United States Environmental Protection Agency

Office of Water
Office of Research and Development
Washington, DC 20460

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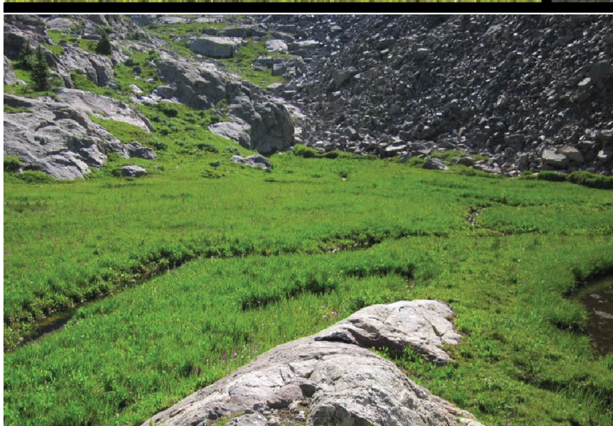
February 2023

National Wetland Condition Assessment

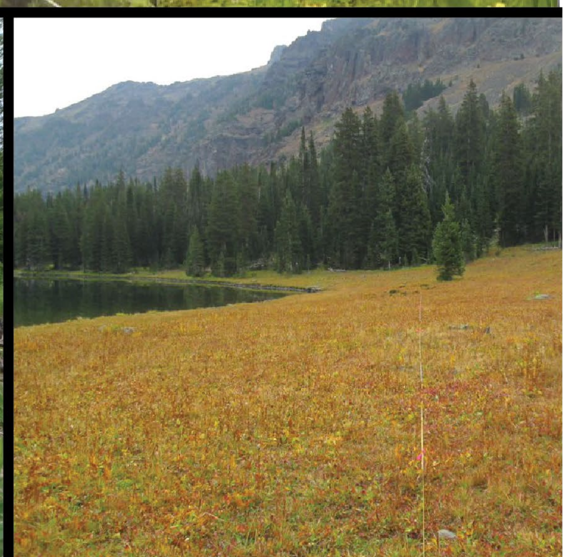
2016 Technical Support Document



National Wetlands Condition Assessment
Assessing the Nation's Waters



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EPA-841-B-23-001

NATIONAL WETLAND CONDITION ASSESSMENT

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US Environmental Protection Agency
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Notice

The *National Wetland Condition Assessment: 2016 Technical Support Document* (EPA-841-B-23-001) details methods and analysis approaches used in the 2016 National Wetland Condition Assessment (NWCA) conducted by the United States Environmental Protection Agency (USEPA) and partner organizations. This document supports the NWCA results presented in *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (EPA-841-R-23-001).

The information in the Technical Support Document has been funded wholly or in part by the US Environmental Protection Agency. This technical report has been subjected to review by the USEPA Office of Water and approved for publication. Approval does not signify that the contents reflect the views of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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Companion documents for the NWCA are:

> *National Wetland Condition Assessment 2016: Quality Assurance Project Plan* (EPA-843-R-15-008)
> *National Wetland Condition Assessment 2016: Site Evaluation Guidelines* (EPA-843-R-15-010)
> *National Wetland Condition Assessment 2016: Field Operations Manual* (EPA-843-R-15-007)
> *National Wetland Condition Assessment 2016: Laboratory Operations Manual* (EPA-843-R-15-009)
> *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (EPA-841-R-23-001)

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Acronym List

AA	Assessment Area
AR	Attributable Risk
BPJ	Best Professional Judgement
CCs	Coefficients of Conservatism
CDF	Cumulative Distribution Function
C-value	Coefficients of Conservatism
EF	Enrichment Factor
FQAI	Floristic Quality Assessment Index
GIS	Geographic Information System
GRTS	Generalized Random Tessellation Stratified (in relation to the survey design)
HGM	Hydrogeomorphic Class
HMI	Heavy Metal Index
IM	Information Management
IQR	Interquartile Ranges
MDL	Minimum Detection Limit
Mean C	Mean Coefficients of Conservatism
NARS	USEPA National Aquatic Resource Surveys
NFQD	National Floristic Quality Database
NPS	US National Park Service
NNPI	Nonnative Plant Indicator
NRCS	Natural Resources Conservation Service
NWCA	USEPA National Wetland Condition Assessment
NWPL	National Wetland Plant List
ORD	USEPA Office of Research and Development
OW	USEPA Office of Water
PQL	Practical Quantitation Limit
QA	Quality Assurance
RR	Relative Risk
S&T	USFWS Status and Trends
S:N	Signal:Noise (i.e., signal to noise ratio)
UID	Unique Identification
US	United States
USACE	US Army Corps of Engineers
USDA	US Department of Agriculture
USEPA	US Environmental Protection Agency
USFWS	US Fish and Wildlife Service
VMMI	Vegetation Multimetric Index
WD	USEPA Office of Water, Wetland Division
WIS	Wetland Indicator Status

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Foreword

The National Wetland Condition Assessment (NWCA) is a collaboration among the USEPA, State, Tribal, and Federal partners. It is part of the National Aquatic Resource Survey (NARS) program, a broad effort to conduct national scale assessments of aquatic resources to generate statistically valid and environmentally relevant reports on the condition of the nation's aquatic resources every five years. The 2016 NWCA is the second survey of wetland condition and indicators of stress likely affecting condition that is applicable to national and regional scales. With results from both the 2011 and 2016 NWCA, changes in wetland condition can also begin to be assessed.

The goals of the NWCA are to:

- Produce a national report describing the ecological condition of the nation's wetlands and anthropogenic stressors commonly associated with poor condition;

- Collaborate with states and tribes in developing complementary monitoring tools, analytical approaches, and data management technology to aid wetland protection and restoration programs; and

- Advance the science of wetland monitoring and assessment to support wetland management needs.

This document, the *National Wetland Condition Assessment: 2016 Technical Support Document*, accompanies the *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (referred to as the "Web Report"). The Web Report describes the background and main findings of the 2016 NWCA. The Technical Support Document supports the findings presented in the Public Report by describing the development of the survey design and the scientific methods used to collect, evaluate, and analyze data collected for the 2016 NWCA.

The Technical Support Document includes information on the target population, sample frame, and site selection underlying the 2016 NWCA survey design. The report provides a synthesis of data preparation and management processes, including field and laboratory data entry, review, and several quality assurance checks used in 2016 NWCA analysis. The NWCA evaluates the ecological condition of and potential stress to wetlands along a gradient of disturbance, based on comparison to sites designated as "least-disturbed" (or "reference"). The Technical Support Document provides a thorough overview of the development and application of this approach.

A variety of biological, chemical, and physical data were collected and developed into several indicators of ecological condition or stress to wetlands that inform the population estimate results of the 2016 NWCA. For each of these indicators the Technical Support Document provides background and underlying rationale, evaluation of candidates, and development of the final indicators chosen for the NWCA, including defining threshold categories for condition and disturbance in order to evaluate and compare data.

The information described in the Technical Support Document was developed through the efforts and cooperation of NWCA scientists from USEPA, technical experts and participating cooperators from academia and state and tribal wetland programs. While this Technical Support Document provides a comprehensive summary of NWCA procedures, including design, sampling, and analysis of data, it is not intended to present an in-depth report of data analysis results.

Chapter 1: Overview of Analysis

The analysis for the 2016 National Wetland Condition Assessment (NWCA) involved a number of interrelated tasks composed of multiple steps. This brief overview of the entire process provides a context for the details of each of the major tasks described in this document.

Figure 1-1, which can be found on the following page, illustrates the analysis process, beginning with field sampling probability and handpicked sites (left side of chart) and concluding with the population estimates of wetland condition extent, stressor condition extent, and relative and attributable risk (right side of chart) for the NWCA target population in the conterminous US. The components of each of the major tasks are indicated by text boxes and include the chapter number in which details may be found.

The key elements of the analysis outlined in the flowchart are:

1) Field sampling using protocol from the 2016 Field Operations Manual (USEPA 2016) results in data acquisition for probability (**Chapter 2:**) and handpicked sites (**Chapter 3:**). This data is prepared, and quality assurance continues throughout all of the analyses resulting in the production of the data tables used by the analysts (**Chapter 4:**).

2) Metrics and indices used to develop disturbance and stressor thresholds are calculated for each site, including Human-Mediated Physical Disturbances (**Chapter 11:**), Soil Heavy Metals (**Chapter 12:**), Percent Relative Cover of Nonnative Plant Species (**Section 6.6**), Nonnative Plant Index (NNPI) (**Chapter 10:**), Water Chemistry (**Chapter 13:**), and Microcystins (**Chapter 14:**).

3) Three types of data are used to develop disturbance gradient thresholds and categorize each site as least-, intermediate-, or most-disturbed (**Chapter 6:**). These data types include physical data (human-mediated physical alterations), chemical data (soil heavy metals), and biological data (percent relative cover of nonnative plant species).

4) Five types of data are used to develop stressor thresholds, including human-mediated physical alterations, soil heavy metals, Nonnative Plant Index (NNPI), water chemistry, and microcystins, found at the end of their individual chapters (**Chapter 10:** through **Chapter 14:**).

5) To develop Vegetation Multimetric Indices (VMMIs), first a vegetation analysis approach is identified and data acquisition and preparation (**Chapter 7:**) is conducted, followed by prerequisite analyses to vegetation indicator development (**Chapter 8:**). Using least- and most-disturbed sites, VMMIs are developed and thresholds for good, fair, and poor wetland condition are established (**Chapter 9:**).

6) Finally, site weights and only probability sites are used to calculate results for the wetland population (**Chapter 15:**) and various subpopulations (**Chapter 5:**). Results include wetland condition extent, stressor condition extent, change in both wetland condition extent and stressor condition extent from the 2011 NWCA and the 2016 NWCA, and relative and attributable risk. Final results are published using the online dashboard at https://wetlandassessment.epa.gov/dashboard.

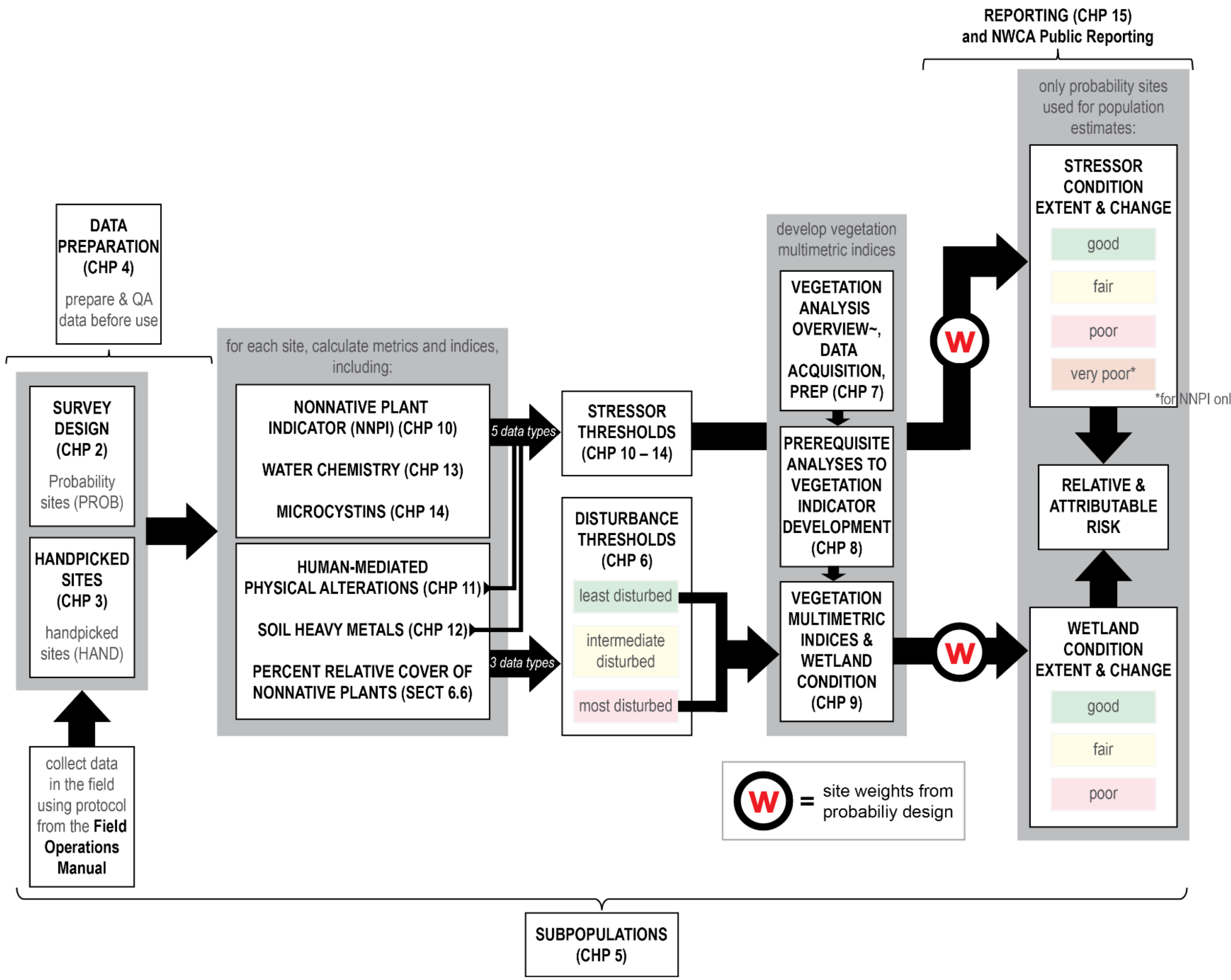

Figure 1-1. Annotated analysis flow chart indicating the chapter number (abbreviated as "CHP") in which details may be found.

Chapter 2: Survey Design

NWCA was designed to assess the ecological condition of broad groups or populations of wetlands, rather than as individual wetlands or wetlands across individual states. The NWCA design allows characterization of wetlands at national and regional scales using indicators of ecological condition and stress. It is not intended to represent the condition of individual wetlands. The statistical design also accounts for the distribution of wetlands across the country – some areas have fewer wetlands than others – so that, even in areas of the country where there are few sample sites, regional and national results still apply to the broader target population. Olsen et al. (2019) provide an overview of the NWCA design from the 2011 NWCA survey, the concepts of which are largely the same for the 2016 NWCA design.

2.1 Description of the NWCA Wetland Type Population

The ***target population*** for the NWCA included all wetlands of the conterminous United States (US) not currently in crop production, including tidal and nontidal wetted areas with rooted vegetation and, when present, shallow open water less than one meter in depth. A wetland's status under state or federal regulatory programs did not factor into this definition. Wetland attributes are assumed to vary continuously across a wetland.

2.2 Sample Frame, Survey Design, and Site Selection

Probability sites that were sampled as part of the NWCA were selected using a sample frame on which the survey design was based. The following sections provide details about how the sample frame and survey design were developed, and how sites were selected.

2.2.1 *Sample frame*

The foundation of the survey design is a ***sample frame***, or the geographic data layers that identify locations and boundaries of all wetlands that meet the definition of the target population. The sample frame for the 2016 NWCA was developed using two different geographic data layers: US Fish & Wildlife Service (USFWS) National Wetland Status and Trends (S&T) (Dahl and Bergeson 2009, Dahl 2011) and USFWS National Wetland Inventory (NWI) (USFWS 2014).

A sample frame obtained from the USFWS was utilized by the NWCA to gain aerial imagery interpretation of land cover types and to identify wetlands. The USFWS sample frame was created for the S&T program, which surveys approximately 5,000 4-mi^2 plots (i.e., 2-mile by 2-mile plots) every five to ten years to assess the extent (including gains and losses) in wetland area within the conterminous US. The S&T sample frame is stratified by state and physiographic region (i.e., each plot is associated with a state and physiographic region) and may result in a plot being subdivided on state and physiographic region boundaries. The entirety of the 5,000 4-mi^2 S&T plots were considered when developing the NWCA sample frame.

The 2011 NWCA relied solely on S&T plots for the sample frame, resulting in too few sites in the western US and the occurrence of multiple sites within the same S&T plots. Consequently, the 2016 NWCA sample frame was expanded to include wetland polygons from the NWI in addition to the S&T plots from the

2005 S&T survey. The NWI is the most complete spatial information on wetlands in the US (Horvath et al. 2017) and consists of millions of polygons across the contiguous 48 states, representing Cowardin wetland classes (Cowardin et al. 1979). The numerous Cowardin wetland classes found in the NWI polygons were consolidated and cross walked to the S&T Class Codes[1] and finally to NWCA Wetland Types (**Table 2-1**) by the NWCA Analysis Team to provide a consistent terminology for the NWCA sample frame. A wall-to-wall 4-mi^2 national-grid across the contiguous 48 states was overlayed on the NWI polygons to select 4-mi^2 NWI plots for inclusion in the NWCA sample frame.

Table 2-1. USFWS S&T Wetland Class Codes with crosswalk to NWCA Wetland Types.

S&T Code	NWCA Wetland Type	Description of wetlands included in each NWCA Wetland Type
E2EM	EH	Estuarine intertidal (E) emergent (H = herbaceous)
E2SS	EW	Estuarine intertidal (E) forested and shrub (W= woody)
PEM	PRL-EM	Emergent wetlands (EM) in palustrine, shallow riverine, or shallow lacustrine littoral settings (PRL)
PSS	PRL-SS	Shrub-dominated wetlands (SS) in palustrine, shallow riverine, or shallow lacustrine littoral settings (PRL)
PFO	PRL-FO	Forested wetlands in palustrine (FO), shallow riverine, or shallow lacustrine littoral settings (PRL)
Pf	PRL-f	Farmed wetlands (f) in palustrine, shallow riverine, or shallow lacustrine littoral settings (PRL); only the subset that was previously farmed, but not currently in crop production
PUBPAB*	PRL-UBAB	Open-water ponds and aquatic bed wetlands

*PUBPAB covered S&T Wetland Classes: PAB (Palustrine Aquatic Bed), PUBn (Palustrine Unconsolidated Bottom, natural), PUBa (aquaculture), PUBf (agriculture use), PUBi (industrial), PUBu (PBU urban).

[1] Note that the S&T Class Codes for the NWCA Wetland Types often encompass more kinds of wetlands than the code might suggest. For example, E2SS includes both estuarine intertidal shrub and forested wetlands. Palustrine codes (e.g., PEM and others) reflect palustrine wetlands, and also riverine and lacustrine wetlands with < 1 m water depth. Palustrine farmed (Pf) and Palustrine Unconsolidated Bottom (PUBPAB) wetlands with non-natural modifiers were retained in the NWCA frame to allow evaluation of whether they met NWCA Wetland Type criteria; those that did not were identified as non-target during site evaluation.

Two major S&T wetland categories, Marine Intertidal (M1, near shore coastal waters) and Estuarine Intertidal Unconsolidated Shore (E1UB, beaches, bars, and mudflats), were not included in the NWCA because they fall outside the NWCA target population, i.e., typically occurring in deeper water (> 1m deep) or unlikely to contain rooted wetland vegetation. Other S&T Categories not meeting NWCA criteria or that were not wetlands were also excluded: Estuarine Intertidal Aquatic Bed (E2AB) or Unconsolidated Shore (E2US), Marine Subtidal (M2), deep-water Lacustrine (LAC, lakes and reservoirs) and Riverine (RIV, river systems), Palustrine Unconsolidated Shore (PUS), Upland Agriculture (UA), Upland Urban (UB), Upland Forest Plantations (UFP), Upland Rural Development (URD), and Other Uplands (UO).

Several attributes were added to the wetland polygons in the 4-mi^2 plots in the sample frame either for their use in the survey design or survey analyses:

- States (PSTL_CODE),
- EPA Regions (EPA_REG),
- Omernik Level III Ecoregion (Omernik 1987),
- Three Aggregated Ecoregions (AG_ECO3)
- Nine Aggregated Ecoregions (AG_ECO9), and
- USFWS S&T Wetland Classes (**Table 2-1**, WETCLS_EVAL).

For more details about each attribute and for descriptions of the capitalized alphanumeric codes[2] in parentheses after each attribute, see **Chapter 5:**.

2.2.2 *Survey design*

The 2016 NWCA ***survey design*** is a combination of a) a set of new probability sites selected from the sample frame described in the previous section (**2.2.1 Sample frame**) and b) a subset of probability sites resampled from the 2011 NWCA survey. The NWCA uses a Generalized Random Tessellation Stratified (GRTS) survey design to select sites, which provides spatially distributed samples, and thus, are more likely to be representative of the population than other common spatial survey designs (Stevens and Olsen 2004, Olsen et al. 2012).

2.2.2.1 *Two-step survey design to select new probability sites*

The initial step in selecting new probability sites is to apply a GRTS survey design to select a subset of 4-mi^2-sample-frame-plots from all S&T plots and NWI plots within the 4-mi^2 national-grid described in **Section 2.2.1**. This survey design was stratified by state, resulting in the selection of 50 to 400 plots for each state depending on its area. This provided an initial set of 9,100 4-mi^2-sample-frame-plots and their component wetland polygons [the number of which may range from zero to many].

In the second step, a GRTS survey design for an area resource (i.e., the area of the NWCA wetland population across the US) was applied to all wetland polygons identified from the initial step. This survey design was stratified by state with unequal probability of selection based on geographic regions and Wetland Groups (WETCLS_GRP) see **Table 5-1** in **Chapter 5:**) within each state. The combination of these regions and Wetland Groups are represented by the subpopulations of the Twelve NWCA Reporting Groups (RPTGRP_12, **Table 2-2** and **Figure 2-1**).

[2] Note that the capitalized alphanumeric codes in parentheses (i.e., also found in **Table 5-1**) following each attribute are *analogous* to those used in the design but not exactly the same, as the design information was gleaned from spatial information and not data directly collected in the field. For example, the S&T Class Code may have been updated for a site if the field crews arrived at a site and determined that the S&T Class differed on the ground from that expected based on the spatial data.

Table 2-2. Crosswalk between regions and Wetland Groups, and the Twelve NWCA Reporting Groups (RPTGRP_12) subpopulations.

RPTGRP_12 Region Description	RPTGRP_12 Wetland Group Description	RPTGRP_12 Code
All Estuarine (ALL)	Estuarine Herbaceous (EH)	ALL-EH
	Estuarine Woody (EW)	ALL-EW
Coastal Plains (CPL)	Palustrine, Riverine, and Lacustrine Herbaceous (PRLH)	CPL-PRLH
	Palustrine, Riverine, and Lacustrine Woody (PRLW)	CPL-PRLW
Eastern Mountains & Upper Midwest (EMU)	Palustrine, Riverine, and Lacustrine Herbaceous (PRLH)	EMU-PRLH
	Palustrine, Riverine, and Lacustrine Woody (PRLW)	EMU-PRLW
Interior Plains (IPL)	Palustrine, Riverine, and Lacustrine Herbaceous (PRLH)	IPL-PRLH
	Palustrine, Riverine, and Lacustrine Woody (PRLW)	IPL-PRLW
Western Valleys & Mountains (WMT)	Palustrine, Riverine, and Lacustrine Herbaceous (PRLH)	WMT-PRLH
	Palustrine, Riverine, and Lacustrine Woody (PRLW)	WMT-PRLW
Xeric West (XER)	Palustrine, Riverine, and Lacustrine Herbaceous (PRLH)	XER-PRLH
	Palustrine, Riverine, and Lacustrine Woody (PRLW)	XER-PRLW

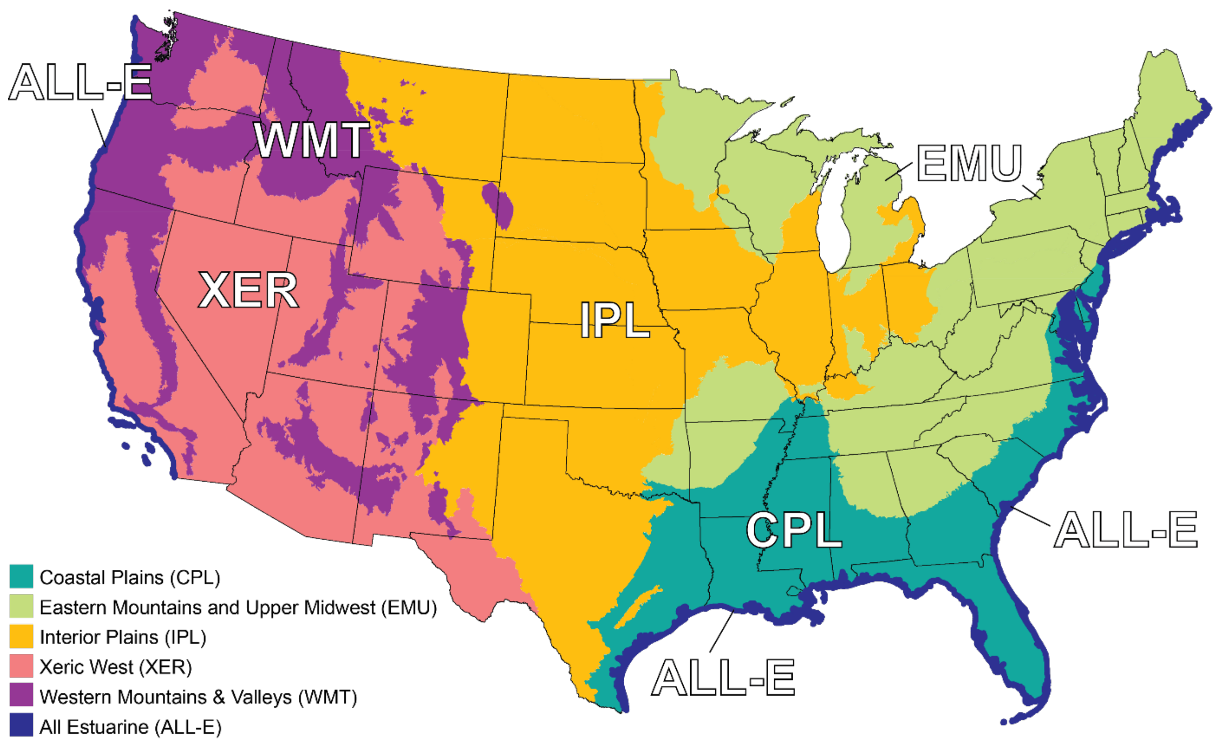

Figure 2-1. Regions captured in the Twelve NWCA Reporting Groups (RPTGRP_12) subpopulations. Wetland Group classifications (i.e., EH, EW, PRLH, PRLW (see **Table 2-2** for descriptions)) are site-specific and cannot be represented on this map as sites have not been selected at this point in the survey design development.

