each unique species i: frequency = 0-100%, calculated as the percent of veg plots in which it occurred

Hypothetical Site NNPI Condition

White vegetation represents nonnative species

Examples in all condition types



	VERY POOR CONDITION	POOR CONDITION	FAIR CONDITION	GOOD CONDITION
XRCOV_AC (thresholds 5, 15, 40)	VERY POOR	POOR	FAIR	GOOD
TOTN_AC (thresholds 5, 10, 15)	VERY POOR	GOOD	FAIR	GOOD
RFREQ_AC (thresholds 10, 30, 60)	POOR	POOR	FAIR	GOOD

CONCEPTS EXPLAINED

Coefficient of Conservatism (C-value)

The Floristic Quality Assessment Index (FQAI) employs a measure of conservatism (C-value) along with species richness of a plant community (N) to estimate habitat quality.

C-values range from 0 to 10, and rate an individual plant species based on its ability to tolerate human-mediated disturbance to its habitat. Plant taxa that are obligate to high quality natural areas (9 or 10) whereas taxa found in a wide variety of habitats and that are tolerant of disturbance are assigned low C-values (0 to 3). Nonnative taxa receive a C-value of 0. C-values for the same taxa may vary considerably by region.

Metrics using C-values

Highly Tolerant Species
C-values = 0-2
Species with a C-value of 0-2 are found in a variety of plant communities, are often early colonizers of disturbed sites, and are opportunistic invaders of natural areas.

Tolerant Species
C-values = 0-4
Species with a C-value of 0-4 have a wide range of ecological tolerances and are found in a variety of plant communities, are often early colonizers of disturbed sites.

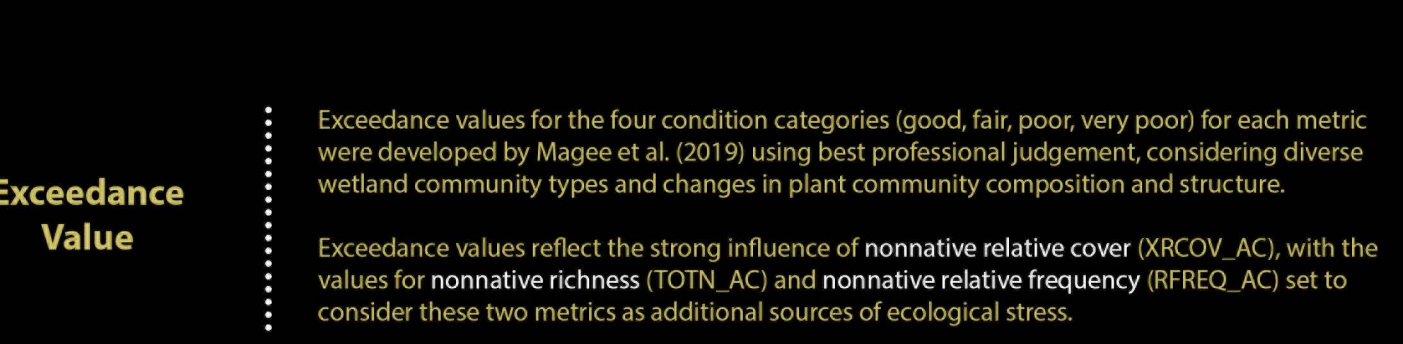
Intermediate-Sensitive Species
C-values = 5-6
Species with a C-value of 5-6 have an intermediate range of ecological tolerances and are usually typical of one or more specific native plant communities and can tolerate moderate disturbance.

Sensitive Species
C-values = 7-10
Species with a C-value of 7-10 have a narrow range of ecological tolerances and are typical of a stable or advanced successional phase of a plant community. These species have little tolerance to disturbance.

Mean C-value
C-values = 0-10
The C-values of all species in a wetland site are averaged together to determine the relative tolerance of species to disturbance.

FQAI
C-values = 0-10
FQAI is a quantitative measure to express the relative condition, or ecological quality of a site. A range of indices from 0-3 = low ecological quality; a range of 3.1-6.9 = medium quality; and a range of 7-10 = high quality.

Vegetation Examples



Exceedance Value

Exceedance values for the four condition categories (good, fair, poor, very poor) for each metric were developed by Magee et al. (2019) using best professional judgement, considering diverse wetland community types and changes in plant community composition and structure.

Exceedance values reflect the strong influence of nonnative relative cover (XRCOV_AC), with the values for nonnative richness (TOTN_AC) and nonnative relative frequency (RFREQ_AC) set to consider these two metrics as additional sources of ecological stress.

Federal Geographic Data Committee. (2013). Classification of wetlands and deepwater habitats of the United States. FGDC-STD-004-2013. Second Edition. Wetlands Subcommittee, Federal Geographic

Magee, T. K., Blocksom, K. A., & Fennessy, M. S. (2019). A national-scale vegetation multimetric index (VMMI) as an indicator of wetland condition across the conterminous United States. Environmental Monitoring and Assessment, 191(1), 1-28.