2.2.2.2 *Survey design to select resampled sites*

Resample sites are probability sites that were originally sampled in the field in the previous NWCA survey (i.e., 2011) and selected to be sampled again in the current survey (i.e., 2016). The resample design included 239 sites sampled in the 2011 NWCA. For other NARS, approximately 50% of the sites sampled in a survey are made up of resample sites; however, the 2011 NWCA design limitations led to a decision to reduce the number of resample sites. Limitations were related to lack of sites in the west, multiple sites within the same 4-mi^2-sample-frame-plot, and the sensitivity of wetland ecosystems to damage caused by repeat sampling events. The survey design selected sites that were spatially-balanced across the 48 states with unequal inclusion probabilities defined so that the number of sites in the NWCA categories based on five geographic regions and four Wetland Groups (**Table 2-2**) were:

- ALL_EH = 33
- ALL_EW = 18
- CPL_PRLH = 16
- CPL_PRLW = 25
- EMU_PRLH = 24
- EMU_PRLW = 25
- IPL_PRLH = 29
- IPL_PRLW = 18
- WMT_PRLH = 21
- WMT_PRLW = 15
- XER_PRLH = 9
- XER_PRLW = 6

In addition, 96 of these resampled sites (i.e., the first two sites on the site list per state represented the resample group) were intended to be sampled twice in 2016 field season (i.e., ***revisit sites*** – a site sampled twice within the same year to assess within-season-variability in the collected data). The second visit to a revisit site is not treated as a probability visit in analysis (i.e., it is excluded from extent estimates).

2.2.3 *Site Selection*

Site selection was completed using the R package 'spsurvey' (Kincaid and Olsen 2019, R Core Team 2019). To select sites using the survey design, four panels were included from which sets ***points*** (i.e., site coordinates selected by the survey design) were to be sampled in the listed order (USEPA 2016a, b). The panels (in order) were:

1. **Base11_RVT2**: identifies sites from NWCA 2011 that are to be visited twice within the 2016 season (i.e., both a resample and a revisit site),
2. **Base11**: identifies sites from NWCA 2011 to be visited once as a resample site in 2016,
3. **Base16**: identifies new sites to be visited once, and
4. **Base16_OverSamp**: identifies sites available to be used as replacement sites.

The sites were ordered in reverse hierarchical order to ensure that the final set of sites evaluated satisfied the requirements for a probability survey design (Stevens and Olsen 2004). Sites were sampled based on this order. All sites – from the first one on the list through the last site sampled from the list – were evaluated and, hence, included in the study.

To make certain that a sufficient number of sites were available for sampling, a panel of additional sites was selected as ***oversample sites*** to provide replacements for any sites that were either not part of the target population or could not be sampled (i.e., permission to sample was not provided by the landowner, or access was not possible due to safety or other access issues). Note that no oversample sites from 2011 were included. If any site from 2011 could not be sampled, and all available sites from 2011 were evaluated and sampled, then the next oversample site was the next available new site in Base16_OverSamp.

2.2.4 *Number of Sites Expected to be Sampled*

The expected sample size was 904 probability sites for the conterminous 48 states made up of 239 resampled sites from NWCA 2011 and 665 new probability sites. Each state was expected to revisit two sites within the field season, adding 96 revisits. Therefore, 1,000 site visits (i.e., sampling events) were expected for the 2016 NWCA. The minimum expected number of sites to be sampled in a state was seven (Vermont and West Virginia), with two of these sites revisited, for a total of nine site visits. The maximum number of sites for a state was 61 (Florida) (**Table 2-3**). Additional sites were sampled in some states with the objective of enabling a state-level assessment.

Table 2-3. Number of sites expected to be sampled, reported by state and Twelve NWCA Reporting Groups (RPTGRP_12).

State	ALL_EH	ALL_EW	CPL_PRLH	EMU_PRLH	IPL_PRLH	WMT_PRLH	XER_PRLH	CPL_PRLW	EMU_PRLW	IPL_PRLW	IPL_PRLW	WMT_PRLW	Total
AL	2	2	2	2	0	0	0	7	2	0	0	0	**17**
AR	0	0	3	2	0	0	0	5	2	0	0	0	**12**
AZ	0	0	0	0	0	2	3	0	0	0	2	10	**17**
CA	2	2	0	0	0	10	14	0	0	0	7	14	**49**
CO	0	0	0	0	2	9	4	0	0	2	9	2	**28**
CT	2	2	0	2	0	0	0	0	2	0	0	0	**8**
DE	2	2	2	2	0	0	0	2	2	0	0	0	**12**
FL	6	19	21	0	0	0	0	15	0	0	0	0	**61**
GA	5	2	4	2	0	0	0	10	2	0	0	0	**25**
IA	0	0	0	2	3	0	0	0	2	5	0	0	**12**
ID	0	0	0	0	0	7	5	0	0	0	6	5	**23**
IL	0	0	2	2	3	0	0	2	2	9	0	0	**20**
IN	0	0	0	2	2	0	0	0	2	5	0	0	**11**
KS	0	0	0	2	4	0	0	0	2	2	0	0	**10**
KY	0	0	2	2	2	0	0	2	2	3	0	0	**13**
LA	18	2	8	0	0	0	0	12	0	0	0	0	**40**
MA	2	2	2	2	0	0	0	2	2	0	0	0	**12**
MD	3	2	2	2	0	0	0	2	2	0	0	0	**13**
ME	2	2	0	2	0	0	0	0	3	0	0	0	**9**
MI	0	0	0	4	2	0	0	0	6	5	0	0	**17**
MN	0	0	0	10	5	0	0	0	7	4	0	0	**26**
MO	0	0	2	2	3	0	0	2	2	7	0	0	**18**
MS	2	2	4	0	0	0	0	9	0	0	0	0	**17**
MT	0	0	0	0	5	6	2	0	0	2	5	2	**22**
NC	4	2	2	2	0	0	0	9	2	0	0	0	**21**
ND	0	0	0	0	14	0	0	0	0	2	0	0	**16**
NE	0	0	0	0	5	0	0	0	0	3	0	0	**8**
NH	2	2	0	2	0	0	0	0	2	0	0	0	**8**
NJ	3	2	2	2	0	0	0	3	2	0	0	0	**14**
NM	0	0	0	0	2	3	3	0	0	2	2	3	**15**
NV	0	0	0	0	0	2	5	0	0	0	2	10	**19**
NY	2	2	2	3	0	0	0	2	3	0	0	0	**14**
OH	0	0	0	2	2	0	0	0	2	3	0	0	**9**
OK	0	0	2	2	3	0	0	2	2	6	0	0	**17**
OR	2	2	0	0	0	13	6	0	0	0	10	5	**38**
PA	0	0	2	2	0	0	0	2	2	0	0	0	**8**
RI	2	2	2	2	0	0	0	2	2	0	0	0	**12**
SC	5	2	3	2	0	0	0	7	2	0	0	0	**21**
SD	0	0	0	0	11	2	0	0	0	2	2	0	**17**
TN	0	0	2	2	0	0	0	3	2	0	0	0	**9**
TX	4	2	9	0	7	2	2	5	0	5	0	2	**38**
UT	0	0	0	0	0	3	18	0	0	0	2	3	**26**
VA	3	2	2	2	0	0	0	3	2	0	0	0	**14**
VT	0	0	0	2	0	0	0	0	5	0	0	0	**7**
WA	2	2	0	0	0	7	3	0	0	0	13	3	**30**
WI	0	0	0	5	3	0	0	0	5	6	0	0	**19**
WV	0	0	0	2	0	0	0	0	5	0	0	0	**7**

State	ALL_EH	ALL_EW	CPL_PRLH	EMU_PRLH	IPL_PRLH	WMT_PRLH	XER_PRLH	CPL_PRLW	EMU_PRLW	IPL_PRLW	IPL_PRLW	WMT_PRLW	Total
WY	0	0	0	0	2	5	5	0	0	2	5	6	**25**
Total	**75**	**59**	**82**	**74**	**80**	**71**	**70**	**108**	**80**	**75**	**65**	**65**	**904**

2.2.5 *State-Requested Modifications to the Survey Design*

Two states Kentucky and North Dakota intensified their state designs to do a state-level assessment. They used the same survey design as planned for NWCA 2016 but increased the sample size of the over sample sites to ensure a sufficient number of sites were available.

Minnesota elected to modify the survey design for their state because of the availability of additional wetland mapping information. In 2006, Minnesota developed a Comprehensive Wetland Assessment, Monitoring, and Mapping Strategy (CWAMMS). One of the primary outcomes of the CWAMMS was the development of statewide random surveys under the Wetland Status and Trends Monitoring Program (WSTMP), to begin assessing the status and trends of wetland quantity and quality in Minnesota (Kloiber 2010). The wetland quantity survey, implemented by the Minnesota Department of Natural Resources, was modeled after the USFWS S&T program (Dahl 2006, 2011). The WSTMP survey design was the basis for the Minnesota NWCA design.

The WSTMP design contains 1-mi^2 grid cells for Minnesota (and requires that at least 25% of grid cell be within state of Minnesota) where the grid matches the USFWS S&T 4-mi^2 grid boundaries. Each 4-mi^2 grid cell was subdivided into four 1-mi^2 grid cells. An equal-probability GRTS survey design was used to select 4,740 1-mi^2 plots. All wetland habitats within these plots were delineated using aerial imagery obtained in years 2009, 2010, and 2011. Where portions of some 1-mi^2 plots fell outside of state boundaries, only the portion occurring within the state was photo-interpreted and mapped. Therefore, the total area of the sample frame extent was less than 4,740 mi^2. S&T Class Codes for the NWCA Wetland Types (**Table 2-1**) were PEM, PSS, PFO, Pf, and PUBPAB. The next step was to select 150 sample sites using a GRTS equal-probability survey design from the delineated wetland polygons. The 26 Minnesota sites required for NWCA 2016 were two sites from NWCA 2011 to be sampled twice in 2016, five sites from NWCA 2011 to be sampled once in 2016 and 19 new sites to be sampled once for NWCA 2016. These sites were identified by the panels Base11_MN_NWCA_RVT2, Base11_MN_NWCA, and Base16. Additional panels identified the remaining sites to be sampled as part of Minnesota's state-level design as well as over sample sites to be used when the base site could not be sampled. An additional 150 sites were selected for use if any of the initial 150 sites could not be sampled, using the same process described in **Section 2.2.4**.

2.3 Wetland Area in the NWCA Sample Frame

Using the NWCA sample frame, the total area of the contiguous US is estimated to be approximately 2 billion acres, with approximately 157 million total acres designated as wetlands. Of the wetland acres, 106,672,330 acres are included in the NWCA sample frame. The wetland area included in the NWCA 2016 sample frame is provided in **Table 2-4** summarized by state and reporting domain.

Table 2-4. Wetland area (acres) in the NWCA sample frame reported by state and Twelve NWCA Reporting Groups (RPTGRP_12).

State	ALL_EH	ALL_EW	CPL_PRLH	EMU_PRLH	IPL_PRLH	WMT_PRLH	XER_PRLH	CPL_PRLW	EMU_PRLW	IPL_PRLW	WMT_PRLW	XER_PRLW	Total
AL	26,385	2,186	180,070	103,255	0	0	0	2,755,276	378,189	0	0	0	**3,445,361**
AR	0	0	231,161	98,872	0	0	0	1,759,186	69,859	0	0	0	**2,159,078**
AZ	0	0	0	0	0	36,867	209,993	0	0	0	6,567	182,220	**435,647**
CA	60,084	248	0	0	0	597,822	1,642,708	0	0	0	134,368	273,360	**2,708,590**
CO	0	0	0	0	207,116	478,456	326,590	0	0	58,792	190,905	17,011	**1,278,870**
CT	12,413	158	0	54,529	0	0	0	0	149,454	0	0	0	**216,554**
DE	73,297	723	12,771	330	0	0	0	166,846	1,172	0	0	0	**255,139**
FL	465,483	660,844	3,708,175	0	0	0	0	6,580,196	0	0	0	0	**11,414,698**
GA	350,854	6,554	408,670	98,042	0	0	0	4,113,984	327,607	0	0	0	**5,305,711**
IA	0	0	0	19,896	359,588	0	0	0	28,228	335,915	0	0	**743,627**
ID	0	0	0	0	0	354,303	408,060	0	0	0	113,369	71,580	**947,312**
IL	0	0	4,323	8,800	357,681	0	0	15,433	33,540	758,742	0	0	**1,178,519**
IN	0	0	0	105,896	196,380	0	0	0	151,874	402,331	0	0	**856,481**
KS	0	0	0	639	468,307	0	0	0	1,135	75,189	0	0	**545,270**
KY	0	0	15,591	100,591	41,930	0	0	76,219	61,144	153,353	0	0	**448,828**
LA	1,683,190	11,853	1,337,689	0	0	0	0	5,185,023	0	0	0	0	**8,217,755**
MA	47,991	1,017	7,752	116,985	0	0	0	22,988	334,309	0	0	0	**531,042**
MD	205,114	19,296	39,412	17,558	0	0	0	370,216	26,850	0	0	0	**678,446**
ME	24,241	115	0	286,830	0	0	0	0	1,743,150	0	0	0	**2,054,336**
MI	0	0	0	742,967	86,306	0	0	0	5,421,291	370,157	0	0	**6,620,721**
MN	0	0	0	2,555,414	765,580	0	0	0	6,942,990	251,113	0	0	**10,515,097**
MO	0	0	99,502	123,264	362,516	0	0	115,033	109,742	527,460	0	0	**1,337,517**
MS	53,557	1,171	388,813	0	0	0	0	3,588,651	0	0	0	0	**4,032,192**
MT	0	0	0	0	806,574	312,709	208	0	0	38,536	88,087	232	**1,246,346**
NC	225,299	15,782	165,226	84,240	0	0	0	3,367,410	202,760	0	0	0	**4,060,717**
ND	0	0	0	0	2,814,048	0	0	0	0	34,237	0	0	**2,848,285**
NE	0	0	0	0	746,646	0	0	0	0	110,704	0	0	**857,350**
NH	5,947	2	0	69,899	0	0	0	0	208,812	0	0	0	**284,660**
NJ	200,584	1,626	57,357	40,703	0	0	0	486,735	134,746	0	0	0	**921,751**
NM	0	0	0	0	145,213	111,785	253,325	0	0	6,825	6,564	37,878	**561,590**

State	ALL_EH	ALL_EW	CPL_PRLH	EMU_PRLH	IPL_PRLH	WMT_PRLH	XER_PRLH	CPL_PRLW	EMU_PRLW	IPL_PRLW	WMT_PRLW	XER_PRLW	Total
NV	0	0	0	0	0	1,359	540,770	0	0	0	600	189,888	**732,617**
NY	27,498	1,084	3,573	423,371	0	0	0	7,801	1,444,673	0	0	0	**1,908,000**
OH	0	0	0	142,350	120,615	0	0	0	276,273	119,558	0	0	**658,796**
OK	0	0	39,309	71,974	444,034	0	0	107,473	116,152	446,583	0	0	**1,225,525**
OR	14,563	173	0	0	0	802,918	650,867	0	0	0	199,674	74,912	**1,743,107**
PA	0	0	2,134	137,184	0	0	0	2,614	296,379	0	0	0	**438,311**
RI	3,579	76	282	7,485	0	0	0	104	54,933	0	0	0	**66,459**
SC	343,224	4,395	264,397	45,285	0	0	0	2,873,956	111,063	0	0	0	**3,642,320**
SD	0	0	0	0	2,033,837	3,140	0	0	0	44,637	243	0	**2,081,857**
TN	0	0	69,986	98,590	0	0	0	590,908	140,130	0	0	0	**899,614**
TX	295,910	3,287	1,371,288	0	1,134,629	659	92,946	1,717,953	0	338,293	0	20,622	**4,975,587**
UT	0	0	0	0	0	127,509	2,227,873	0	0	0	22,212	36,328	**2,413,922**
VA	181,909	7,457	103,162	99,129	0	0	0	674,148	243,042	0	0	0	**1,308,847**
VT	0	0	0	73,069	0	0	0	0	181,237	0	0	0	**254,306**
WA	24,035	131	0	0	0	340,142	151,237	0	0	0	285,714	24,843	**826,102**
WI	0	0	0	883,021	435,491	0	0	0	3,800,364	491,010	0	0	**5,609,886**
WV	0	0	0	45,125	0	0	0	0	24,749	0	0	0	**69,874**
WY	0	0	0	0	130,143	250,495	538,390	0	0	7,837	97,632	85,210	**1,109,707**
Total	**4,325,159**	**738,178**	**8,510,644**	**6,655,292**	**11,656,635**	**3,418,163**	**7,042,968**	**34,578,153**	**23,015,848**	**4,571,273**	**1,145,934**	**1,014,083**	**106,672,330**

2.4 Survey Analysis

Any statistical analysis of data must incorporate information about the monitoring survey design. When estimates of characteristics for the entire target population are computed, called ***population estimates*** (discussed in **Chapter 15**), the statistical analysis must account for any stratification or unequal probability selection in the design. The statistical analysis of the NWCA population estimates were completed using the R package ‘spsurvey’ (Kincaid and Olsen 2019), which implements the methods described by Diaz-Ramos et al. (1996).

2.5 Estimated Wetland Extent of the NWCA Wetland Population and Implications for Reporting

Using a site evaluation process (USEPA 2016b), points selected by the NWCA survey design were screened using aerial photo interpretations and GIS analyses to eliminate locations not suitable for NWCA sampling (e.g., non-NWCA wetland types, wetlands converted to non-wetland land). Sites could also be eliminated during field reconnaissance if they were a non-target type or could not be assessed due to accessibility issues. Dropped sites were systematically replaced from a pool of replacement sites (i.e., oversample panel discussed in **Section 2.2.3**) from the survey design.

Eliminated sites affect how the final population results are estimated and reported. Accounting for non-NWCA wetland types (e.g., wetlands in active crop production, deeper water ponds, mudflats), there were an estimated 95.7 million acres of wetlands in the population across the conterminous US. Throughout this report, wetland area as percentages is relative to the 95.7 million acres.

Table 2-5 illustrates the distribution of estimated extents of the 1) total NWCA wetland population, 2) the sampled area (based on sampled probability sites), and 3) non-assessed area (based on probability sites that could not be assessed) for the nation (conterminous US) and within the Twelve NWCA Reporting Groups (RPTGRP_12).

Table 2-5. Total estimated areal extents for the total target NWCA population, the sampled area extents, and non-assessed area extents for the nation and by Twelve NWCA Reporting Groups (RPTGRP_12). Results are reported as millions of acres or percent (%) of total estimated NWCA wetland area for the nation or by RPTGRP_12.[1] The number of sites in each group is provided as n.

RPTGRP_12	**Target NWCA Wetland Population** millions acres	**Sampled** millions acres (% area)	**Access Denied** millions acres (% area)	**Inaccessible** millions acres (% area)	**Other Non-Assessed** millions acres (% area)
Nation	95.7	52.9 (55%) n = 967	35.6 (37%) n = 1171	5.1 (5%) n = 281	2.1 (2%) n = 227
ALL_EH	4.6	3.4 (71%) n = 133	0.8 (18%) n = 48	0.5 (10%) n = 40	<0.1 (1%) n = 4
ALL_EW	1.1	0.6 (52%) n = 29	0.2 (15%) n = 82	0.4 (32%) n = 82	<0.1 (1%) n = 12
CPL_PRLH	10.2	6.4 (63%) n = 222	2.6 (25%) n = 136	1.1 (11%) n = 38	<0.1 (<1%) n = 4
CPL_PRLW	33.7	17.5 (52%) n = 143	13.8 (41%) n = 160	2.0 (6%) n = 36	0.4 (1%) n = 7
EMU_PRLH	4.4	2.9 (65%) n = 43	1.1 (25%) n = 57	<0.1 (1%) n = 3	0.4 (9%) n = 16
EMU_PRLW	22.6	16.3 (72%) n = 105	5.6 (25%) n = 79	0.6 (3%) n = 5	0.2 (1%) n = 13
IPL_PRLH	9.0	4.4 (49%) n = 81	4.1 (46%) n = 167	<0.1 (1%) n = 4	0.4 (4%) n = 49
IPL_PRLW	4.0	2.1 (54%) n = 96	1.6 (41%) n = 138	0.1 (2%) n = 7	0.1 (4%) n = 19
WMT_PRLH	2.5	0.8 (31%) n = 73	1.5 (59%) n = 80	0.1 (5%) n = 13	0.1 (4%) n = 16
WMT_PRLW	1.2	0.6 (51%) n = 51	0.3 (23%) n = 75	0.2 (13%) n = 13	0.2 (12%) n = 24
XER_PRLH	5.5	1.4 (26%) n = 85	0.2 (69%) n = 75	0.1 (2%) n = 11	0.2 (3%) n = 31
XER_PRLW	0.6	0.4 (48%) n = 43	0.2 (35%) n = 74	<0.1 (4%) n = 24	0.1 (13%) n = 31

[1]Numbers in table may not add to totals due to rounding.

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Chapter 3: Selection of Handpicked Sites

In addition to the probability sites identified by the survey design, ***handpicked sites*** are identified by states, tribes, and other partners. These handpicked sites are suggested based on the expectation that they are minimally disturbed and can be used as least-disturbed (or "reference") sites, although this is not always the case (Herlihy 2008, 2019). The suggested handpicked sites were evaluated prior to the field sampling using a screening process to eliminate those that are not likely to meet the criteria for the NWCA.

3.1 Pre-Sampling Selection of Handpicked Sites

Candidate handpicked sites came from three sources:

1) Best Professional Judgment (BPJ) sites recommended by state, tribal, and federal entities with responsibilities for wetlands;

2) Designated least-disturbed sites from other NARS with associated wetlands; and,

3) In-the-field replacements for sites from sources above that were determined not sampleable due to access, permitting, or other constraints.

BPJ sites and least-disturbed sites designated from other NARS underwent the following screening process.

3.1.1 *Initial Screen*

The initial screening step eliminated candidate handpicked sites not likely to meet the criteria for NWCA sampling and to reduce the number of sites to a reasonable size for a manual evaluation employing analysis of maps and aerial photos. Information provided by the person who suggested each site was considered, and included wetland size and type, as well as data supporting whether a site was least disturbed, e.g., scores from a Floristic Quality Assessment Index (FQAI) or Landscape Development Index (LDI). Wetlands eliminated were typically small, rare types. In cases where many sites were submitted by an entity, those ranking lower than others, given the data submitted, were eliminated from further consideration.

All estuarine sites and sites in the Coastal Plains (see **Figure 2-1** in **Chapter 2:**) were eliminated because an adequate number of least-disturbed sites for this region and Wetland Group were identified in the 2011 NWCA.

3.1.2 *Basic Screen*

Candidate handpicked sites passing the initial screen were mapped in ArcGIS (exemplified in **Figure 3-1**). Maps of each site with recent aerial imagery were assessed to determine if:

- The wetland at the site would support the establishment of a sampleable assessment area
    - The wetland was in the target population for NWCA
    - The wetland was equal or greater than 0.1 ha and at least 20-m wide
    - Less than 10% of the area

        ▪ Contained water greater than 1-m deep,
        ▪ Had conditions that were unsafe or would make effective sampling impossible (e.g., likely unstable substrate), and/or
        ▪ Was upland
    - No hydrogeomorphic boundaries were crossed;
- The site was accessible with moderate effort; and,
- The site was greater than 1km away from a probability site.

If all these criteria were met, the sites were assessed for evidence of visual landscape disturbance.

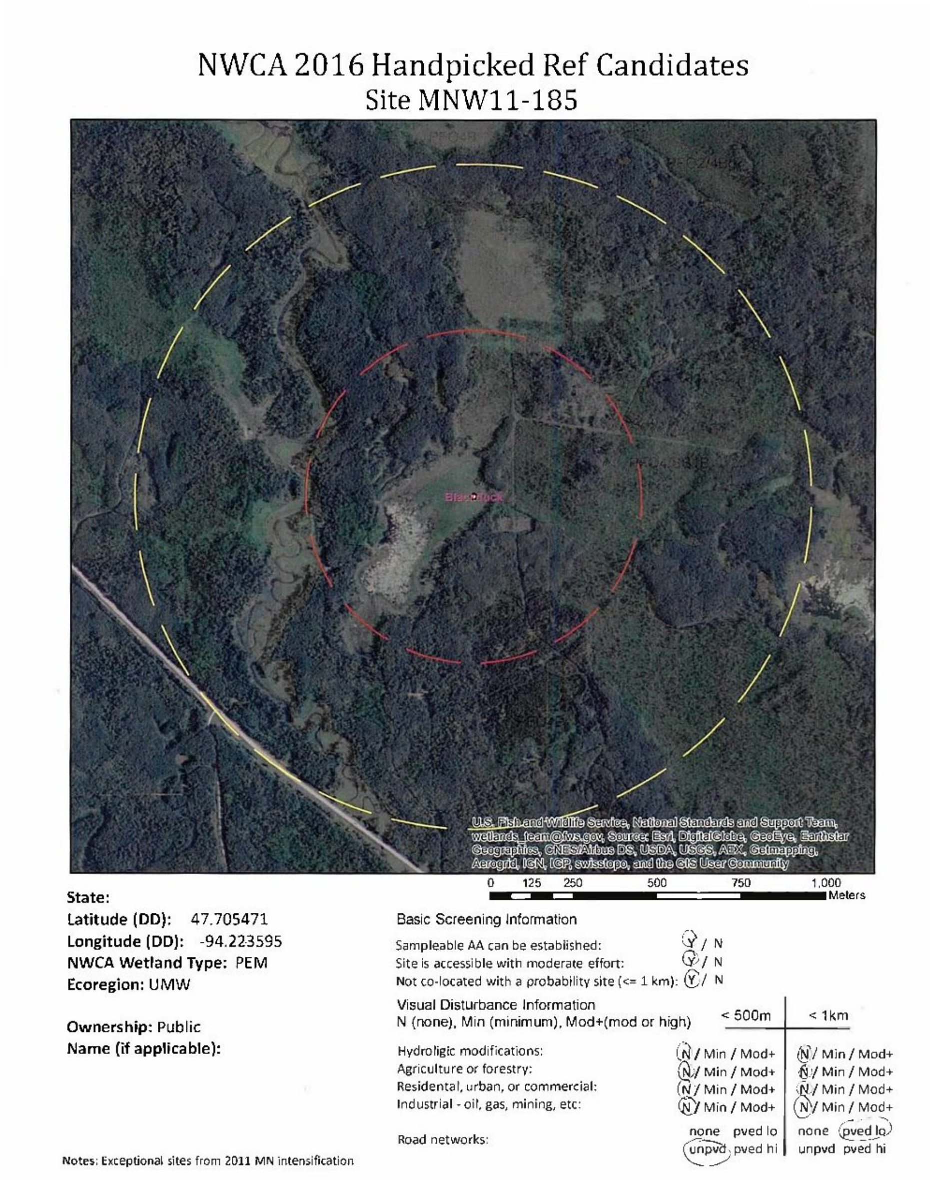

Figure 3-1. Example of map created using ArcGIS software to evaluate candidate handpicked sites. Information from an assessment of the aerial imagery was recorded for basic and landscape screening criteria.

3.1.3 *Landscape Screen*

For candidate handpicked sites that passed the basic screen, aerial photos **Figure 3-1** were used to evaluate the presence of anthropogenic impact within buffers defined by 500m- and 1km-radius circles centered on the likely location of the Assessment Area (AA) that would be used during field sampling.

First, the images were evaluated to determine the level of impact from the following types of anthropogenic activities within the 500m- and 1km-radius buffer:

- Hydrologic modifications (e.g., linear features that would indicate the presence of ditches, dams, or levees);
- Agricultural development (e.g., farm structures, row crops, horticultural fields, pastures) or forestry activities (e.g., rows of trees, tree stumps and debris, logging roads, tree regeneration);
- Residential, urban, or commercial development (e.g., houses, retail malls, commercial buildings, parking lots); and,
- Industrial development (oil and gas structures, mines, gravel pits, industrial facilities).

For each category of activity, the levels were noted as “none”, “minimal” (the activity impacted less than 25% of the area), or “moderate and above” (the activity impacted more 25% or more of the area).

Next, the images were evaluated to determine the presence of road networks within the 500m- and 1km-radius buffer. Road networks were categorized as “none”, “unpaved only”, “paved-low” (paved roads impacted less than 25% of the area), or “paved-high” (paved roads impacted 25% or more of the area).

Sites with no impacts from anthropogenic activities and road networks were prioritized for sampling. Sites with minimal impacts from anthropogenic activities and road networks (“unpaved”, “paved-low”) were retained for potential use in regions with few non-disturbed candidate sites. Sites with “moderate” or greater disturbance in the 500-m buffer were rejected outright.

3.1.4 *Distribution of Handpicked Sites*

Sites prioritized for sampling and retained for potential use were evaluated to assure, to the greatest extent possible, adequate distribution across the regions and Wetland Groups likely to be used for analysis and reporting. Site selection and distribution was also influenced by the availability of field crews to sample handpicked sites in certain areas of the country. For example, EPA staffed regional field crews were limited to sampling sites within their respective EPA Regions.

3.1.5 *Replacement of Handpicked Sites Not Sampleable*

At times, it was necessary to replace sites during the reconnaissance checks performed before sampling or at the time of sampling. Sites were replaced during reconnaissance due to access issues, but also because the Field Crew Leader acquired additional information that either 1) eliminated the site as a candidate for use as “least-disturbed” (e.g., presence of invasive species) or 2) documented there was a better, more appropriate candidate least-disturbed site. Sites were replaced at time of sampling primarily due to access issues (e.g., too difficult to get to the exact location, last minute refusals by property managers).

3.1.6 *Results*

In the end, 90 handpicked sites (10 of which were sampled in 2011 and again (i.e., resampled) in 2016) were selected through this screening process and sampled. **Table 3-1** lists the final distribution of the handpicked sites by the Five NWCA Aggregated Ecoregions and Wetland Group.

Table 3-1. Distribution of 90 handpicked sites sampled in 2016 by Five NWCA Aggregated Ecoregions and the NWCA Wetland Group. Note: All estuarine sites and sites in the Coastal Plains ecoregion were eliminated because an adequate number of least-disturbed sites for this region and Wetland Group were identified in the 2011 NWCA.

Five NWCA Aggregated Ecoregions	PRLH	PRLW	Total
Coastal Plains (CPL)	0	0	0
Eastern Mountains & Upper Midwest (EMU)	24	26	50
Interior Plains (IPL)	16	7	22
Western Valleys & Mountains (WMT)	8	3	11
Xeric West (XER)	5	1	6
Sum	**46**	**34**	**90**

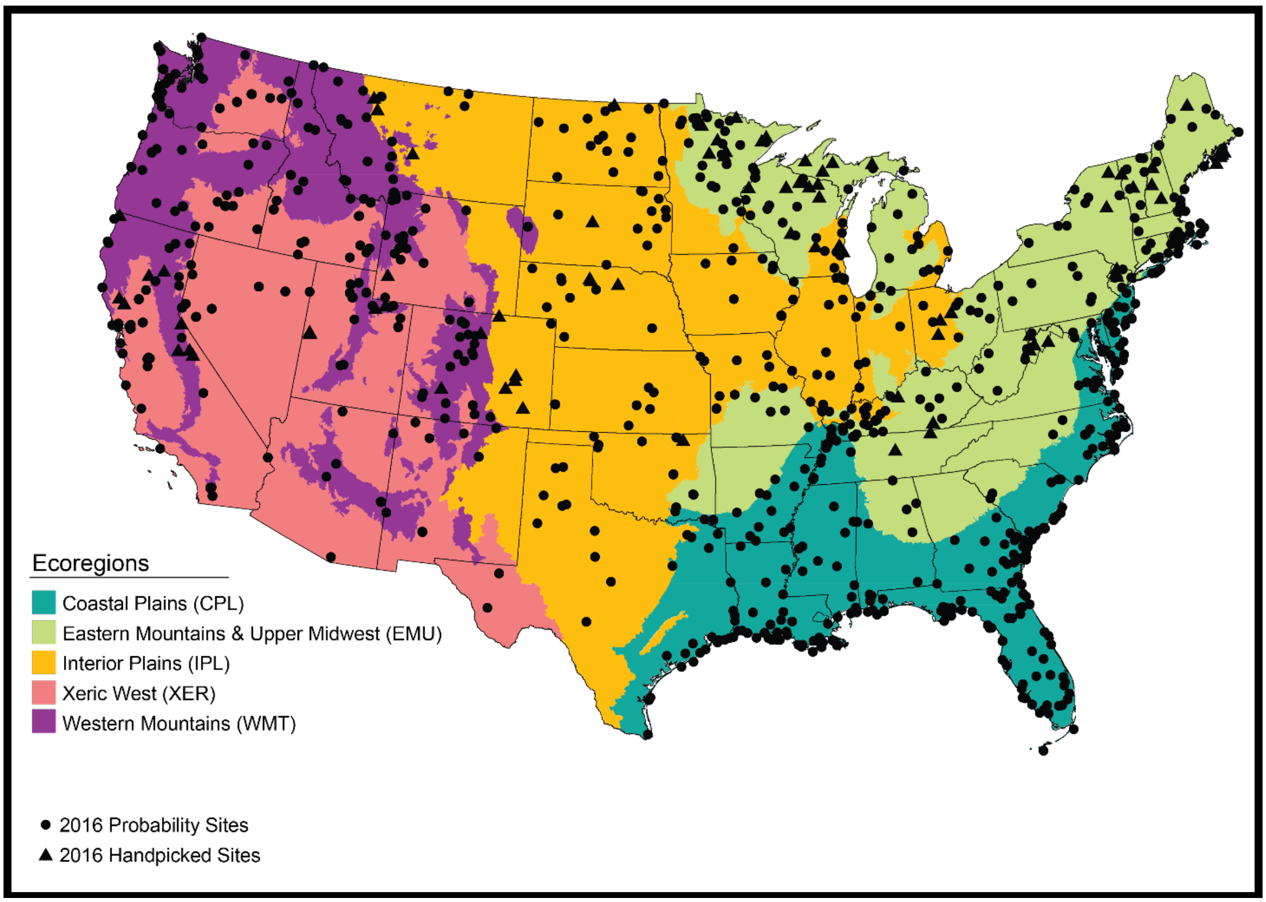

Figure 3-2. Map of the conterminous US showing distribution of handpicked sites (triangles) in relation to probability sites (circles) sampled in the 2016 NWCA.

3.2 Literature Cited

Herlihy AT, Kentula ME, Magee TK, Lomnicky GA, Nahlik AM, Serenbetz G (2019) Striving for consistency in the National Wetland Condition Assessment: developing a reference condition approach for assessing wetlands at a continental scale. Environmental Monitoring and Assessment 191 (S1): 327, doi: 10.1007/s10661-019-7325-3

Herlihy AT, Paulsen SG, Van Sickle J, Stoddard JL, Hawkins CP, Yuan LL (2008) Striving for consistency in a national assessment: the challenges of applying a reference-condition approach at a continental scale. Journal of the North American Benthological Society 27: 860-877

Chapter 4: Data Preparation

The tasks to produce the datasets used in the analysis are described in this chapter. The data checking steps described, here, were designed to catch many errors. Other errors were found and corrected during analysis using processes documented in the chapters following this.

The master database for the 2016 NWCA includes:

1) Raw data collected by Field Crews and from laboratory processing of samples collected in the field (USEPA 2016a, b).
2) Data documenting and characterizing the NWCA sites from the survey design.
3) Field and lab raw data, site information, and ancillary data combined for use in specific analyses.
4) Metrics calculated from raw data from the field forms and the laboratory results.

4.1 Key Personnel

USEPA Office of Water (OW), Office of Wetlands, Oceans and Watersheds, Watershed Restoration, Assessment, and Protection Division (WRAPD) provided overall leadership for the 2016 NWCA. Gregg Serenbetz led the team in WRAPD and coordinated and fostered cooperation with the Analysis Team. Personnel from the Office of Research and Development, Center for Public Health and Environmental Assessment (CPHEA), Pacific Ecological Systems Division (PESD) were responsible for data entry, quality assurance, and preparation of datasets for analysis with input from the Indicator Leads.

Mary E. Kentula, Amanda M. Nahlik, and Teresa K. Magee are the primary contacts at PESD for the 2016 NWCA. Together, they provided oversight and coordination of the various components at PESD and their interactions with Office of Water.

Karen Blocksom deals with all aspects of the management of the data for the NARS surveys, e.g., finding, correcting, and documenting errors, designing formats for the specific datasets needed for the various analyses, and programming required for data management and analyses. She is the primary R programmer and data manager for NARS, including the NWCA.

The Information Management Team (a.k.a., NARS IM) performs data entry and checks, makes and documents corrections to the database, and creates various data sets for analysis for the NARS assessments. The NARS IM for the 2016 NWCA is a group of people on contract to USEPA who are located at PESD.

The NWCA Analysis Team was composed of the Indicator Leads, the scientists working with them on the analysis, and the scientists conducting work that supported multiple analyses. **Table 4-1** lists the members of the Analysis Team and their roles.

Table 4-1. The 2016 NWCA Analysis Team and roles. All people listed are USEPA except as noted.

Core Analyses	Leads	Associates
Survey Design and Population Extent	Anthony R. Olsen	Thomas M. Kinkaid, Michel Dumelle
Selection of Handpicked Sites	Gregg Serenbetz	Alan T. Herlihy, Ann Rossi-Gill, Sarah Lehmann
Data QA and Management	Karen Blocksom	NARS IM contractors^
Subpopulations	Amanda M. Nahlik	Karen Blocksom
Disturbance Gradient	Amanda M. Nahlik	Teresa K. Magee, Alan T. Herlihy, Karen Blocksom, Mary E. Kentula, Anett S. Trebitz
Landscape Metrics	Amanda M. Nahlik	Marc Weber
Population Estimates	Amanda M. Nahlik	Steven G. Paulsen, Thomas M. Kincaid
Indicators	**Leads**	**Associates**
Vegetation Multimetric Indices	Teresa K. Magee	Karen Blocksom, Amanda M. Nahlik, Alan T. Herlihy, Steven G. Paulsen, Mary E. Kentula
Nonnative Plant Indicator	Teresa K. Magee	Karen Blocksom, Amanda M. Nahlik, Alan T. Herlihy
Human-Mediated Physical Alterations	Amanda M. Nahlik	Karen Blocksom, Alan T. Herlihy, Teresa K. Magee, Mary E. Kentula, Steven G. Paulsen
Soil Heavy Metals	Amanda M. Nahlik	Alan T. Herlihy, Karen Blocksom
Water Chemistry	Anett S. Trebitz	Alan T. Herlihy
Microcystins	Danielle Grunzke	N/A
Research Indicators and Topics	**Leads**	**Associates**
Soil and Water Stable Isotopes	Amanda M. Nahlik	J. Renee Brooks
Carbon Storage in Wetland Soils	Amanda M. Nahlik	M. Siobhan Fennessy*, Karen Blocksom, Michael Dumelle

^General Dynamics Information Technology, Inc. (GDIT); *Kenyon College

4.2 Data Entry and Review

4.2.1 *Field Data*

The 2016 NWCA field forms were available in two formats: electronic or paper. While use of paper forms has been the traditional method of collecting field data (i.e., in the 2011 NWCA), an NWCA app was developed for the 2016 survey. Because the NWCA app was new, Field Crews were allowed to opt between paper field forms and the electronic field forms. While a few Field Crews exclusively used electronic field forms, most Field Crews chose to use paper field forms. The same information was collected on both electronic and paper field forms.

4.2.1.1 *Electronic Field Forms*

Electronic field forms are advantageous over paper forms because logic checks and completeness checks can be programmed into them. Electronic field forms in the 2016 NWCA app were available through the App Store by NARS IM. After collecting data for a site, Field Crews submitted electronic field forms as .json files via email directly to NARS IM. These .json file were then parsed into different data types and imported into the appropriate data tables. A PDF file showing the data received in the format of paper field forms was sent back to the crew for review.

4.2.1.2 *Paper Field Forms*

Paper field forms for the 2016 NWCA were created in TeleForm™ software. This form development software uses optical character recognition/intelligent character recognition technology along with operator verification to capture data from paper field forms.

The Field Crews mailed packets of completed paper field forms directly to the data management center at PESD. Form packets were logged and checked for quality and completeness. Field Crews were immediately contacted if the field forms were incomplete or if there were questions regarding data written on the forms. Each page was scanned and evaluated by the scanning software. Because the paper forms were designed in TeleForm™, the evaluation process was coded to flag restricted input. For example, a data field may have an allowable numerical range, or a specified list of expected values. Any data entries not meeting the criteria were marked by the software as potential errors. The operator reviewed the marked entries by comparing the entered value to that on the paper form and making corrections to mis-scanned data.

4.2.1.3 *Field Form Validation*

Both electronic and paper field forms were subjected to visual checks; the entered data was reviewed in tabular form. On a daily basis, the data were reviewed for logical errors, for example:

- Did Sample ID numbers meet sequential expectations?
- If there were flags on a data form, was an associated comment recorded by the Field Crew?
- Were there form images for each sheet?
- Do the samples in the samples table match the samples in the tracking tables?

Once the phase of verification described above was complete, the data were further scrutinized via programmatic validation and logic checks in R.

4.2.2 *Laboratory Data*

Laboratory results were submitted to USEPA WRAPD staff, who checked the data for completeness and obvious errors. Then the data files were transferred to NARS IM for incorporation into the master NWCA database.

The water chemistry data produced by Consolidated Safety Services (CSS) located at PESD was handled by a different process. CSS checks their results based on the approved Quality Assurance Project Plan and the data files are transferred from CSS to the NARS IM through the Work Assignment Contract Officer Representative (COR).

4.3 Quality Assurance Checks

There were three types of Quality Assurance (QA) checks completed before datasets were assembled for analysis:

1) Verification of the fate of every sample point from the 2016 NWCA design;
2) Confirmation of longitudes and latitudes associated with the sites sampled; and
3) Data checks.

4.3.1 *Verification of Points*

Estimates of the wetland area falling into a particular condition category are based on the weight from the survey design used to select the points to be sampled. For examples of how this has been done for other surveys see Stevens and Jensen (2007) and Olsen and Peck (2008), or for an example of how this was done for the 2011 NWCA, see USEPA (2016c) and Olsen et al. (2019). **Chapter 2:** provides specific details of the NWCA survey design, and **Chapter 15:** discusses how estimates for the 2016 NWCA wetland area were made.

In the NWCA survey design, the weight indicates the wetland area in the NWCA target population represented by a point from the sample draw. After the assessment is conducted, the weights were adjusted to account for additional sites (i.e., the oversample points) evaluated when primary sites could not be sampled (e.g., due to denial of access, being non-target).

All points in the design were reviewed to confirm which were sampled, and if not, why not. Three sources were used:

1) Information compiled during the desktop evaluation of sites (see the *NWCA 2016 Site Evaluation Guidelines* (USEPA 2016d)), and documented by state and contractor field crews in spreadsheet submissions to EPA during and after the 2016 field season,

2) Information recorded on Form PV-1 during a field evaluation performed prior to sampling (see the *NWCA 2016 Site Evaluation Guidelines* (USEPA 2016d)), and

3) Information recorded on Form PV-1 at the time of sampling (see Chapter 3 in the *NWCA 2016 Field Operations Manual* (USEPA 2016a)).

Results from this evaluation were added to the database containing site information data from the NWCA survey design and for the handpicked sites.

4.3.2 *Confirmation of Coordinates Associated with the Sites Sampled*

Longitudes and latitudes are taken at various key locations associated with field sampling (e.g., the location of the point from the design). These coordinates are especially important if a point needs to be relocated or shifted to accommodate sampling protocols (see Chapter 3 in the *NWCA 2016 Field Operations Manual* (USEPA 2016a)). The coordinates are used to:

- Verify the relationship between the point coordinates from the design and those of the sampled Assessment Area (AA) that represents the point;

- Tie the field data to landscape data from GIS layers; and

- Relocate the site and key locations of the field sampling protocol (e.g., the AA center, vegetation plots) for resampling in future surveys.

Point coordinates from the design and the field were compared. The locations of points from the field that were more than 60m from the corresponding design coordinates, i.e., that exceeded protocol guideline (see Section 4.2 in the *NWCA 2016 Site Evaluation Guidelines* (USEPA 2016d)), were flagged.

4.3.3 *Data Checks*

The first step in this series of checks was to assure all sites with data from a second field sampling (i.e., Visit 2, which is also known as the Quality Assurance Visit) had a corresponding initial sampling (i.e., Visit 1). Next, for all data types, computer code was written to generate a list of missing data, and checks were performed to identify why they were missing (e.g., part of the sampling was not completed by the Field Crew, data sheet(s) not scanned, etc.). Additional computer code was written to generate a list of data not meeting a series of legal value and range tests. These tests were to confirm that:

- Data type was correct,
- Data fell within the valid range or legal value, and
- Units reported (especially for laboratory results) matched those expected.

Results of the checks were converted to Excel spreadsheets. Each potential error was evaluated by the IT Team or the Indicator Lead using the original forms submitted by the Field Crew. A description of the error and recommended resolution were recorded in the spreadsheet for each type of data and incorporated into the master NWCA database. The Indicator Lead who would be the primary user of the data was consulted in cases where the resolution of the issue could affect the results of the analysis.

4.4 Literature Cited

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Olsen AR, Peck DV (2008) Survey design and extent estimates for the Wadeable Streams Assessment. Journal of the North American Bethological Society 27: 822-836

Stevens DL, Jr., Jensen SF (2007) Sample design, implementation, and analysis for wetland assessment. Wetlands 27: 515-523

USEPA (2016a) National Wetland Condition Assessment 2016: Field Operations Manual. US Environmental Protection Agency, Washington DC. EPA-843-R-15-007.

USEPA (2016b) National Wetland Condition Assessment 2016: Laboratory Operations Manual. US Environmental Protection Agency, Washington DC. EPA-843-R-15-009.

USEPA (2016c) National Wetland Condition Assessment 2011 Technical Report. US Environmental Protection Agency, Washington DC. EPA-843-R-15-006.

USEPA (2016d) National Wetland Condition Assessment 2016: Site Evaluation Guidelines. US Environmental Protection Agency, Washington DC. EPA-843-R-15-010.

Chapter 5: Subpopulations

The conterminous United States is the broadest scale at which the NWCA results are reported. However, the diversity in the Nation's landscape makes it important to assess aquatic resources in the appropriate geographic setting. Regional variation in species composition, environmental conditions, and human-caused disturbance often necessitates a finer scale, i.e., sub-national, to:

- Define quantitative criteria and thresholds for least-disturbed sites and most-disturbed sites;
- Define thresholds for categories of wetland condition and stressors, and
- Report wetland condition extent and stressor condition extent.

These tasks and the need for sub-national, geographic reporting units are inherent to all NARS assessments.

USEPA's Environmental Monitoring and Assessment Program (EMAP) recommends as a general rule that, absent information on the variability in the target population, 50 sites per subpopulation should be assessed to increase the likelihood that the sample will be sufficient to make population estimates. For example, the EPA Level III Ecoregions (Omernik 1987, USEPA 2011a) of the US were aggregated into nine regions for the Wadeable Streams and National Lakes Assessments (USEPA 2006, 2009) to assure an adequate number of sites per subpopulation. For the 2011 NWCA, both regions and Wetland Groups were used to report the results (USEPA 2016b). For the 2016 NWCA, subpopulations for primary reporting and for further investigations were developed (**Table 5-1**, found on the pages following this chapter). We use and discuss several different subpopulation groups throughout the text in this Technical Support Document.

5.1 Literature Cited

Omernik JM (1987) Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77: 118-125

USEPA (2006) Wadeable Streams Assessment 2000-2004: A Collaborative Survey of the Nation's Streams. EPA-841-B-06-002. US Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC

USEPA (2009) National Lakes Assessment 2007: A Collaborative Survey of the Nation's Lakes. EPA-841-R-09-001. US Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC

USEPA (2011a) Level III Ecoregions of the Continental United States (revision of Omernik, 1987). US Environmental Protection Agency, National Health and Environmental Effects Laboratory-Western Ecology Division, Corvallis, OR

USEPA (2016b) National Wetland Condition Assessment 2011: A Collaborative Survey of the Nation's Wetlands. US Environmental Protection Agency, Washington DC. EPA-843-R-15-005.

Table 5-1. Subpopulation information, including the parameter name that is used in the database, all the potential subpopulations included in each subpopulation group, and a description of each subpopulation group.

Subpopulation Group	Parameter Name	Subpopulations	Description
Three Aggregated Ecoregions	AG_ECO3	EHIGH | PLNLOW | WMTNS	Codes for the aggregation of the Omernik Level III Ecoregions into three regions (using 2015 boundaries); Eastern Highlands (EHIGH), Plains and Lowlands (PLNLOW), Western Mountains (WMTNS).
Nine Aggregated Ecoregions	AG_ECO9	CPL | NAP | NPL | SAP | SPL | TPL | UMW | WMT | XER	Codes for the aggregation of the Omernik Level III Ecoregions into nine regions (using 2015 boundaries); Coastal Plains (CPL), Northern Appalachians (NAP), Northern Plains (NPL), Southern Appalachians (SAP), Southern Plains (SPL), Temperate Plains (TPL), Upper Midwest (UMW), Western Mountains (WMT), and Xeric West (XER). For a visual, see the AG_ECO9 tab in this workbook.
USFWS S&T Coastal Regions	COAST_REG	Great Lakes Region | Gulf Coast Region | North East Coast Region | Not Coast | Pacific Coast Region | South East Coast Region	US Fish and Wildlife Service Status and Trends Coastal Regions, including Great Lakes Region, Gulf Coast Region, North East Coast Region, Pacific Coast Region, and South East Coast Region. Sites that are not in a coastal region are designated 'Not Coast'.
EPA Regions	EPA_REG	Region_01 | Region_02 | Region_03 | Region_04 | Region_05 | Region_06 | Region_07 | Region_08 | Region_09 | Region_10	EPA Regions, responsible for the execution of programs within several states and territories: Region 1 serving CT, ME, MA, NH, RI, and VT, Region 2 serving NJ, NY, Puerto Rico, and the US Virgin Islands, Region 3 serving DE, DC, MD, PA, VA, WV and 7 federally recognized tribes, Region 4 serving AL, FL, GA, KY, MS, NC, SC, and TN, Region 5 serving IL, IN, MI, MN, OH, and WI, Region 6 serving AR, LA, NM, OK, and TX, Region 7 serving IA, KS, MO, and NE, Region 8 serving CO, MT, ND, SD, UT, and WY, Region 9 serving AZ, CA, HI, NV, American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia, Guam, Marshall Islands, and Republic of Palau, and Region 10 serving AK, ID, OR, WA and 271 native tribes. For a visual, see the EPA_REGION tab in this workbook.
Federal Lands	FED_NONFED	FEDERAL | NON_FEDERAL	Using OWN_NARS, distinguishes Federal from Non-federal lands, with Federal land comprised of 'BLM', 'BOR', 'DOD', 'FWS', 'NOAA', 'NPS', 'Other Fed', and 'USFS'.
Inland versus Tidal	HYD_CLS	INLAND | TIDAL	Distinguishes tidal saline sites (HYD_CLS = TIDAL) from inland sites (HYD_CLS = INLAND) combining information from the Aggregated S&T Class (WETCLS_GRP). Specifically, EH + EW = TIDAL, and PRLH + PRLW = INLAND.
Major USGS Hydrologic Basins	MAJ_BAS_NM	Arkansas-White-Red Region | California Region | Great Basin Region | Great Lakes Region | Lower Colorado Region | Lower Mississippi Region | Mid-Atlantic Region | Missouri Region | New England Region | Ohio-Tennessee Region | Pacific Northwest Region | Rio Grande-Texas-Gulf Region | Souris-Red-Rainy Region | South-	Major US Geological Survey (USGS) hydrologic basins derived from NHD+ names, with NHD+ codes in parenthesis: Arkansas-White-Red Region, California Region, Great Basin Region, Great Lakes Region, Lower Colorado Region, Lower Mississippi Region, Mid-Atlantic Region, Missouri Region, New England Region, Ohio-Tennessee Region, Pacific Northwest Region, Rio Grande-Texas-Gulf Region, Souris-Red-Rainy Region, South-Atlantic Region, Upper Colorado Region, Upper Mississippi Region.

Subpopulation Group	Parameter Name	Subpopulations	Description
		Atlantic Region | Upper Colorado Region | Upper Mississippi Region	
Mississippi Basin	MISS_BASIN	MISSISSIPPI_BASIN | NOT_MISSISSIPPI_BASIN	Designates whether a site is in the Mississippi Basin, which includes USGS hydrologic basins (from MAJ_BAS_NM): Arkansas-White-Red Region, Lower Mississippi Region, Missouri Region, Ohio-Tennessee Region, Upper Mississippi Region.
USEPA National Estuary Program	NEP_NAT	NEP | Not_NEP	Designates whether a site is in a USEPA National Estuary Program (NEP) watershed. Does not include Chesapeake Bay.
Four NWCA Aggregated Ecoregions	NWCA_ECO4	CPL | EMU | IPL | W	Omernik Level III Ecoregions aggregated into Four NWCA Aggregated Ecoregions: Coastal Plains (CPL), Eastern Mountains & Upper Midwest (EMU), Interior Plains (IPL), and West (W). Note that inland and tidal saline sites are not distinguished. For a visual, see the NWCA_ECO4 tab in this workbook.
Five NWCA Aggregated Ecoregions	NWCA_ECO5	CPL | EMU | IPL | WMT | XER	Omernik Level III Ecoregions aggregated into Five NWCA Aggregated Ecoregions: Coastal Plains (CPL), Eastern Mountains & Upper Midwest (EMU), Interior Plains (IPL), Western Valleys & Mountains (WMT), and Xeric West (XER). Note that inland and tidal saline sites are not distinguished. For a visual, see the NWCA_ECO5 tab in this workbook.
Four NWCA Aggregated Ecoregions x Inland versus Tidal	NWCA_ECO4_HYD	CPL-INLAND | CPL-TIDAL | EMU-INLAND | EMU-TIDAL | IPL-INLAND | W-INLAND | W-TIDAL	Omernik Level III Ecoregions aggregated into Four NWCA Aggregated Ecoregions (NWCA_ECO4) and distinguished by inland sites (HYD_CLS = INLAND) or tidal saline sites (HYD_CLS = TIDAL): Coastal Plains Inland (CPL-INLAND), Coastal Plains Tidal (CPL-TIDAL), Eastern Mountains & Upper Midwest Inland (EMU-INLAND), Eastern Mountains & Upper Midwest Tidal (EMU-TIDAL) , Interior Plains Inland (IPL-INLAND), West Inland (W-INLAND), West Tidal (W-TIDAL). Note that there are no Interior Plains Tidal sites, thus there is no IPL-TIDAL subpopulation.
Five NWCA Aggregated Ecoregions x Inland versus Tidal	NWCA_ECO5_HYD	CPL-INLAND | CPL-TIDAL | EMU-INLAND | EMU-TIDAL | IPL-INLAND | WMT-INLAND | WMT-TIDAL | XER-INLAND | XER-TIDAL	Omernik Level III Ecoregions aggregated into Five NWCA Aggregated Ecoregions (NWCA_ECO5) and distinguished by inland sites (HYD_CLS = INLAND) or tidal saline sites (HYD_CLS = TIDAL): Coastal Plains Inland (CPL-INLAND), Coastal Plains Tidal (CPL-TIDAL), Eastern Mountains & Upper Midwest Inland (EMU-INLAND), Eastern Mountains & Upper Midwest Tidal (EMU-TIDAL) , Interior Plains Inland (IPL-INLAND), Western Valleys & Mountains Inland (WMT-INLAND), Western Valleys & Mountains Tidal (WMT-TIDAL), Xeric West Inland (XER-INLAND), and Xeric West Tidal (XER-TIDAL). Note that there are no Interior Plains Tidal sites, thus there is no IPL-TIDAL subpopulation.
Land Ownership	OWN_NARS	BLM | BOR | City | County | DOD | FWS | NGO | NOAA | Non-Federal | NPS | Other Fed | Regional | State | Tribal | USFS	Designates land ownership: Bureau of Land Management (BLM), Bureau of Reclamation (BOR), City, County, Department of Defense (DOD), Fish and Wildlife Survey (FWS), Non Governmental Organizations (NGO), National Oceanic and Atmospheric Administration (NOAA), National Park Service (NPS), other federal (Other Fed), Regional, State, Tribal, and US Forest Service (USFS) lands. Non Federal lands are designated 'Non-Federal'.
States	PSTL_CODE	AL | AR | AZ | CA | CO | CT | DE | FL | GA |IA | ID | IL | IN | KS | KY |	US State: Alabama (AL), Arizona (AZ), Arkansas (AR), California (CA), Colorado (CO), Connecticut (CT), Delaware (DE), Florida (FL), Georgia (GA), Idaho (ID),

Subpopulation Group	Parameter Name	Subpopulations	Description
		LA | MA | MD | ME | MI | MN | MO | MS | MT | NC | ND | NE | NH | NJ | NM | NV | NY | OH | OK | OR | PA | RI | SC | SD | TN | TX | UT | VA | VT | WA | WI | WV | WY	Illinois (IL), Indiana (IN), Iowa (IA), Kansas (KS), Kentucky (KY), Louisiana (LA), Maine (ME), Maryland (MD), Massachusetts (MA), Michigan (MI), Minnesota (MN), Mississippi (MS), Missouri (MO), Montana (MT), Nebraska (NE), Nevada (NV), New Hampshire (NH), New Jersey (NJ), New Mexico (NM), New York (NY), North Carolina (NC), North Dakota (ND), Ohio (OH), Oklahoma (OK), Oregon (OR), Pennsylvania (PA), Rhode Island (RI), South Carolina (SC), South Dakota (SD), Tennessee (TN), Texas (TX), Utah (UT), Vermont (VT), Virginia (VA), Washington (WA), West Virginia (WV), Wisconsin (WI), Wyoming (WY)
Ten NWCA Reporting Groups	RPTGRP_10	ALL-EH | ALL-EW | CPL-PRLH | CPL-PRLW | EMU-PRLH | EMU-PRLW | IPL-PRLH | IPL-PRLW | W-PRLH | W-PRLW	Ten NWCA Reporting Groups used for the NWCA analysis that combines Four NWCA Aggregated Ecoregions (NWCA_ECO4) and Aggregated S&T Classes (NWCA_WET_GRP): All Estuarine Herbaceous (ALL-EH), All Estuarine Woody (ALL-EW), Coastal Plains Palustrine, Riverine, and Lacustrine Herbaceous (CPL-PRLH), Coastal Plains Palustrine, Riverine, and Lacustrine Woody (CPL-PRLW), Eastern Mountains & Upper Midwest Palustrine, Riverine, and Lacustrine Herbaceous (EMU-PRLH), Eastern Mountains & Upper Midwest Palustrine, Riverine, and Lacustrine Woody (EMU-PRLW), Interior Plains Palustrine, Riverine, and Lacustrine Herbaceous (IPL-PRLH), Interior Plains Palustrine, Riverine, and Lacustrine Woody (IPL-PRLW), West Palustrine, Riverine, and Lacustrine Herbaceous (W-PRLH), West Palustrine, Riverine, and Lacustrine Woody (W-PRLW). Note that estuarine sites (ALL-EH and ALL-EW) are combined for the contiguous US.
Twelve NWCA Reporting Groups	RPTGRP_12	ALL-EH | ALL-EW | CPL-PRLH | CPL-PRLW | EMU-PRLH | EMU-PRLW | IPL-PRLH | IPL-PRLW | WMT-PRLH | WMT-PRLW | XER-PRLH | XER-PRLW	Twelve NWCA Reporting Groups used for the NWCA analysis that combines Five NWCA Aggregated Ecoregions (NWCA_ECO5) and Aggregated S&T Classes (NWCA_WET_GRP): All Estuarine Herbaceous (ALL-EH), All Estuarine Woody (ALL-EW), Coastal Plains Palustrine, Riverine, and Lacustrine Herbaceous (CPL-PRLH), Coastal Plains Palustrine, Riverine, and Lacustrine Woody (CPL-PRLW), Eastern Mountains & Upper Midwest Palustrine, Riverine, and Lacustrine Herbaceous (EMU-PRLH), Eastern Mountains & Upper Midwest Palustrine, Riverine, and Lacustrine Woody (EMU-PRLW), Interior Plains Palustrine, Riverine, and Lacustrine Herbaceous (IPL-PRLH), Interior Plains Palustrine, Riverine, and Lacustrine Woody (IPL-PRLW), Western Valleys & Mountains Palustrine, Riverine, and Lacustrine Herbaceous (WMT-PRLH), Western Valleys & Mountains Palustrine, Riverine, and Lacustrine Woody (WMT-PRLW), Xeric West Palustrine, Riverine, and Lacustrine Herbaceous (XER-PRLH), Xeric West Palustrine, Riverine, and Lacustrine Woody (XER-PRLW). Note that estuarine sites (ALL-EH and ALL-EW) are combined for the contiguous US.
Ten Reporting Units	RPT_UNIT	ARW | ATL | GFC | GPL | ICP | NCE | PAC | SAP | TPL | WVM	Ten Reporting Units created using a combination of information from AG_ECO9 and WETCLS_GRP to distinguish regions of inland sites from regions of tidal saline sites: Atlantic Coast (ATL), Arid West (ARW), Gulf & Florida Coasts (GFC), Great Plains (GPL), Inland Coastal Plains (ICP), North Central East (NCE), Pacific Coast (PAC), Southern Appalachians (SAP), Temperate Plains (TPL), and Western Valleys & Mountains (WVM). Note that the inland region names have been changed to

Subpopulation Group	Parameter Name	Subpopulations	Description
			distinguish regions with similar boundaries but combine inland and tidal saline site (e.g., CPL from NWCA_ECO4 and NWCA_ECO5 includes ATL, IPL, and GPL sites from RPT_UNIT). For a visual, see the RPT_UNIT tab in this workbook. The DATA CROSSWALK tab in this workbook explains how the units were derived (and how they refer to other parameters).
Five Reporting Units	RPT_UNIT_5	EMU | ICP | PLN | TDL | WST	Five Reporting Units for reporting that uses tidal saline wetlands as a distinct region from the Four Aggregated NWCA Ecoregions (NWCA_ECO4), and created by collapsing the Ten Reporting Units (RPT_UNIT): Eastern Mountains & Upper Midwest (EMU = NCE + SAP), Inland Coastal Plains (ICP), Plains (PLN = GPL + TPL), Tidal Saline (TDL = ATL + GFC + PAC), West (WST = ARW + WVM).
Six Reporting Units	RPT_UNIT_6	ARW | EMU | ICP | PLN | TDL | WVM	Six Reporting Units for reporting that uses tidal saline wetlands as a distinct region from the Five Aggregated NWCA Ecoregions (NWCA_ECO5), and created by collapsing the Ten Reporting Units (RPT_UNIT): Arid West (ARW), Eastern Mountains & Upper Midwest (EMU = NCE + SAP), Inland Coastal Plains (ICP), Plains (PLN = GPL + TPL), Tidal Saline (TDL = ATL + GFC + PAC), Western Valleys & Mountains (WVM).
12-Ecoregion x Wetland Group Reporting Units	RPT_UNIT12	ARW-H | ARW-W | EMU-H | EMU-W | ICP-H | ICP-W | PLN-H | PLN-W | TDL-H | TDL-W | WVM-H | WVM-W	Twelve reporting units derived from the combination of Six Reporting Units (RPT_UNIT_6) and Wetland Groups (WETCLS_GRP): Arid West Herbaceous (ARW-H), Arid West Woody (ARW-W), Eastern Mountains & Upper Midwest Herbaceous (EMU-H), Eastern Mountains & Upper Midwest Woody (EMU-W), Inland Coastal Plains Herbaceous (ICP-H), Inland Coastal Plains Woody (ICP-W), Plains Herbaceous (PLN-H), Plains Woody (PLN-W), Tidal Saline Herbaceous (TDL-H), Tidal Saline Woody (TDL-W), Western Valleys & Mountains Herbaceous (WVM-H), Western Valleys & Mountains Woody (WVM-W).
Twenty Reporting Units	RPT_UNIT20	ARW-H | ARW-W | ATL-H | ATL-W | GFC-H | GFC-W | GPL-H | GPL-W | ICP-H | ICP-W | NCE-H | NCE-W | PAC-H | PAC-W | SAP-H | SAP-W | TPL-H | TPL-W | WVM-H | WVM-W	Twenty Reporting Units created using a combination of information from AG_ECO9 and WETCLS_GRP to distinguish regions of inland sites from regions of tidal saline sites, and WETCLS_GRP to distinguish herbaceous (H) from woody (W) dominated sites: Atlantic Coast Herbaceous (ATL-H), Atlantic Coast Woody (ATL-W), Arid West Herbaceous (ARW-H), Arid West Woody (ARW-W), Gulf & Florida Coasts Herbaceous (GFC-H), Gulf & Florida Coasts Woody (GFC-W), Great Plains Herbaceous (GPL-H), Great Plains Woody (GPL-W), Inland Coastal Plains Herbaceous (ICP-H), Inland Coastal Plains Woody (ICP-W), North Central East Herbaceous (NCE-H), North Central East Woody (NCE-W), Pacific Coast Herbaceous (PAC-H), Pacific Coast Woody (PAC-W), Southern Appalachians Herbaceous (SAP-H), Southern Appalachians Woody (SAP-W), Temperate Plains Herbaceous (TPL-H), Temperate Plains Woody (TPL-W), Western Valleys & Mountains Herbaceous (WVM-H), and Western Valleys & Mountains Woody (WVM-W). Note that the inland region names have been changed to distinguish regions with similar boundaries but combine inland and tidal saline site (e.g., CPL from NWCA_ECO4 and NWCA_ECO5 includes ATL, IPL, and GPL sites from RPT_UNIT). For a visual, see the RPT_UNIT tab in this workbook. The DATA

Subpopulation Group	Parameter Name	Subpopulations	Description
			CROSSWALK tab in this workbook explains how the units were derived (and how they refer to other parameters).
USFWS S&T Wetland Classes	WETCLS_EVAL	E2EM | E2SS | NONE | PEM | PF | PFO | PSS | PUBPAB	US Fish and Wildlife Service Status and Trends wetland class designated in the field on Form AA-2 on date of sampling. If evaluated in field but not sampled, then wetland class is assigned from field visit. If site only evaluated in office, then wetland class assigned at that time. If no site evaluation information on wetland class, then wetland class assigned wetland class used for the survey design. Hand-picked sites should be assigned during field sampling. Wetland classes use FWS S&T classes: Estuarine Intertidal Emergent (E2EM), Estuarine Intertidal Forest/Shrub (E2SS), Palustrine Emergent (PEM), Palustrine Farmed (PF), Palustrine Forested (PFO), Palustrine Shrub (PSS), and Palustrine Unconsolidated Bottom/Aquatic Bed (PUBPAB). See Reference Card AA-3, Side A in the 2011 and 2016 NWCA Field Operations Manuals for details. NONE only applies to non-sampled sites.
Wetland Groups	WETCLS_GRP	EH | EW | PRLH | PRLW	Aggregated US Fish and Wildlife Service Status and Trends wetland class based on the design that combines wetland type and dominant vegetation type for reporting: Estuarine Herbaceous (EH), Estuarine Woody (EW), Palustrine, Riverine, and Lacustrine Herbaceous (PRLH), and Palustrine, Riverine, and Lacustrine Woody (PRLW).
Hydrogeomorphically-Altered	WETCLS_ALT	HGM_ALTERED | HGM_NOT_ALTERED	Using WETCLS_HGM2, distinguishes HGM altered sites from not altered sites using QAed and validated values (HGM_CLASS_VALID and HGM_SUBCLASS_VALID in tblASSESSMENT) designated in the field on Form AA-2 on date of sampling. HGM_ALTERED includes 'DEPRESSION_ALT', 'FLATS_ALT', 'LACUSTRINE_ALT', 'RIVERINE_ALT', 'SLOPE_ALT', and 'TIDAL_ALT' while HGM_NOT_ALTERED includes 'DEPRESSION', 'FLATS', 'LACUSTRINE', 'RIVERINE', 'SLOPE', and 'TIDAL'.
Hydrogeomorphic Classes	WETCLS_HGM	DEPRESSION | FLATS | LACUSTRINE | RIVERINE | SLOPE | TIDAL	Hydrogeomorphic (HGM) class from QAed and validated values (HGM_CLASS_VALID in tblASSESSMENT) designated in the field on Form AA-2 on date of sampling, including depression (DEPRESSION), flats (FLATS), lacustrine fringe (LACUSTRINE), riverine (RIVERINE), slope (SLOPE), and tidal (TIDAL) wetland classes. See Reference Card AA-3, Side B in the 2011 and 2016 NWCA Field Operation Manuals for details.
Hydrogeomorphic Classes Distinguishing Natural versus Altered	WETCLS_HGM2	DEPRESSION | DEPRESSION_ALT | FLATS | FLATS_ALT | LACUSTRINE | LACUSTRINE_ALT | RIVERINE | RIVERINE_ALT | SLOPE | SLOPE_ALT | TIDAL | TIDAL_ALT	Hydrogeomorphic (HGM) classes, separated into natural and altered HGM subclasses from QAed and validated values (HGM_CLASS_VALID and HGM_SUBCLASS_VALID in tblASSESSMENT) designated in the field on Form AA-2 on date of sampling. Unaltered HGM classes include depression (DEPRESSION), flats (FLATS), lacustrine fringe (LACUSTRINE), riverine (RIVERINE), slope (SLOPE), and tidal (TIDAL). Altered HGM subclasses are indicated by an appended '_ALT' and include DEPRESSION_ALT (includes subclasses 'Closed, Human Impounded', 'Closed, Human Excavated', 'Closed, Human Excavated and Impounded', 'Open, Human Impounded', 'Open, Human Excavated', 'Open, Human Excavated and Impounded', FLATS_ALT (includes subclass 'Human Altered'), LACUSTRINE_ALT

Subpopulation Group	Parameter Name	Subpopulations	Description
			(includes subclass 'Artificially Flooded') , RIVERINE_ALT (includes subclass 'Human Altered'), SLOPE_ALT (includes subclass 'Human Altered'), and TIDAL_ALT (includes subclass 'Human Altered'). See Reference Card AA-3, Side B in the 2011 and 2016 NWCA Field Operations Manuals for details. Note that '_ALT' indicates the historic HGM class that should be at the site, denoting that it has been altered (e.g., a site that was historically FLATS but excavated into a depression would be designated as FLATS_ALT).

Chapter 6: Assigning Disturbance Class

Anthropogenic disturbances to wetlands vary in impacts and intensities across different regions of the United States (USEPA 2016a,b, Lomnicky et al. 2019). Following the practice of previous NARS assessments (e.g., USEPA 2006, 2008, 2009, 2016a), the NWCA uses a quantitative definition of disturbance using physical, chemical, and biological data collected at wetland sites sampled as part of the NWCA. These data reflect a continuous gradient of anthropogenic disturbance – ranging from no observable or measurable anthropogenic impacts to highly altered wetland sites. Wetland sites that fall along this continuous ***disturbance gradient*** are assigned to one of three disturbance classes: "least disturbed", "intermediate disturbed", or "most disturbed" (**Figure 6-1**, USEPA 2016a). Thus, ***thresholds*** that delineate the boundaries of each disturbance class must be set.

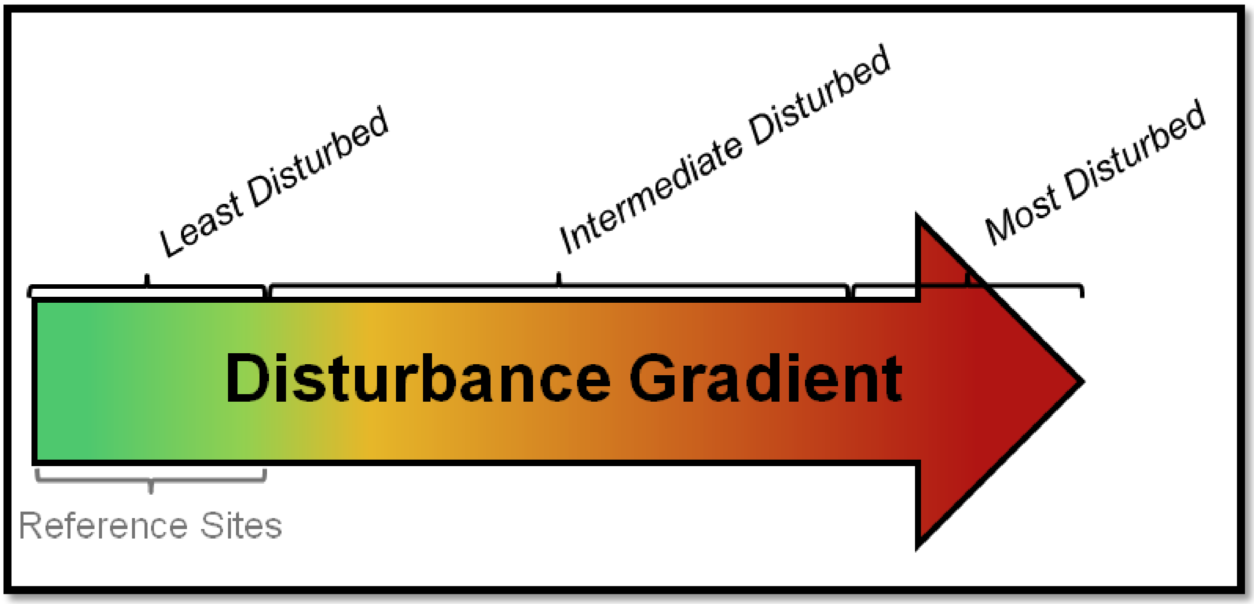

Figure 6-1. Diagram of the disturbance gradient used in the NWCA with three classes of disturbance.

Because pristine conditions are uncommon or absent in most places, the NWCA uses the characteristics found in least-disturbed sites as "reference". ***Least-disturbed*** sites are those with the best available physical, chemical, and biological condition given the current status of the landscape in which the site is located (Stoddard et al. 2006). Least-disturbed status for the NWCA is defined using a set of explicit quantitative criteria for specific disturbance indicators. It is expected that these least-disturbed sites will represent good ecological condition (Karr 1991, Dale and Beyeler 2001, Stoddard et al. 2006, 2008), although this may not always be the case given that "least disturbed" in some areas of the country still has considerable disturbance.

The planning for the NWCA assumes:

- The survey design provides a representative sample of the target population;
- Least-disturbed sites reflect the functional capacity and delivery of services typical of a given wetland type in a particular landscape setting (e.g., ecoregion, watershed); and,
- Thresholds developed from data collected on-site and used to define disturbance classes provide benchmarks against which to compare assessment results.

Least- and most-disturbed sites are needed in the development of condition indicators – both for the evaluation of candidate metrics (**Chapter 8:**) that may reflect ecological condition and for the development of Vegetation Multimetric Indices (VMMIs) (**Chapter 9:**). Specifically, least-disturbed sites are used in setting thresholds for good, fair, and poor condition based on VMMI values (Magee et al. 2019a, Herlihy et al. 2019).

This chapter documents the complex process for 1) developing quantitative definitions of site-level anthropogenic disturbance based on physical, chemical, and biological data, 2) establishing least- and most-disturbed thresholds, and 3) assigning sampled sites to least-, intermediate-, and most-disturbed classes. The process for calculating indices and metrics and for assigning disturbance class is summarized in *An Illustrative Guide to Assigning Disturbance Class in Six Steps* found in **Section 6.9, Appendix A**.

6.1 Sites Used to Establish the Disturbance Gradient

Data from a total of 1,987 unique probability and handpicked sites across both the 2011 NWCA *and* the 2016 NWCA (**Table 6-1**) were used in a screening process to establish a disturbance gradient. The sampling events at these 1,987 ***unique sites*** are referred to as ***Index Visits***, as they include only the first sampling visit (i.e., Visit 1) and only the 2016 site data (i.e., not the 2011 site data) if a site from 2011 was also sampled in 2016. In other words, if the same site was sampled in both 2011 and 2016, the most recent Visit 1 was used as the Index Visit. For the 208 ***resampled*** sites, we chose to use the 2016 data over the 2011 data because of improvements in the field protocols for collecting disturbance information, and because using data associated with the most recent survey is standard across other NARS. The probability sites were either from the NWCA design or a related probability design produced by NARS for a state intensification (**Chapter 2:**). The handpicked sites included those identified for and sampled in the 2016 survey (**Chapter 3:**) and the handpicked sites sampled in the 2011 survey (USEPA 2016a).

Table 6-1. The number of Visit 1 (V1) probability and handpicked sites sampled in 2011 and 2016, with their totals. Additionally, the numbers of resampled sites are reported in paratheses to indicate that these are subtracted from the subtotals above. The total number of unique probability and handpicked sites are reported with the final number of Index Visit sites (in the red cell) used in the establishment of the NWCA disturbance gradient. Note that this table does not include the 96 Visit 2 sites sampled in 2011 and 94 Visit 2 sites sampled in 2016, which are only used to calculate Signal-to-Noise ratios for some indicators/metrics (see **Chapter 8:** for details).

SURVEY YEAR	V1 PROBABILITY (n-sites)	HANDPICKED (n-sites)	TOTAL
2011 NWCA	967	171	**1138**
2016 NWCA	967	90	**1057**
SUBTOTAL	**1934**	**261**	**2195**
2011 Sites Resampled in 2016	(207)	(1)	**(208)**
TOTAL UNIQUE SITES	**1727**	**260**	**1987**

6.2 Establishing a Disturbance Gradient

The general steps in the process of establishing a disturbance gradient are:

- Develop indices or metrics that reflect anthropogenic disturbance,
- Set thresholds for "least disturbed" for each index or metric,
- Set thresholds for "most disturbed" for each index or metric, and
- Use a screening process to define each site as "least", "intermediate", or "most disturbed" (Herlihy et al. 2008, 2019).

To develop the disturbance gradient for the 2016 NWCA, a stepwise process was used in which sites were first screened using physical indices, then by chemical indices, and finally through a biological metric. Methods for calculating the indices and metrics used in screening are explicitly discussed in **Chapter 11:** and **Chapter 12:**. The general process for setting thresholds and assigning disturbance classes are described in the following sections.

6.2.1 *Indices and Metrics*

Physical, chemical, and biological data collected in the field and laboratory were evaluated for use in screening sites to establish the disturbance gradient. Indices and ***metrics*** were chosen based on evidence of a strong association with anthropogenic stress and on the robustness of the data. The indices and metrics used in the 2016 NWCA are described in **Table 6-2**.

Table 6-2. Indices and metrics used in the 2016 NWCA to establish the disturbance gradient. Final indices and metrics for which thresholds were created are in uppercase, bold type.

Screen Type	Data Type	Indices and Metrics		Reference
Physical	Human-Mediated Physical Alterations	• Vegetation Removal (PALT_VEGRMV) • Vegetation Replacement (PALT_VEGREP) • Water Addition/Subtraction (PALT_WADSUB) • Water Obstruction (PALT_WOBSTR) • Soil Hardening (PALT_SOHARD) • Surface Modification (PALT_SOMODF)	• **PALT_ANY** • **PALT_SUM**	Chapter 11
Chemical	Soil Chemistry	• Enrichment Factor (EF)	• **EF_MAX**	Chapter 12
		• Heavy Metal Index (**HMI**)		
Biological	Vegetation	• Relative Percent Cover of Nonnative (alien and cryptogenic) Plant Species (**XRCOV_AC**)		Section 6.6

Physical and chemical indices were used to define least- and most-disturbed sites based primarily on abiotic characteristics under the variable name REF_NWCA_ABIOTIC. The biological metric was used to further screen the least-disturbed sites designated in REF_NWCA_ABIOTIC, resulting in some of these sites being rejected from least-disturbed status. The resulting final disturbance class designations are found under the variable name REF_NWCA.

Although water chemistry is a part of the NWCA field protocol, only 56% and 65% of the wetlands in 2011 and 2016, respectively, sampled across both Visit 1 and Visit 2 had sufficient surface water to collect and analyze. In addition, wetland hydroperiod– especially during the growing season when NWCA sampling occurred – can greatly influence water chemistry (e.g., nutrients can become highly concentrated during drawdowns) and introduce bias into the types of wetlands sampled for water chemistry (see Kentula et al. 2020). Thus, water chemistry was excluded from the generation of the disturbance gradient. However, the water chemistry analyses, including how disturbance classes were assigned to just the wetland sites sampled for water chemistry, are presented in a stand-alone chapter of this report (**Chapter 13:**).

Additionally, while we were able to gather landscape data (e.g., land use within a 1-km buffer of the AA) using GIS layers, we opted not to use these data to screen sites for the disturbance gradient. This was for two reasons: 1) the GIS layers are less precise than the data we were able to gather in the field, and 2) it is possible that wetlands in good condition exist in what is considered an "impacted" landscape. Therefore, we used only information directly measured by Field Crews on the ground to establish the disturbance gradient.

6.2.2 *Setting Least-Disturbed Thresholds*

For each of the indices and metrics in **Table 6-2**, a least-disturbed threshold was set. Physical and chemical thresholds were set independently by the subpopulation group Five Reporting Units (RPT_UNIT_5), as the extent of human disturbance can vary greatly among regions. Following the definition of least-disturbed as the best-available sites (Stoddard et al. 2006), thresholds for "least disturbed" in ubiquitously impacted regions may be greater than those for "intermediate disturbed" or even "most disturbed" in regions that have greater amounts of intact area. Initially, physical and chemical thresholds were set to zero human disturbance in all regions. However, if a subpopulation (i.e., region) did not have a sufficient number of least-disturbed sites with these stringent thresholds, the thresholds were relaxed so that approximately 15-25% of the sites in the subpopulation passed the screens to obtain a sufficient number of least-disturbed sites for data analysis. The set of least-disturbed sites identified using the physical and chemical screens were further screened using a biological metric, and any sites that exceeded 10% relative cover of nonnative plants were rejected from least-disturbed status.

6.2.3 *Setting Most-Disturbed Thresholds*

Most-disturbed sites were defined using a screening process in the same manner as for least-disturbed sites. The same physical and chemical measures of disturbance were used, and thresholds for most disturbed were set for each measure. If any single threshold for any measure was exceeded, the site was considered a most-disturbed site. As "most disturbed" is a relative definition, our objective was to define approximately 20-30% of the sites in a subpopulation as "most disturbed", and thresholds were set accordingly.

6.2.4 *Classifying Disturbance at Each Site for each Sampling Visit*

Finally, disturbance status was assigned to each site for each of its sampling visits (i.e., Visit 1, Visit 2, and both 2011 and 2016 visits for resampled sites). Disturbance status was assigned by screening each site visit to test for exceedance of least- and most-disturbed thresholds. Sites were first screened using the physical and chemical indices and metrics. If a site exceeded the most-disturbed thresholds, it was considered most-disturbed. If any single physical or chemical threshold was exceeded at a site, it was not considered "least-disturbed". Sites identified as least-disturbed based on this screen were further screened using the biological metric. Thus, the final set of least-disturbed sites were those that were below the thresholds for all physical, chemical, and biological measures. Sites not falling into either least- or most-disturbed categories were classified as having intermediate disturbance.

The following sections provide details about the data used to develop thresholds for each index or metric in **Table 6-2** and the thresholds used for defining least- and most-disturbed sites.

6.3 Human-Mediated Physical Alteration Screens and Thresholds

Human-Mediated Physical Alteration scores were calculated for each site using methods described in **Chapter 11:** and summarized in **Section 6.9, Appendix A: Steps 1 and 2**. Thresholds were developed for Five Reporting Units (RPT_UNIT_5, see **Table 5-1** in **Chapter 5:**), which include the subpopulations Tidal Saline (TDL), Inland Coastal Plains (ICP), Eastern Mountains & Upper Midwest (EMU), Plains (PLN), and West (WST). Two screens that integrate scores from all six physical alteration indices (VEGRMV, VEGRPL, WADSUB, WOBSTR, SOHARD, and SOMODF, see **Table 6-2**) were applied to each site using the thresholds described in **Table 6-3**:

- PALT_ANY – For any given site, the PALT_ANY screen for "least disturbed" was applied by considering each of the six physical alteration indices individually. If the score **for any one index** (i.e., the maximum score among all six indices) was greater than a threshold, the site was no longer considered "least disturbed". The threshold varies by subpopulation, ranging from 0 to ≤ 20, meaning that a least-disturbed site may have (up to) a few observed physical alterations in the buffer plots, but no observations of physical alterations in the AA (see **Chapter 11**:, **Figure 11-2**).

- PALT_SUM – The PALT_SUM screen for "least disturbed" was developed to capture instances where there were multiple observed physical alterations at a site, but those observances were spread across multiple indices and, therefore, may have passed the PALT_ANY screen despite moderate to high levels of overall disturbance. For any given site, the PALT_SUM screen was applied by considering the sum of the scores from all six physical alteration indices. If **the sum of scores** for all six indices was greater than a threshold, the site was no longer considered "least disturbed". Like PALT_ANY, the threshold varies by subpopulation, ranging from 0 to ≤ 40, meaning that there were no or few observations of physical alterations regardless of index in the AA or buffer.

Sites may pass the PALT_ANY screen and fail the PALT_SUM screen if there are several observations in buffer plots within different physical alteration categories. Sites ultimately classified as "least disturbed" had to pass both the PALT_ANY and the PALT_SUM screens (in addition to other chemical and biological screens described in the following sections of this Technical Support Document). The least-disturbed thresholds and the number of sites that passed the physical alteration screens (and were considered candidate least-disturbed sites) are presented in **Table 6-3a**.

Table 6-3. a) Least-disturbed thresholds and b) most-disturbed thresholds for the two physical alteration screens and the number of sites that passed the screens (i.e., are considered candidate "least disturbed" or "most disturbed") presented for Five Reporting Units (RPT_UNIT_5).

a) Physical Screens for Least-Disturbed Sites	Tidal Saline (TDL)	Inland Coastal Plains (ICP)	Eastern Mountains & Upper Midwest (EMU)	Plains (PLN)	West (WST)
PALT_ANY	0	0	0	10	20
PALT_SUM	0	0	0	10	40
n-sites	200	100	117	100	83

b) Physical Screens for Most-Disturbed Sites	Tidal Saline (TDL)	Inland Coastal Plains (ICP)	Eastern Mountains & Upper Midwest (EMU)	Plains (PLN)	West (WST)
PALT_ANY	30	50	40	50	70
PALT_SUM	60	100	80	100	140
n-sites	87	95	61	84	87

The most-disturbed sites on the disturbance gradient were defined using a screening process in the same manner as for least-disturbed sites. Thresholds for "most disturbed" were set for PALT_ANY and PALT_SUM. If any single threshold for any measure was exceeded, the site was considered a most-disturbed site. As "most disturbed" is a relative definition, our objective was to classify approximately 20-30% of the sites in a subpopulation as "most disturbed", and thresholds were set accordingly. The most-disturbed thresholds and the number of sites considered candidate "most disturbed" are presented in Table 6-3b.

Sites that did not meet "least disturbed" or "most disturbed" threshold criteria were classified as "intermediate disturbed".

For some sites, data were not collected at all on the H-1 Form and/or B-1 Form, or an insufficient number of buffer plots (<5) were sampled. In these cases, the sites could not be evaluated using the physical screens (i.e., PALT_ANY and PALT_SUM) and were categorized as "unknown" (coded as "?") for their physical screen disturbance class.

6.4 Chemical Screens and Thresholds

Two chemical screens were used as the second set of screens (with the first set being the physical screens discussed in the previous section) to assign ***abiotic disturbance class*** (REF_NWCA_ABIOTIC) to each site. These screens are 1) the Heavy Metal Index (HMI) and 2) the Maximum Enrichment Factor (EF_MAX), the calculations for which are detailed in **Chapter 12:** and summarized in **Section 6.9, Appendix A: Steps 3 - 5**. In brief, the Enrichment Factor (EF) is calculated for each of 12 heavy metals at each site to capture the degree to which soils are enriched. Using the EF information, the HMI is calculated, which indicates the number of heavy metals with moderate enrichment or greater (EF ≥ 3). Finally, the EF_MAX is calculated, indicating the highest degree to which a site was contaminated by any of the 12 heavy metals.

Sites ultimately assigned as abiotic "least disturbed" had to pass the PALT_ANY and the PALT_SUM screens *and* the HMI and EF_MAX screens. National thresholds for "least disturbed" were used for both the HMI and EF_MAX and were:

- HMI ≤ 1
- EF_MAX < 5

In other words, regardless of the region in which a site was located, for a site to be considered "least disturbed", only one heavy metal EF could be equal to or above three, *and* the EF of any heavy metal had to be less than five. Although national thresholds were used for the HMI and EF_MAX screens, region-specific heavy metal background concentrations were used in the EF calculation (specifically, as the denominator) (see **Chapter 12:** and **Section 6.9, Appendix A: Step 4** for details). The chemical screen thresholds for "least disturbed" and the number of sites that passed the chemical screens (i.e., were considered abiotic "least disturbed" (REF_NWCA_ABIOTIC)) are presented in **Table 6-4a**.

Table 6-4. a) Least-disturbed thresholds and b) most-disturbed thresholds for the two chemical screens and the number of sites that passed the screens (i.e., are considered abiotic "least disturbed" or "most disturbed") presented for Five Reporting Units (RPT_UNIT_5).

a) Chemical Screens for Least-Disturbed Sites	Tidal Saline (TDL)	Inland Coastal Plains (ICP)	Eastern Mountains & Upper Midwest (EMU)	Plains (PLN)	West (WST)
HMI	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
EF_MAX	< 5	< 5	< 5	< 5	< 5
n-sites	180	96	105	98	68

b) Chemical Screens for Most-Disturbed Sites	Tidal Saline (TDL)	Inland Coastal Plains (ICP)	Eastern Mountains & Upper Midwest (EMU)	Plains (PLN)	West (WST)
HMI	> 1	> 1	> 1	> 1	> 1
EF_MAX	> 10	> 10	> 10	> 10	> 10
n-sites	109	105	72	88	101

The most-disturbed sites on the disturbance gradient were defined using a screening process in the same manner as for least-disturbed sites. National thresholds for most disturbed were set for the HMI and EF_MAX and were:

- HMI > 1
- EF_MAX > 10

If any threshold of either chemical screen (i.e., HMI or EF_MAX) was exceeded, the site was considered "most-disturbed". In other words, regardless of the region in which a site was located, any more than one heavy metal EF equal to or above three *or* an EF of any heavy metal greater than five resulted in a site regarded as "most disturbed". As "most disturbed" is a relative definition, our objective was to define approximately 20-30% of the sites in a subpopulation as most disturbed, and thresholds were set accordingly. In particular, the EF_MAX was set above ten to equate a level of severe enrichment with a most-disturbed site. The most-disturbed thresholds and the number of sites considered "abiotic most disturbed" are presented in **Table 6-4b**.

It is important to note that the thresholds established for heavy metals do not reflect toxicity thresholds. These thresholds are indicators of human disturbance.

For some sites, soil chemistry samples were not collected. In these cases, the sites could not be evaluated using the chemical screens (i.e., HMI and EF_MAX) and were categorized as "unknown" for their chemical screen disturbance class.

6.5 Abiotic Disturbance Class Assignments

Physical and chemical screens were combined to assign sites to abiotic disturbance classes of "least disturbed", "intermediate disturbed", "most disturbed", and "unknown", coded in the data as REF_NWCA_ABIOTIC. In general, the highest disturbance class between the physical and chemical screens is used to assign the abiotic disturbance class. If physical alteration data were missing from a site, the abiotic disturbance class was assigned as "unknown". If soil chemistry data were missing from a site, the abiotic disturbance class was set to that of the physical screen disturbance class[3]. The application of rules used to assign abiotic disturbance classes is illustrated in **Figure 6-2**.

For any single site:

Physical Screen Disturbance Class	Chemical Screen Disturbance Class		Abiotic Disturbance Class
L	L		L
L	I		I
L	M		M
L	?		L
I	L		I
I	I		I
I	M	➡	M
I	?		I
M	L		M
M	I		M
M	M		M
M	?		M
?	L		?
?	I		?
?	M		?
?	?		?

Figure 6-2. A visual summary of how rules for assigning abiotic disturbance classes based on the physical and chemical screens are applied to a site, where L = "least disturbed", I = "intermediate disturbed", M = "most disturbed", and ? = "unknown". Note that the physical and chemical screens were evaluated together to determine the abiotic disturbance class assignment for a site.

A summary of the number of sites within each abiotic disturbance class are reported by region (RPT_UNIT_5) in **Table 6-5**.

[3] The decision to use the physical screen disturbance level instead of assigning "unknown" when soil chemistry data were missing from a site was based on the low prevalence of sites with "intermediate disturbance" or "high disturbance" assignments based on the chemical screens alone.

Table 6-5. n-sites of abiotic disturbance class assignments (REF_NWCA_ABIOTIC) reported by region (RPT_UNIT_5) for Visit 1, Index Visit 2011 and 2016 sites

Region	Least Disturbed (L)	Intermediate Disturbed (I)	Most Disturbed (M)	Unknown (?)	Regional Totals
Tidal Saline (TDL)	180	170	109	3	**462**
Inland Coastal Plains (ICP)	96	207	105	4	**412**
E. Mts & Upper Midwest (EMU)	105	172	72	1	**350**
Plains (PLN)	98	163	88	2	**351**
West (WST)	68	242	101	1	**412**
National Totals	**547**	**954**	**475**	**11**	**1987**

6.6 Biological Screen and Threshold

Many sites designated as "least disturbed" using the physical and chemical screens had high relative cover of nonnative plants, and such sites do not reflect natural vegetation conditions (Sala et al. 1996, Lesica 1997, Vitousek et al. 1997, Ehrenfeld 2003, Dukes and Mooney 2004, Magee et al. 2010, 2019b). Consequently, the set of abiotic least-disturbed sites (REF_NWCA_ABIOTIC == L) were screened with a biological screen, resulting in a new set of final least-disturbed sites.

The biological screen was comprised of a single metric – the relative percent cover of nonnative (alien and cryptogenic) plants species (XRCOV_AC), summarized in **Section 6.9, Appendix A: Step 6**. Relative percent cover of nonnative plant species (XRCOV_AC) is calculated as the relative cover of alien and cryptogenic species across the five sampled 100-m^2 vegetation plots[4] as a percentage of total plant cover, or:

$$\text{XRCOV\_AC} = \left(\sum \frac{\text{cover of all alien + cryptogenic taxa across 5 plots}}{\text{cover of all individual taxa across 5 plots}} \right) * 100$$

The final set of least-disturbed sites for the NWCA (see the REF_NWCA variable) had to pass the PALT_ANY, PALT_SUM, HMI, and EF_MAX least-disturbed screens *and* the XRCOV_AC least-disturbed screen. The national threshold used for "least disturbed" was:

- XRCOV_AC < 10%

In other words, regardless of region, for a site to be considered "least disturbed", nonnative plants had to make up less than 10% of the total vegetation cover. The biological screen threshold and the number of sites that passed this screen (i.e., assigned "least-disturbed" status) are presented in **Table 6-6**.

[4] Data describing the abundance (percent cover) of all vascular species were collected in five 100-m2 vegetation plots systematically distributed within each NWCA Assessment Area according to the Vegetation Protocol (USEPA 2011b, USEPA 2016c). Data collection methods are summarized in **Section 7.3**. In addition, each individual plant taxon-state pair identified in NWCA 2011 and 2016 was assigned to a native status category: native, introduced, adventive, cryptogenic, or unknown (see **Chapter 7:, Section 7.8** and **Table 7-5**).

Table 6-6. The least-disturbed threshold for the biological screen, and the number of sites passing the screen (and thus, are assigned final "least-disturbed" status as indicated in REF_NWCA) for the Five Reporting Units (RPT_UNIT_5).

Biological Screen for Least-Disturbed Sites	Tidal Saline (TDL)	Inland Coastal Plains (ICP)	Eastern Mountains & Upper Midwest (EMU)	Plains (PLN)	West (WST)
XRCOV_AC	< 10%	< 10%	< 10%	< 10%	< 10%
n-sites	149	86	101	53	50

Contrary to the methods used for physical and chemical disturbance gradient screens, the biological screen was *not* used to designate most-disturbed sites. Instead, abiotic least-disturbed sites (based on the physical and chemical screens) that were rejected using the biological screen were reassigned as intermediate-disturbed sites. Thus, the set of least- and intermediate-disturbed sites are different for REF_NWCA_ABIOTIC and REF_NWCA. However, the set of most-disturbed sites are the same.

6.7 Final Disturbance Class Assignments

The *final disturbance class* site assignments, which include "least disturbed", "intermediate disturbed", and "most disturbed", are recorded as the variable, REF_NWCA, and was used for evaluation of vegetation candidate metrics and for VMMI development based on data from NWCA 2011 and 2016 (see Chapter 8: and Chapter 9:).

A summary of final disturbance designations (REF_NWCA) reporting the number of sites within each disturbance class by region (RPT_UNIT_5) is provided in Table 6-7 and mapped in Figure 6-3.

Table 6-7. n-sites within final disturbance class assignments (REF_NWCA) reported by region (RPT_UNIT_5) for Visit 1, Index Visit 2011 and 2016 sites. Note that two sites (one from TDL and another from ICP) were dropped due to insufficient vegetation data and assigned as "unknown".

Region	Least Disturbed (L)	Intermediate Disturbed (I)	Most Disturbed (M)	Unknown (?)	Regional Totals
Tidal Saline (TDL)	149	201	108	4	462
Inland Coastal Plains (ICP)	86	216	105	5	412
E. Mts & Upper Midwest (EMU)	101	176	72	1	350
Plains (PLN)	53	208	88	2	351
West (WST)	50	260	101	1	412
National Totals	439	1061	474	13	1987

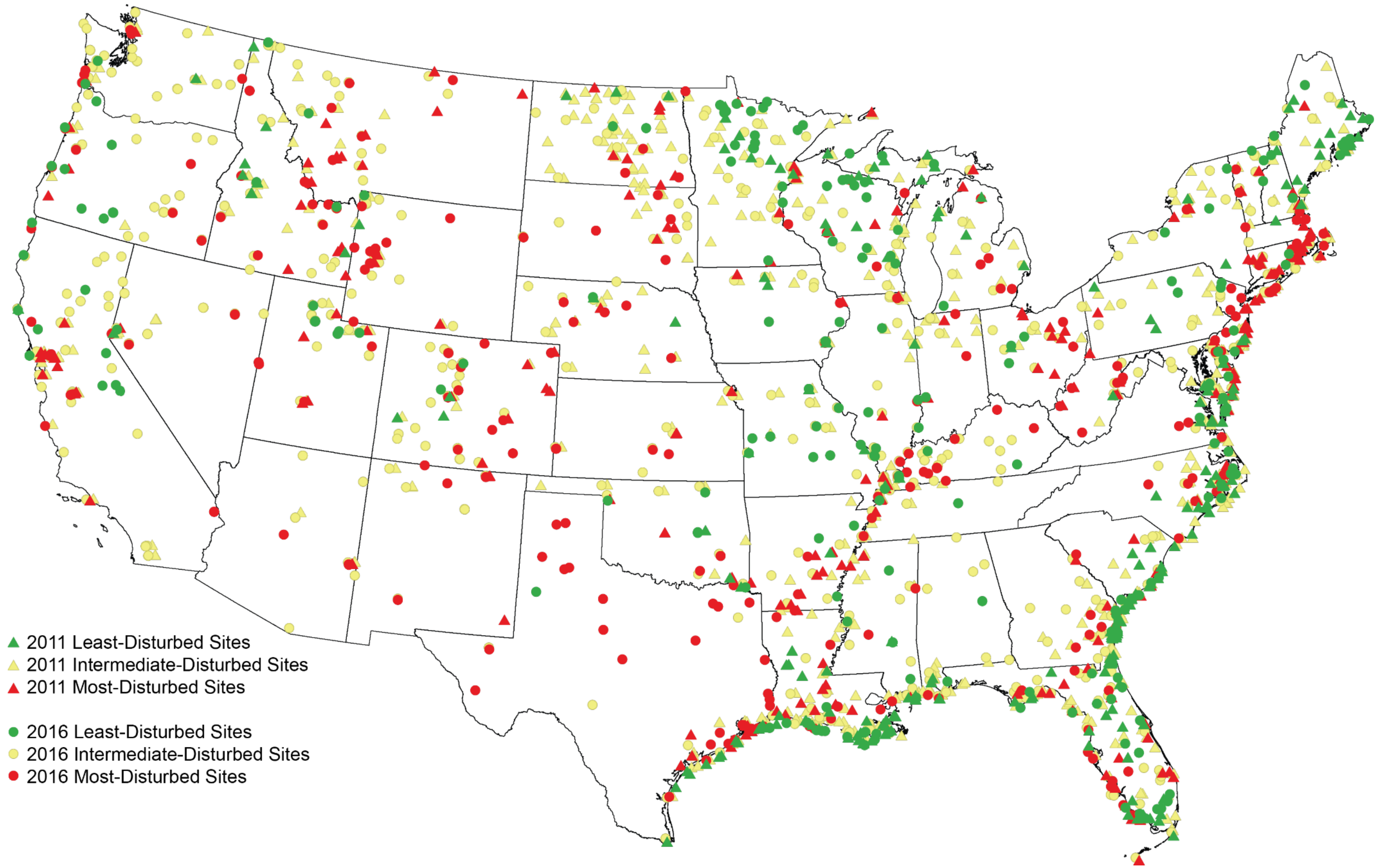

Figure 6-3. Map of sampled sites and their final disturbance class (REF_NWCA) assignments.

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6.9 Appendix A: Illustrative Guide to Assigning Disturbance Class in Six Steps

STEP 1

CALCULATE PHYSICAL ALTERATION INDICES

For each Visit 1, Index Visit probability and handpicked site, calculate a score for each of six Physical Alteration indices (VEGRMV, VEGRPL, WADSUB, WOBSTR, SOHARD, and SOMODF). Evaluate the highest score among all six Physical Alteration indices to determine PALT_ANY and the total score among all six Physical Aleration indices to determine PALT_SUM.

For each of the six Physical Alteration indices (VEGRMV, VEGRPL, WADSUB, WOBSTR, SOHARD, SOMODF), sum the score of the observed metrics (i.e., eight metrics in each of the six indices) in the AA and buffer plots.

Where, VEGRMV	Vegetation Removal
VEGRPL	Vegetation Replacement
WADSUB	Water Addition/Subtraction
WOBSTR	Water Obstruction
SOHARD	Soil Hardening
SOMODF	Surface Modification

↓

Calculate PALT_ANY and PALT_SUM.

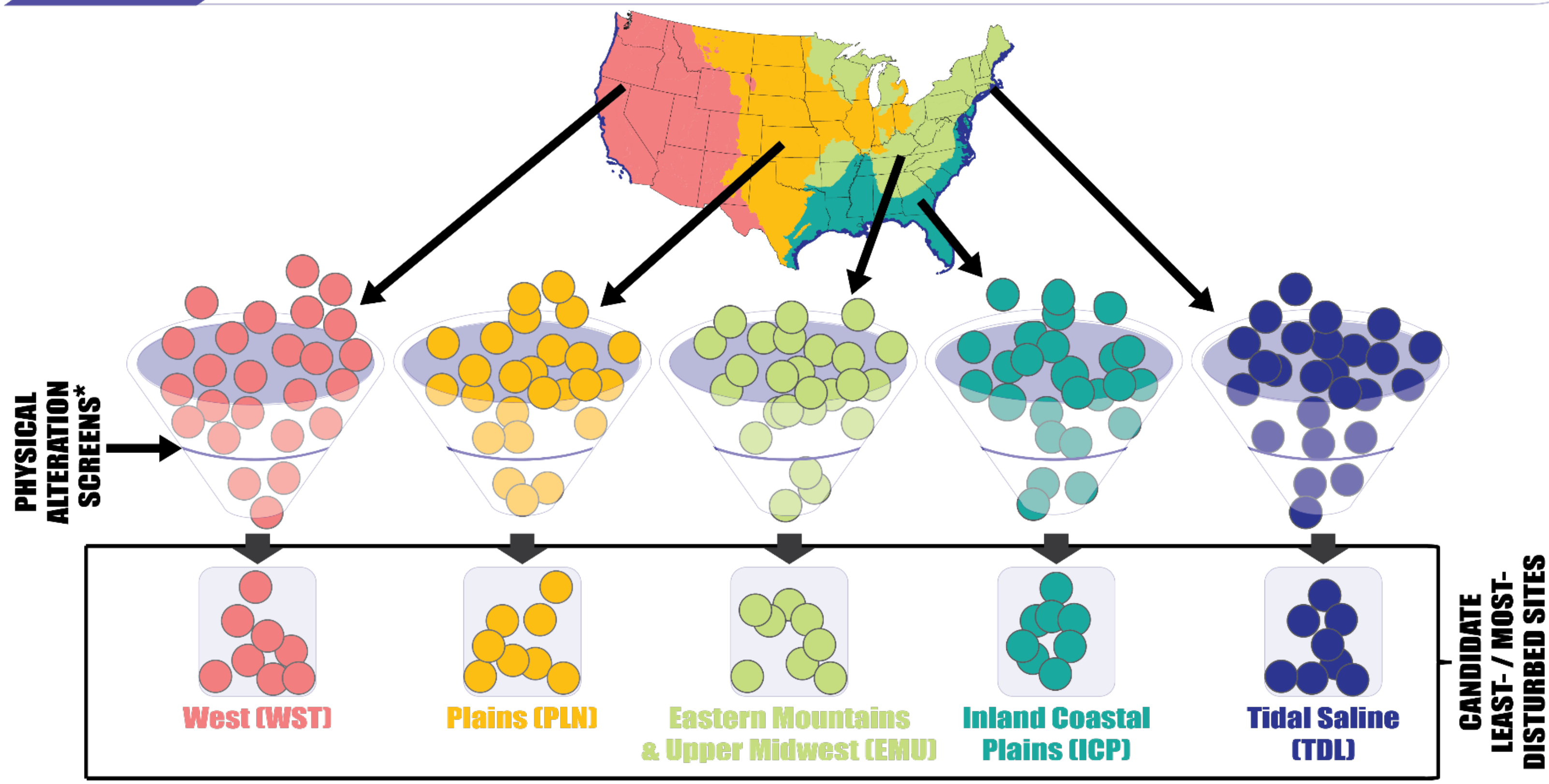
Where, PALT_ANY=
The maximum score among all six Physical Alteration indices.

Where, PALT_SUM=
The total score by summing the scores of all six Physical Alteration indices.

STEP 2

SCREEN SITES THROUGH PHYSICAL ALTERATION INDICES

Screen sites using least-disturbed and most-disturbed Physical Alteration thresholds in five regions using Physical Alteration indices: PALT_ANY (VEGRMV, VEGRPL, WADSUB, WOBSTR, SOHARD, SOMODF) and PALT_SUM. All Visit 1 sites (probability and handpicked) sampled in 2011 and 2016 are evaluated. Sites that pass the screens remain candidates for least- or most-disturbed sites.



*PHYSICAL ALTERATION THRESHOLDS

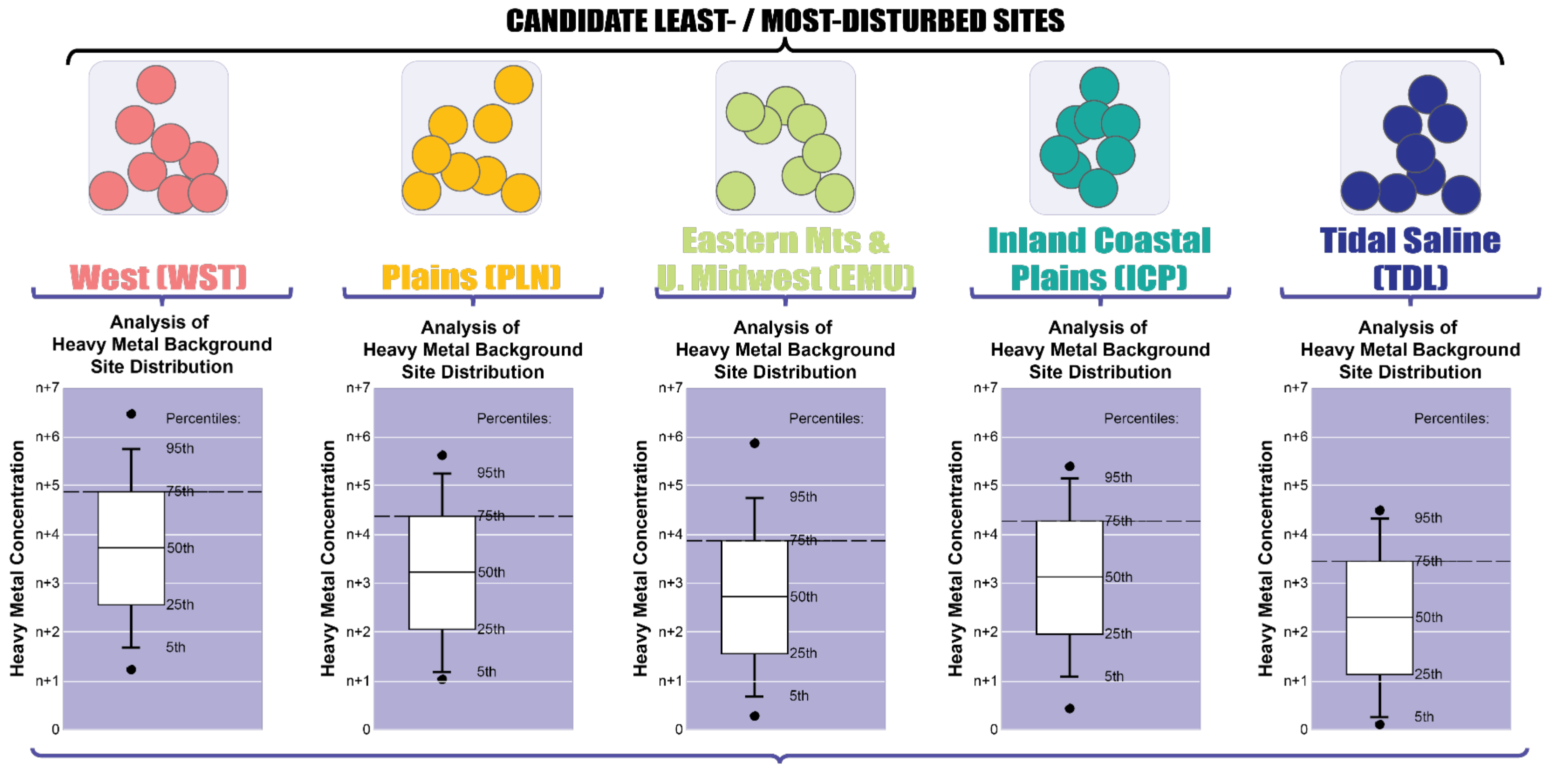
LEAST-DISTURBED	WST	PLN	EMU	ICP	TDL
PALT_ANY	20	10	0	0	0
PALT_SUM	40	10	0	0	0
n-sites	83	100	117	100	200

MOST-DISTURBED	WST	PLN	EMU	ICP	TDL
PALT_ANY	70	50	40	50	30
PALT_SUM	140	100	80	100	60
n-sites	87	84	61	95	87

STEP 3

ESTIMATE SOIL HEAVY METAL BACKGROUNDS

Using the candidate least-disturbed sites that passed the Physical Alteration screens in Steps 1 and 2, calculate the 75th percentile of the concentration of each of 12 heavy metals (Ag, Cd, Co, Cr, Cu, Ni, Pb, Sb, Sn, V, W, Zn) within each of Five Reporting Units (RPT_UNIT_5). Note: heavy metal concentration graphs illustrate how 75th percentiles are determined and do not show actual results.



HEAVY METAL BACKGROUND CONCENTRATIONS (ppm)

75th Percentile (ppm)	Ag	Cd	Co	Cr	Cu	Ni	Pb	Sb	Sn	V	W	Zn
WST	0.19	0.46	8.99	39.7	28.5	22.6	24.3	0.47	1.46	65.4	0.19	81.7
PLN	0.17	0.55	9.17	38.8	19.5	23.3	26.4	0.34	1.45	65.6	0.04	97.2
EMU	0.15	0.82	5.17	22.9	15.2	13.8	37.4	0.40	1.41	33.9	0.18	61.7
ICP	0.09	0.26	8.06	39.4	14.2	18.3	24.6	0.31	1.47	52.9	0.05	64.6
TDL	0.15	0.15	7.30	53.8	17.2	21.4	25.1	0.29	1.69	75.8	0.06	73.0

STEP 4 CALCULATE ENRICHMENT FACTORS AND HEAVY METAL INDEX

For each site, calculate an Enrichment Factor, or EF, (Chen et al. 2007) for each of the 12 heavy metals using the regional heavy metal background estimated from Step 3. Then, combine the 12 EFs into a Heavy Metal Index (HMI) and calculate the maximum EF (EF_MAX) for each site, which are used in combination as the chemical screen in abiotic reference site selection (Step 5).

Enrichment Factor = EF = $\left(\frac{\text{Observed heavy metal concentration at a site}}{\text{Regional 75th percentile heavy metal background}}\right)$

Where, EF < 1	no enrichment
EF < 3	minor enrichment
EF = 3-5	moderate enrichment
EF = 5-10	moderately severe enrichment
EF = 10-25	severe enrichment
EF = 25-50	very severe enrichment
EF > 50	extremely severe enrichment

For each site, EF_AG, EF_CD, EF_CO, EF_CR, EF_CU, EF_NI, EF_PB, EF_SB, EF_SN, EF_V, EF_W, EF_ZN

$\sum$ **number of heavy metals with EF ≥ 3 = Heavy Metal Index = HMI**

Where, the maximum of the HMI can be 12 for any site (i.e., if all 12 heavy metal EFs are equal to or greater than 3, indicating moderate enrichment or greater depending on the EF values).

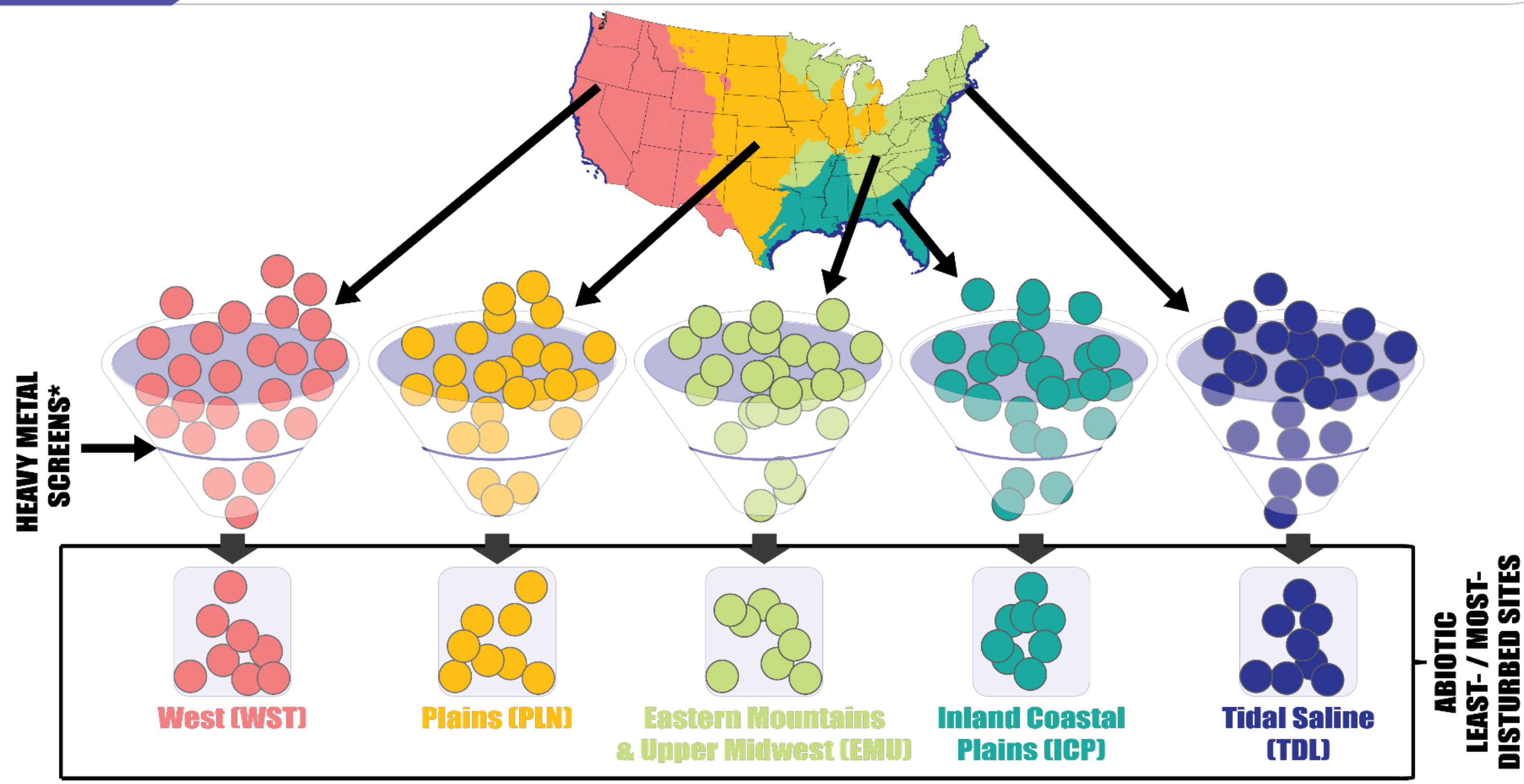
Maximum Enrichment Factor = EF_MAX = maximum value of the 12 heavy metal EFs

Chen, C.W., C.M. Kao, C.F. Chen, & C.D. Dong (2007) Distribution and accumulation of heavy metals in the sediments of Kaohsiung Harbor, Taiwan. Chemosphere 66(8): 1431–1440.

STEP 5

SCREEN SITES THROUGH HEAVY METAL INDICES

Using the sites that passed the Physical Alteration screens (i.e., candidate least-disturbed / most-disturbed sites), rescreen the sites using the heavy metal screens (HMI and EF_MAX) in Five Reporting Units (RPT_UNIT_5). Sites that pass the screens are the final abiotic least- or most-disturbed sites (i.e., sites passed all the physical and chemical screens).



*HEAVY METAL THRESHOLDS

LEAST-DISTURBED	WST	PLN	EMU	ICP	TDL
HMI	≤ 1	≤ 1	≤ 1	≤ 1	≤ 1
EF_MAX	< 5	< 5	< 5	< 5	< 5
n-sites	68	98	105	96	180

MOST-DISTURBED	WST	PLN	EMU	ICP	TDL
HMI	> 1	> 1	> 1	> 1	> 1
EF_MAX	> 10	> 10	> 10	> 10	> 10
n-sites	101	88	72	105	109

STEP 6 CALCULATE RELATIVE PERCENT COVER OF NONNATIVES & SCREEN

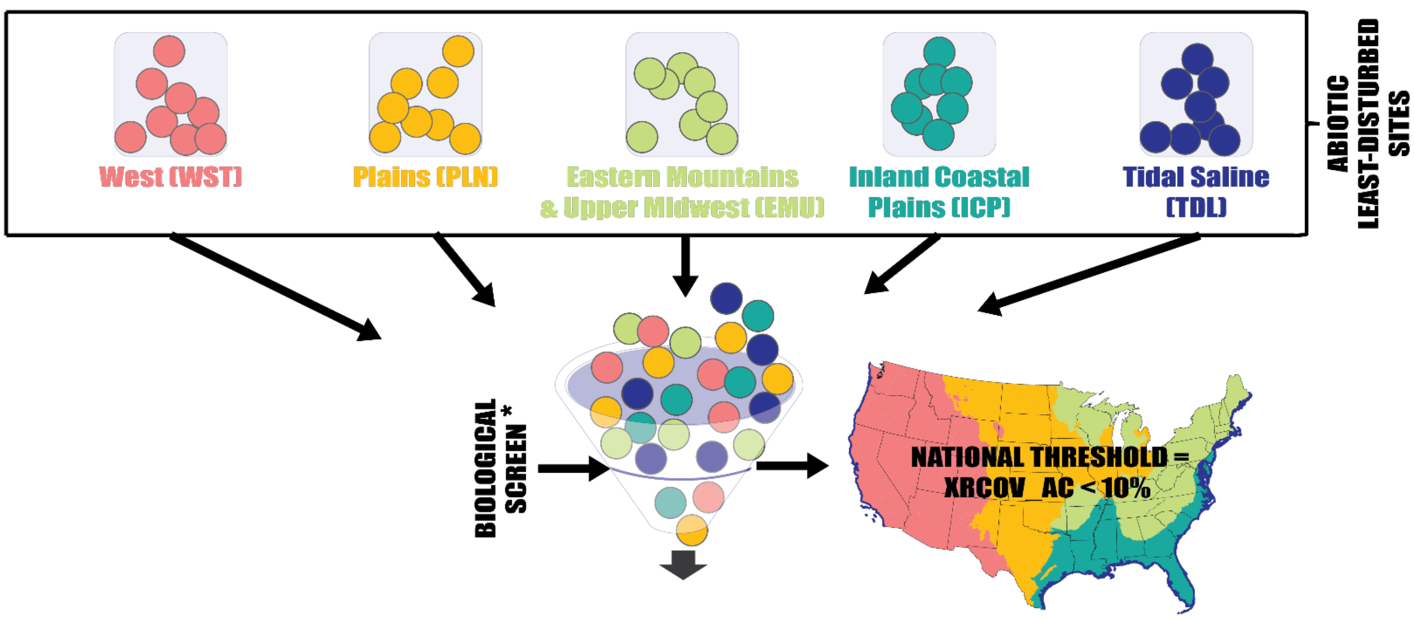
Calculate the relative percent cover of nonnative (alien and cryptogenic) plant species, XRCOV_AC, of each site. Then, screen only the abiotic least-disturbed sites (i.e., sites that passed all the physical and chemical screens) using a national biological screen with a threshold of XRCOV_AC < 10%. Any site that does not pass the biological screen is classified as "intermediate disturbed".

STEP 6A: CALCULATE

For each site, calculate the relative percent cover of nonnative (alien and cryptogenic) plant species (XRCOV_AC):

$$XRCOV\_AC = \left(\sum \frac{\text{cover of all alien + cryptogenic taxa across 5 plots}}{\text{cover of all individual taxa across 5 plots}} \right) * 100$$

STEP 6B: SCREEN



Sites that pass the biological screen are designated as final least-disturbed, or "reference", sites. Sites that do not pass are classified as "intermediate-disturbed".

Chapter 7: Vegetation Analysis Overview, Data Acquisition, and Preparation

7.1 Background

The status of natural vegetation has been increasingly and effectively used as an indicator of ecological condition in wetlands (Mack and Kentula 2010, USEPA 2016a, Magee et al. 2019a). In wetland ecosystems, vegetation provides biodiversity, primary productivity, habitat for organisms in other trophic levels, and contributes to energy, nutrient, and sediment or soil dynamics (Mitsch and Gosselink 2007, Tiner 1999). Wetland vegetation both responds to and influences hydrology, water chemistry, soils, and other components of the biophysical habitat of wetlands. Because plants respond directly to physical, chemical, and biological conditions at multiple temporal and spatial scales, they can be excellent indicators of ecological condition or stress (McIntyre and Lavorel 1994, McIntyre et al. 1999). For example, wetland plant species 1) represent diverse adaptations, ecological tolerances, and life history strategies, and 2) integrate environmental conditions, species interactions, and human-caused disturbance. As a result, many human-mediated disturbances are reflected in shifts in the presence or abundance of particular plant species, plant functional groups (Quétier et al. 2007), plant communities (Galatowitsch et al. 1999, DeKeyser et al. 2003), and vegetation structural elements (Mack 2007). In addition, some vegetation metrics are likely to be more prominently expressed in particular wetland types, and some wetland types may be more likely than others be subjected to higher anthropogenic disturbance levels or to be less resilient to this disturbance (USEPA 2016b, Magee et al 2019a).

Data describing plant species composition (species identity, presence, and abundance) and vegetation structure were collected in the 2011 and 2016 NWCA Surveys. Such data are powerful, robust, relatively easy to gather and can be summarized into myriad candidate metrics that may be related to ecological condition (USEPA 2002, Mack and Kentula 2010, Magee et al. 2019a). In addition to reflecting ecological condition, some plant species groups can be indicators of stress to wetlands. Nonnative plant species, in particular, are recognized as indicators of declining ecological condition, or as stressors to ecological condition (Magee et al. 2008, Ringold 2008, Magee et al. 2010, Magee et al. 2019b).

Vegetation Multimetric Indices (VMMI) and a Nonnative Plant Indicator of Stress (NNPI) were used to aid in evaluating wetland condition based on the 2016 NWCA and changes in condition observed between the 2011 and 2016 NWCAs.

Vegetation Multimetric Indices (VMMI) of Condition

Background: VMMIs include several metrics describing different aspects of the observed vegetation that together can reflect wetland condition in relation to least-disturbed wetland sites. In developing VMMIs, individual candidate vegetation metrics are evaluated for their utility in distinguishing least disturbed sites from those that are most disturbed. Several of most effective metrics are then selected and combined into a VMMI as an indicator of wetland condition. VMMIs commonly include a suite of vegetation metrics (representing aspects of plant communities, vegetation structure, and functional or life history guilds) (e.g., DeKeyser et al. 2003, Miller et al. 2006, Reiss 2006, Rocchio 2007, Veselka et al. 2010, Euliss and Mushet 2011, Genet 2012, Rooney et al. 2012, Deimeke et al. 2013, Wilson et al. 2013).

NWCA VMMIs:

- *NWCA 2011*: A four-metric VMMI that is applicable across the national-scale of the conterminous US was developed and employed in assessing wetland condition based on data from the 2011 NWCA (USEPA 2016a, USEPA 2016b, Magee et al. 2019a).

- *NWCA 2016*: For the NWCA 2016 analysis, the combined number of wetland sites sampled in the 2011 and 2016 NWCAs provided sufficient data to allow development of separate VMMIs for four major Wetland Groups: Estuarine Herbaceous, Estuarine Woody, Inland Herbaceous, and Inland Woody.

Nonnative Plant Indicator of Stress (NNPI)

The NNPI was developed for the 2011 NWCA (USEPA 2016a, USEPA 2016b, Magee et al. 2019b) and this indicator is also used for the 2016 NWCA analyses. The NNPI incorporates attributes of richness, occurrence, and abundance for nonnative (alien and cryptogenic) plant species and can be used to assess the extent of potential stress to wetlands from nonnative plants (see **Chapter 10**). In addition to describing stress to a wetland, the NNPI can also be viewed as an indicator of vegetation condition.

7.2 Overview of Vegetation Analysis Process

As the primary biotic indicator of wetland condition for the NWCA, vegetation is a major component of the NWCA analysis pathway (see **Figure 1-1**). Evaluating vegetation in the NWCA included three sequential phases, each with several major analysis steps (**Figure 7-1**). First, data acquisition and preparation are covered in this chapter. **Chapter 8** describes prerequisite steps for vegetation indicator development, including candidate metric calculation and evaluation. Development of the 2016 NWCA VMMIs is described in **Chapter 9**, and the Nonnative Plant Indicator is summarized in **Chapter 10**.

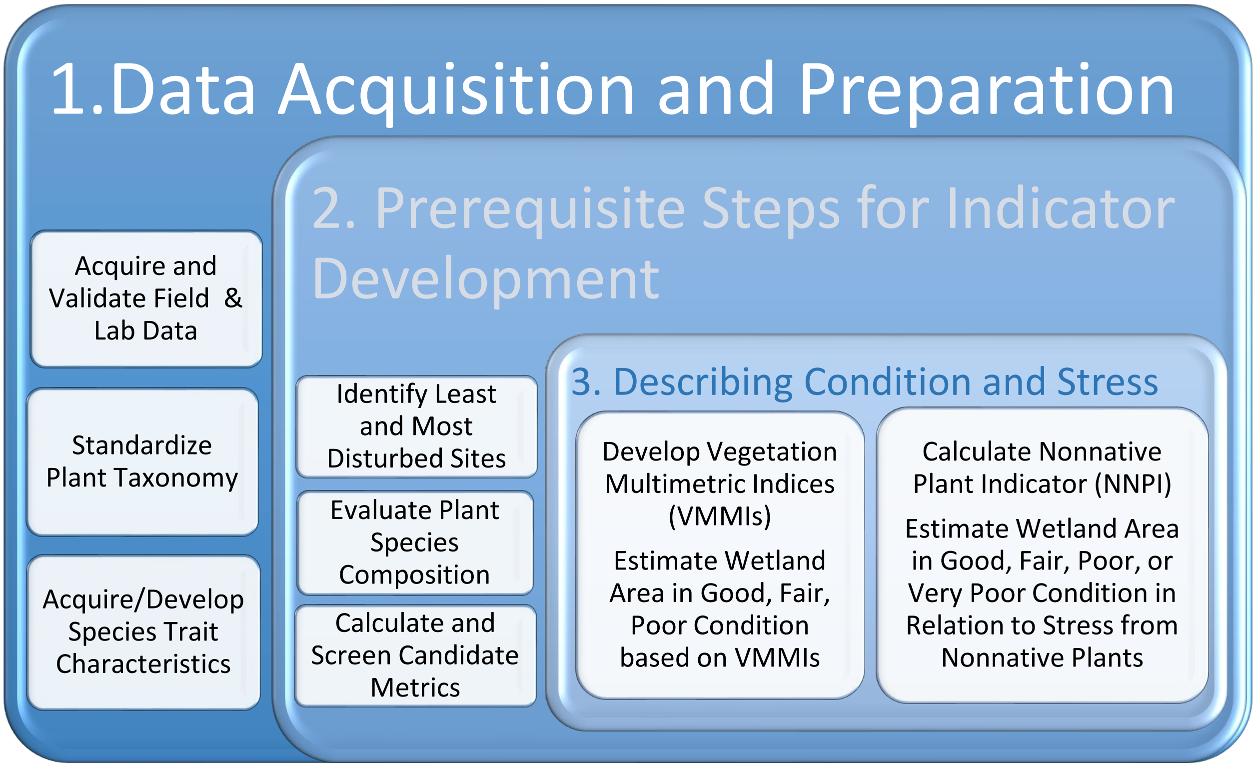


Figure 7-1. Overview of vegetation data preparation and analysis steps used in assessing NWCA wetlands.

The three analysis elements depicted in **Figure 7-1**, their included steps, and the Sections or Chapters in which they are discussed are listed below:

1. *Data Acquisition and Preparation*
   - Collect field data (**Section 7.3**)
   - Validate raw data (**Section 7.4**)
   - Standardize plant species taxonomy (**Section 7.5**)
   - Acquire or develop plant species trait information used in development of candidate vegetation metrics (**Sections 7.6 – 7.9)**

2. *Steps Prerequisite to Indicator Development*
   - Define disturbance gradients by identifying least- and most-disturbed sampled sites (**Section 8.2** and **Chapter 6**)
   - Evaluate plant species composition in relation to ecoregion and wetland type to maximize homogeneity within groups of sites for analysis and potential VMMI development (**Section 8.3**)
   - Use raw vegetation data (**Section 7.12 Appendix C**) and species trait information (**Sections 7.6 - 7.9**) to calculate candidate vegetation metrics (**Section 8.4**)
   - Evaluate candidate vegetation metrics for potential utility for use in VMMI development (**Section 8.5**).

3. *Description of Ecological Condition and Stress*
   - For each of four major Wetland Groups, develop a Vegetation Multimetric Index that reflects wetland condition along an anthropogenic disturbance gradient (**Chapter 9**).

- Describe how VMMIs are used to estimate wetland area in good, fair, and poor condition across the conterminous US and within various wetland subpopulations (**Chapter 15**:),
- Calculate Nonnative Plant Indicator of stress (NNPI) (**Chapter 10**)
- Describe how NNPI is used to estimate wetland area, across the conterminous US and within various wetland subpopulations, that has good, fair, poor, or very poor condition in relation to stress from nonnative plants (**Chapter 15**:).

7.3 Vegetation Data Collection

The Vegetation Protocols for the NWCA were designed to address the survey objectives, while meeting logistics constraints of completion in one sampling day per site by a four-person Field Crew. The sampling protocols are detailed in the *NWCA 2016 Field Operations Manual* (FOM) (USEPA 2016c), which has updates and additions compared to the 2011 FOM (USEPA 2011a). A brief overview of the standardized NWCA field sampling and plant data collection protocols, and identification protocols for unknown plants represented by collected specimens, is provided in the following two subsections.

7.3.1 *Field Sampling*

To facilitate consistency and quality in vegetation data collection, Field Crews were provided with:

- Standardized training in vegetation sampling protocols prior to beginning sampling; and
- An Assistance Visit from NWCA experts to a sample site to answer any crew questions about protocol implementation, generally during the first week of field sampling.

Vegetation data for the NWCA were collected during the peak growing season when most plants were in flower or fruit to optimize species identification and characterization of species abundance. At each NWCA sample point location, data were gathered in five 100-m^2 Vegetation (Veg) Plots.

- The five Veg Plots were placed systematically in a ½ hectare Assessment Area (AA) at each site.
- In each plot vegetation data were collected across the entire 100-m^2 plot and also in smaller nested quadrats within each plot.
- Alternate configurations for AA shape and plot locations were used only, when necessary, as determined by rules related to specific site conditions (USEPA 2016c).
- Standard AA and Veg Plot layouts are illustrated in **Figure 7-2**, the configuration of each plot is shown in **Figure 7-3**.
- Key activities of the vegetation sampling protocol, and the data collected in each step are provided in the flowchart in **Figure 7-4**.

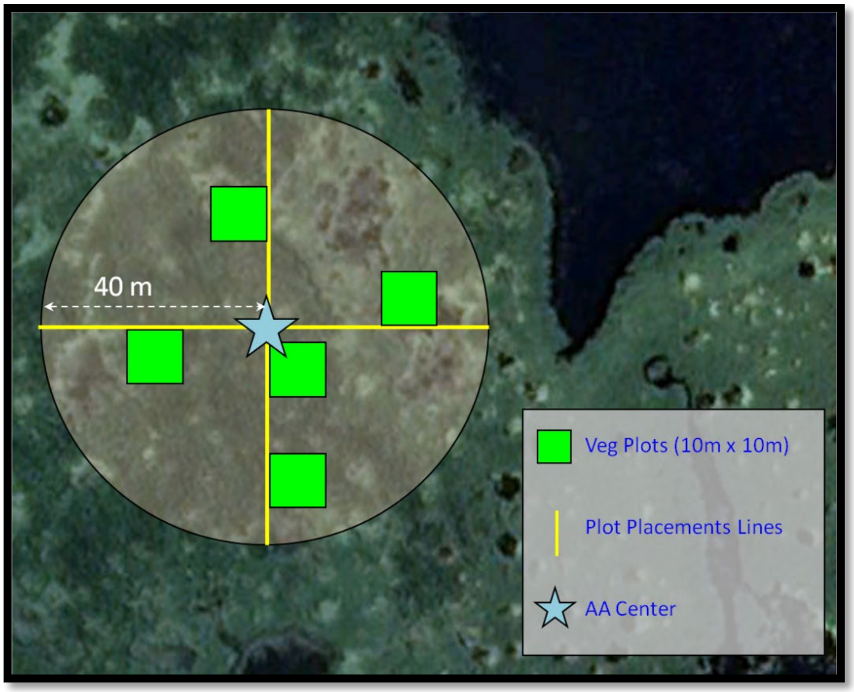


Figure 7-2. Standard NWCA Assessment Area (AA) (shaded circular area) and standard layout of Vegetation Plots.

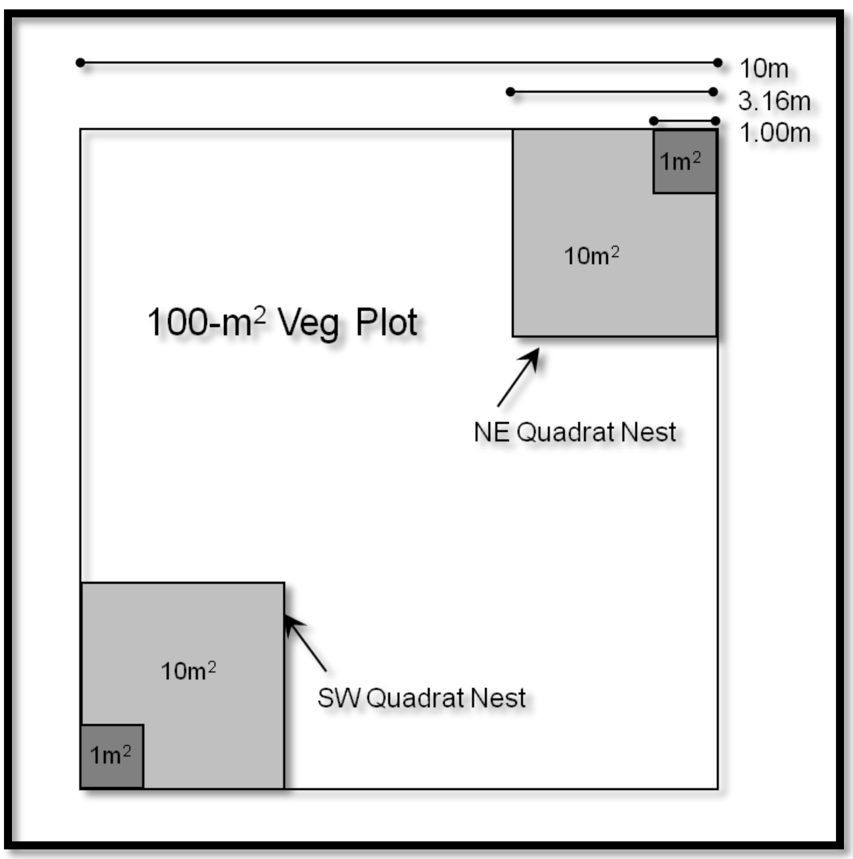


Figure 7-3. Diagram of a Vegetation Plot illustrating plot boundaries and positions of nested quadrats.

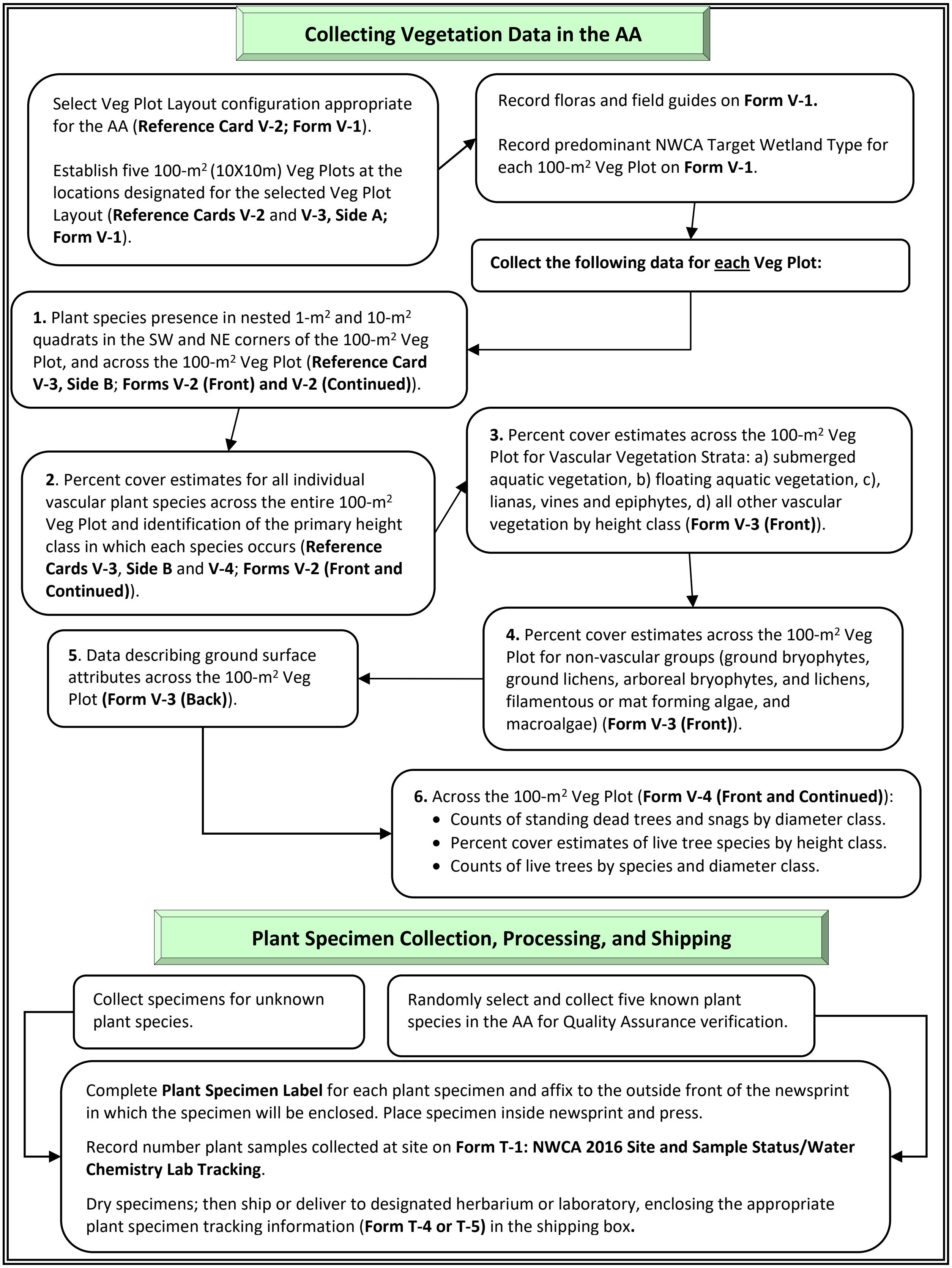


Figure 7-4. Overview of vegetation data collection protocol for the 2016 NWCA (USEPA 2016c).

7.3.2 *Identification of Unknown Plant Species*

Plant species observed in the Veg Plots at each site that could not be identified in the field, were collected for later identification. Specimen collection, labeling, specimen preservation (pressing and drying), shipping or delivering dried specimens to a designated laboratory or herbarium, and specimen tracking were completed according to standard protocols described in the *NWCA 2016 Field Operations Manual* (USEPA 2016c).

Identification of unknown plant taxa was guided by protocols in the *NWCA 2016 Laboratory Operations Manual* (USEPA 2016d). Unknown plant specimens from each Field Crew were identified at a specific designated regional laboratory or herbarium (hereafter, lab) by one or more lab botanists. As quality control for the identification process, ten percent of the lab identifications for unknowns were independently verified by another botanist at the lab. Lab botanists maintained a detailed spreadsheet that included for each unknown specimen collected in the field: the collection number and pseudonym from the field collection, the location of collection (plot and site number), date of sampling, the name assigned during lab identification based on a regional flora, and any notes related to the identification. The lab botanists also reviewed quality assurance (QA) plant voucher specimens (5 per site) collected by the field crew to confirm identifications of these species by the field botanists and to calculate percent taxonomic agreement between lab and field botanists.

All identifications of unknown and QA vouchers were recorded in the *2016 NWCA Plant ID Lab Spreadsheets* (an Excel workbook). This Excel workbook includes instructions for required information to be recorded for each specimen, as well as user information tabs that provide quick reference lists and instructions for recording data on the Unknown and QA voucher spreadsheets. For example, a list of growth-habit codes as well as floras and field guides are included for quick reference while other tabs provide examples and specific instructions on how to fill out the various data fields of the Excel spreadsheets for the QA voucher and Unknown specimen spreadsheets.

The identification spreadsheets were forwarded to the NWCA Data Management and Analysis Teams. The Vegetation Analysis Team reviewed the identification spreadsheets submitted by the labs and standardized nomenclature to the USDA-NRCS PLANTS database (USDA, NRCS 2019-2020). The validated identifications of unknown taxa were integrated with the NWCA raw plant data tables, replacing the pseudonyms recorded by the Field Crews for unknowns with their accepted scientific names (see Section 7.4.2).

7.4 Data Preparation – Parameter Names, Legal Values, and Data Validation

7.4.1 *Description of Vegetation Field Data Tables*

The data from the completed vegetation field forms were electronically scanned into several predefined long format, raw data tables in the NWCA database. A separate table was created for each of the three primary vegetation data forms:

- tblPLANT – data from Form V-2: NWCA 2016 Vascular Species Presence and Cover
- tblVEGTYPE table – data from Form V-3: NWCA 2016 Vegetation Types (Front) and NWCA 2016 Ground Surface Attributes (Back), and from Form V1 (predominant wetland type section).
- tblTREE table – data from Form V-4: NWCA 2016 Snag and Tree Counts and Tree Cover

Examples of the NWCA 2016 vegetation field forms can be found in **Section 7.11, Appendix B**.

Form V-1 data describe the vegetation plot layout at each site and the wetland type observed in each of the five 100-m^2 Veg Plots.

Form V-2 data describe vascular plant species identity, presence, cover, and height for each observed taxon and were collected in each 100-m^2 Veg Plot. Taxa typically represent species or lower level (e.g., subspecies, variety) classification, but occasionally individual taxa were identified only to genus, family, or growth form. For convenience, in this report, vascular plant taxa are generally referred to as species even though in some cases lower or higher taxonomic levels are reflected. Form V-2 data used in candidate metric development for the 2016 NWCA analyses included taxon name, presence, and percent cover (COVER).

Other species level data were collected using Form V-2 but were reserved for further research and not incorporated in the analysis of condition for the 2016 NWCA. These other data included predominant height for each species across each plot, and presence of individual species at different spatial scales, i.e., within the S = 1-m^2 quadrats, M = 10-m^2 quadrats) nested in the two corners of plot and within the overall plot (L = 100-m^2 plot), see **Section 7.3.1**). The former can reflect vegetation structure and, when used with cover, volume by species or guild groups. The latter address fine scale diversity patterns.

Form V-3 data encompass descriptors of the structure of vascular vegetation, non-vascular groups present, and ground surface attributes which are each sampled in the five 100-m^2 Veg Plots. All these data were used in developing candidate metrics.

Form V-4 data include counts by diameter class of dead trees/snags, as well as cover by height classes and by diameter classes for individual tree species in each 100-m^2 Veg Plot. Tree data were used in candidate metric development.

Parameter names and legal values or ranges for the field collected vegetation data are listed in **Section 7.12, Appendix C**. The quality of all the vegetation field data was carefully examined during data validation.

7.4.2 *Data Validation*

Whenever large quantities of data are collected, it is not surprising for errors related to data or sample collection, recording, sample analysis, or data entry to occasionally occur. Therefore, a series of quality assurance (QA) review checks were conducted to identify and resolve any errors to ensure high quality data. The NWCA established numerous cross-checks in the data collection and processing procedures, within the protocols and field forms, to help limit potential errors during data collection. Verification and update of the scanned vegetation data involved several QA steps conducted by members of the Information Management Team and the Vegetation Analysis Team. Some checks required manual evaluation of the paper forms or data scanned into the databases; others involved the use of specific R Code written to identify records with specific kinds of potential errors. Tasks conducted by the Information Management Team and the Vegetation Analysis Team are listed below.

Information Management Team:

- Verified that the data from the Vegetation Forms scanned properly
- Where possible, verified spelling of plant species name with USDA PLANTS database
- Conducted quality assurance checks for valid ranges and legal values for all data

Vegetation Analysis Team:

- Updated the names for unknown taxa at each site based on plant specimen identification (see Section 7.3.2)

- Conducted nomenclatural resolution, correcting species name spelling errors and resolving taxon names that were recorded as synonyms to accepted names of the USDA PLANTS database (see Section 7.5)

- Reviewed and resolved all instances of missing, out of range or non-legal values identified by the IM Team:
    - Review of the field forms often indicated a scanning or recording error that was readily resolved and the data updated
    - Where no resolution was apparent the data were flagged, and the error described

- Conducted logic checks and data type specific checks using R code to identify:
    - Missing data (e.g., checking that if a certain type of data is present, another specific type must also have a value)
    - Recording errors (e.g., data recorded in a form workspace, rather than in the data field)
    - Incongruities in values among related data
    - Instances of individual plant species recorded multiple times at one site (i.e., multiple data rows for the same species at one site which may have resulted when an unknown was identified and was the same taxon as one already recorded)

- Determined the cause of each instance of a potential error revealed by logic checks
    - Resolved these issues and provided a brief explanation of the issue and resolution in tracking spreadsheets

- For all these data the relevant updates to the database were implemented using R-code, and a brief explanation of the resolution was included with each of these records in the database

- For situations, where no resolution was apparent the data were flagged, and the errors described

The vast majority of concerns identified by these QA screenings were readily resolved allowing accurate updates to the data. For the instances where specific issues could not be corrected, the data were flagged with restrictions for use. Where corrections were needed, all original data values were retained as inactive records in the NWCA database.

7.5 Nomenclatural Standardization

Across the 2011 and 2016 field sampling seasons, approximately 170 regional floras and field guides were used by Field Crews for identification of plants. Thus, a wide range of taxonomies were applied to the occurrences of taxon-site pairs observed across the United States. Consequently, a critical step in data preparation was standardization of plant nomenclature to ensure that each taxonomic entity was called by the same name throughout the NWCA study area. The PLANTS nomenclatural database (USDA-NRCS 2020) was used as the national standard for taxonomy for the NWCA.

In the NWCA, plant species names originated from raw data records collected using Form V-2: NWCA Vascular Species Presence and Cover, Form V-4: NWCA Snag and Tree Counts and Tree Cover, and from lab identifications of unknown taxa that were collected in the field. The process for reconciliation of nomenclature outlined in **Section 7.5.1** was used for all three data types. **Section 7.5.2** provides a brief description of procedures for taxonomic review and documentation of name assignments that were used for data from Form V-2. The documentation process for tree data (Form V-4) and the lab identifications of unknown plants were similar but tailored to structures of these data.

Nomenclatural standardization was a complex undertaking, and in this section, we provide an overview of the process used for NWCA 2016.

7.5.1 *Nomenclature Reconciliation Methods*

We reconciled names for the 2016 NWCA observed plant taxa, at each location of their occurrence, to the PLANTS nomenclatural database (hereafter, PLANTS) (USDA-NRCS 2020) using the methods (**Figure 7-5**) we developed for the 2011 NWCA (USEPA 2016a). For species where PLANTS accepted names had changed between the 2011 NWCA analysis and 2020, we also updated nomenclature for these 2011 observations to maintain consistency in plant names for analyses that use data from both surveys. A series of automated filters based on the components in **Figure 7-5** were employed via R code, written using R software (R Core Team 2018-2019), to link recorded names for NWCA observations to PLANTS accepted names and to identify names and records 1) that matched accepted PLANTS names and 2) those that required further evaluation by a botanist to resolve nomenclature.

Step 1: Identify NWCA name-location pairs directly matching PLANTS accepted names

A large proportion of the plant name-site pairs recorded in the NWCA could be directly matched to PLANTS accepted names. These included records where:

1) The original NWCA name was the same as the accepted PLANTS name and there were no synonyms for the name.
2) The original NWCA name pointed to one or more synonyms that all pointed to the same, single accepted PLANTS name.

Step 2: Identify NWCA name-location pairs needing botanical review to reconcile to PLANTS accepted names

Even though most NWCA names could be directly matched to PLANTS nomenclature in Step 1, a large number required botanical review to select the correct PLANTS accepted name. There were three primary types of name issues which necessitated further botanical review:

1) Unmatched Names – no PLANTS accepted name or synonym matched a particular NWCA name-site pair. Common reasons for unmatched names were misspelling or mis-scanning of the record or use of an abbreviation or common name. Rarely, the taxon represented a name or taxon not included in the PLANTS database.
2) Same Name with Different Authorities (shorthand terminology = Multiple Authorities) – refers to an NWCA name which pointed to synonyms with exactly the same genus and species epithets, but which had different botanical authorities for the name.
3) Species Concept Unclear – NWCA binomial name was contained in multiple potential PLANTS accepted names or multiple synonym names that point to multiple possible PLANTS accepted names.

Step 3: Review name-site pairs identified in Step 2 and determine correct name assignment

The set of names and records identified as requiring further evaluation were reviewed by the NWCA lead botanist/ecologist, using a general stepwise procedure for nomenclatural determination:

1) Identify and correct spelling errors or abbreviated names.
2) Identify all synonyms and accepted PLANTS name(s) that could apply to each ambiguous taxon-site pair name.
3) Compare geographic distribution of potential synonyms and accepted PLANTS names with location of the observed NWCA taxon.
4) Review field records and notes from the NWCA Field Crew regarding the observed NWCA taxon.
5) Review the species concept for the taxon based on flora(s) used by field botanist, as well as other pertinent taxonomic resources and floristic databases.

The procedures in Step 3 allowed determination of the PLANTS nomenclature accepted name for the majority of taxon-site pairs that needed botanical review. For taxa where the appropriate PLANTS accepted name could not be definitively resolved using these procedures, a taxonomist at the PLANTS database was consulted for assistance with final name determination. This consultation involved discussions between the NWCA lead botanist/ecologist and the PLANTS taxonomist to review floras, historical records, and floristic/taxonomic databases pertinent to each taxon-location pair considered. In a few cases, the PLANTS taxonomist consulted with other botanists across the US with specific expertise regarding a particular taxonomic group (e.g., species, genus, family) to resolve a naming issue.

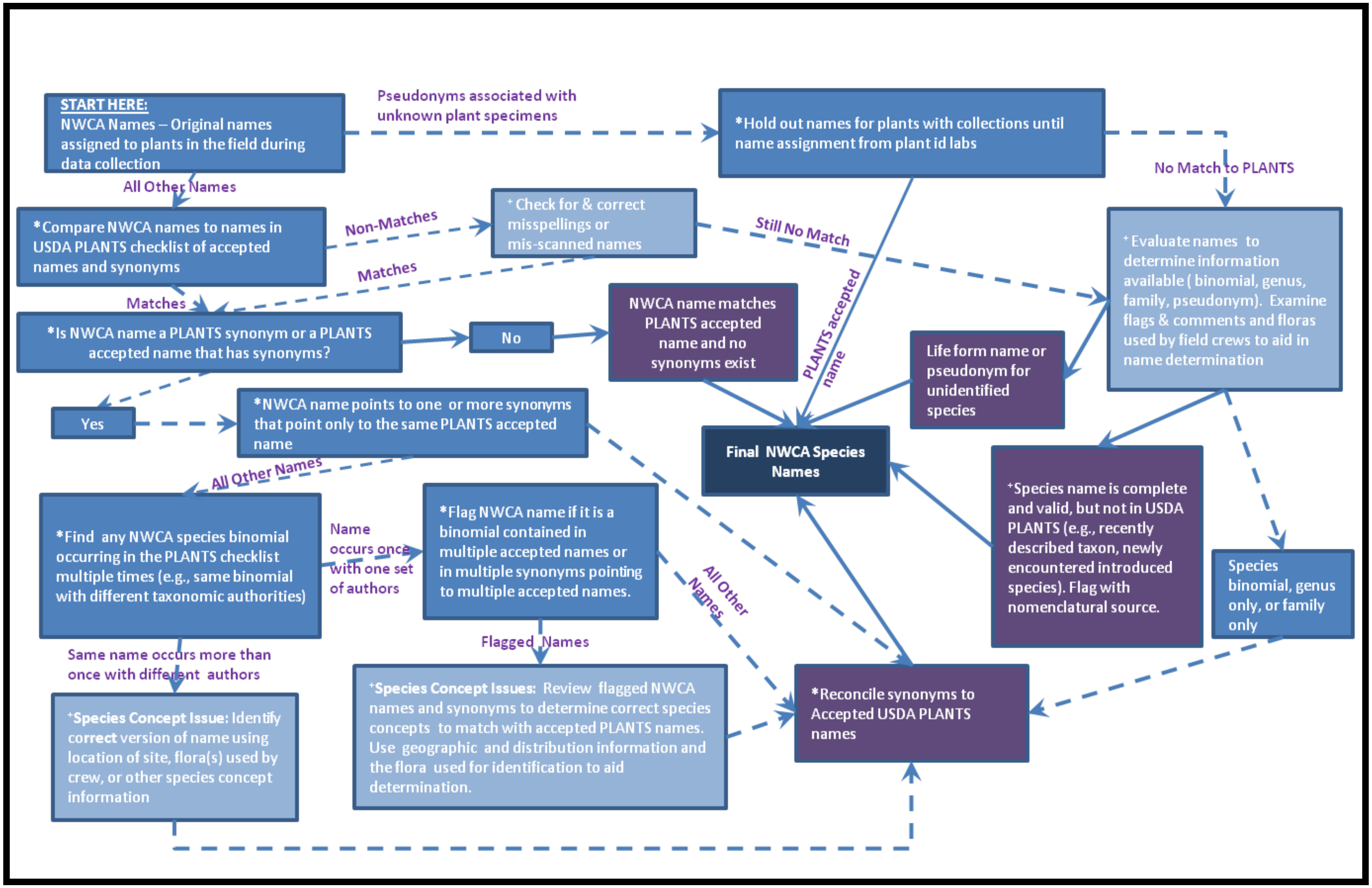


Figure 7-5. Process for screening and reconciling names of plant taxa observed in the NWCA. Dark blue boxes = steps completed using R code, light blue boxes = steps requiring botanical review, purple boxes = type of name resolution applied, and the dark blue central box = final name resolution.

7.5.2 *Nomenclature Standardization Results and Documentation*

For the 2011 NWCA, we developed and applied a standard approach for organizing, resolving, and documenting the name reconciliations for plant name-site pairs needing review (USEPA 2016a). We used the same general procedure to reconcile plant nomenclature for the 2016 NWCA data to the PLANTS database. The NWCA 2011 plant data were also reviewed at this time to identify and update any plant names that were no longer congruent with the current PLANTS database nomenclature.

Specific NWCA species records (including name, cover value, and other data), along with information from the PLANTS database, were exported into an Excel Workbook for Nomenclature Resolution. This workbook gathered key information in one location to facilitate review of the taxonomy and to highlight when other information was needed. Important NWCA data elements included in the Excel Workbook were NWCA SITE_ID and UID, state, county, latitude and longitude, wetland type, a list of the floras used by the Field Crew at a particular site, and a link to the scanned field form image. Access to the scanned field form allowed easy viewing of any notes Field Crews may have made in relation to a particular species, as well as a view of other taxa present at a site. Critical information from the PLANTS database included synonyms and accepted names that could potentially correspond to the specific taxon-site pairs. Various other location pertinent floristic resources and databases were also used when needed by the NWCA botanist/ecologist in resolving name issues.

The Excel Nomenclature Workbook includes separate spreadsheet tabs for reviewing unresolved names in three categories: Unmatched Names, Multiple Authorities, and Species Concept Issues (see Step 2 in **Section 7.5.1**, for definitions). For each taxon-site pair to be evaluated (rows in spreadsheets) listed, the associated columns (e.g., NWCA data, taxonomic and distributional information from the PLANTS database, and other information) informed name resolution. An instruction page in the Workbook described the associated data included in each of the spreadsheets and the ways this information could aid in name determination. During nomenclatural review, the rationale for assignment of the correct PLANTS accepted name to each name-site pair in the NWCA data was documented by specifying a reason code and, where needed, providing narrative notes and citations of taxonomic sources.

Following taxonomic standardization, the master list of plants observed in the 2011 and/or 2016 NWCAs included: *5,045 taxa* that occurred as *21,359 taxon-state pairs* and *73,119 taxon-site pairs.* The majority of taxa observed in the NWCA were identified to the species, subspecies, or varietal level (n = 4,586, 23 of these were hybrids). The remaining taxa in the list represented identifications made at higher taxonomic levels, e.g., genus, family.

Once nomenclature for the NWCA name-site pairs was resolved, the appropriate accepted PLANTS name was applied to each NWCA record. The original names recorded by the Field Crew or lab identifications were retained as inactive data. Names (NWCA_NAME) and symbols (ACCEPTED_SYMBOL) for the 5,045 taxa are listed in the plant taxa file (*nwca_2016_plant_taxa.csv*[5]). The NWCA_NAME typically reflects an accepted scientific name from the PLANTS nomenclature and ACCEPTED_SYMBOL typically reflects the PLANTS accepted symbol. In a few cases (20 taxa), where an appropriate taxonomic concept was not available in PLANTS, we determined the name from other sources and assigned an ACCEPTED_SYMBOL preceded by the number 1. For these 20 taxa, the complete name with authorities for the relevant taxon can be found in the SCI_NAME_AUTH column. Taxa that were identifiable only to growth form were

[5] .csv files referenced throughout the vegetation chapters are available to download from the USEPA NARS website (https://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys).

assigned an NWCA_NAME representing one of 35 detailed standardized growth habit/category designations, each of which were connoted by an ACCEPTED_SYMBOL preceded by the number "2".

7.6 Species Traits – Life History: Growth-habit, Duration, and Plant Category

Traits reflecting species life history based on growth-habit, duration, and plant category for all vascular taxa observed in the NWCA were downloaded from the PLANTS database (USDA-NRCS 2020). This trait information was used directly or summarized to reduce the number of classes in each life history group. Life history designations for each taxon observed in the 2011 and 2016 NWCAs are included in the plant taxa file (*nwca_2016_plant_taxa.csv*). Life history information was used in combination with presence, frequency, and cover data for individual species to develop candidate metrics to summarize the distribution and importance of life history traits across each sampled site (see **Section 8.8: Appendix E**).

7.6.1 *Growth-Habit*

Primary growth-habit types for the plant taxa observed in the 2011 and 2016 NWCAs were based on growth-habit designations in the PLANTS database (USDA-NRCS 2019-2020).

In the PLANTS database, individual species were frequently identified as spanning multiple growth-habit types. This results in numerous combined growth-habit categories, each often representing few taxa. To facilitate data analysis, we merged some of multiple growth-habit groups from the PLANTS database into larger categories for the NWCA data analysis (**Table 7-1**).

7.6.2 *Duration*

Duration or longevity for plants is described by annual, biennial, and perennial life cycles. Some individual species may exhibit different durations depending on growing conditions. Consequently, in addition to the individual duration classes, a variety of mixed duration categories occur in the PLANTS trait database. To facilitate data analysis, we merged some multiple type groups from the PLANTS database into larger categories (**Table 7-2**).

Table 7-1. Growth-habit categories, for species observed in the 2011 and 2016 NWCAs and used in analysis, with a crosswalk to PLANTS database growth-habit designations. Capitalized Growth-habit Category Names are used in calculation of Growth-habit metrics (see **Section 8.8: Appendix E**).

NWCA Growth-habit	PLANTS Database Growth-habit 'Designations' for NWCA Observed Species included in NWCA Growth-habit Category
GRAMINOID	'Graminoid'; 'Subshrub, shrub, graminoid'; ''Graminoid, shrub, subshrub''; 'Graminoid, shrub, vine; subshrub'; 'Graminoid, shrub'; ''Subshrub, shrub, graminoid'
FORB	'Forb/herb'; 'Forb/herb, shrub'; 'Forb/herb, shrub, subshrub'; 'Forb/herb, subshrub'; 'Forb/herb, subshrub, shrub'
SUBSHRUB-FORB	'Subshrub, forb/herb'; 'Subshrub, forb/herb, shrub'; 'Subshrub, shrub, forb/herb'
SUBSHRUB-SHRUB	'Subshrub, shrub'; 'Shrub, forb/herb, subshrub'; 'Shrub, subshrub'; 'Subshrub'
SHRUB	'Subshrub, forb/herb, shrub, tree'; 'Shrub, tree'; 'Shrub', 'Tree, subshrub, shrub'
TREE-SHRUB	'Tree, shrub'; 'Tree, shrub, subshrub'; 'Tree, shrub, vine'
TREE	'Tree'
VINE	'Vine'; 'Vine, forb/herb'; 'Subshrub, forb/herb, vine'; 'Forb/herb, vine'; 'Vine, herbaceous'; 'Vine, forb/herb'; 'Vine, forb/herb, subshrub'
VINE-SHRUB	'Vine, shrub'; 'Vine, subshrub'; 'Subshrub, vine'; 'Shrub, vine'; 'Shrub, forb/herb, subshrub, vine'; 'Shrub, subshrub, vine'
NWCA Growth-habit	NWCA Growth-habit Category Combinations
HERB	GRAMINOID + FORB
SHRUB-COMB	SUBSHRUB-SHRUB + SHRUB
TREE-COMB	TREE-SHRUB + TREE
VINE-ALL	VINE + VINE-SHRUB

Table 7-2. Duration categories used in the NWCA analyses and a crosswalk to PLANTS database duration designations for NWCA observed species. Capitalized Duration Category Codes are used in calculation of Duration Metrics (see Section 8.8: Appendix E).

NWCA Duration Categories	**PLANTS Database Duration 'Designations' for NWCA Observed Species**
ANNUAL	'Annual'
ANN_BIEN (Annual-Biennial)	'Annual, biennial'; 'Biennial'; 'Biennial, an'
ANN_PEREN (Annual-Perennial)	'Annual, biennial, perennial'; 'Annual, perennial'; 'Annual, perennial biennial'; 'Biennial, perennial'; 'Biennial, perennial, an';
PERENNIAL	'Perennial'; 'perennial, an'; 'Perennial, annual'; 'Perennial, annual, biennial'; 'Perennial, biennial'; 'Perennial, biennial, an'; Perennial, biennial, annual'

7.6.3 *Plant Categories*

Several major plant categories were considered in summarizing raw data to develop guild-based candidate metrics. The categories assigned for individual NWCA vascular taxa based on PLANTS database categories were:

- Dicot
- Monocot
- Gymnosperm
- Fern
- Horsetail
- Lycopod
- Quillwort

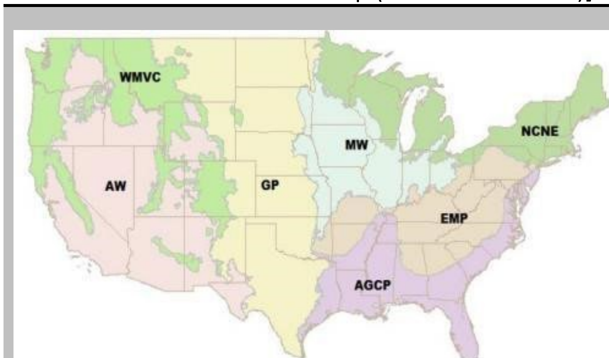
7.7 Species Traits – Wetland Indicator Status

Hydrophytic status for plants observed in the NWCA surveys was defined using ***Wetland Indicator Status*** (WIS) (**Table 7-3**). WIS values for individual species vary across 7 Wetland Regions (**Table 7-4**). A WIS category was assigned for each taxon-wetland region pair observed in 2011 or 2016 (see *nwca_2016_plant_wis.csv*). Most of the NWCA WIS assignments originated from the *National Wetland Plant List* (NWPL) (USACE 2016-2018). However, the NWPL lacked WIS values for some NWCA taxon-wetland region pairs. NWCA evaluated this subset of taxon-wetland region pairs and assigned WIS values (**Table 7-3**) as appropriate: 1) UPL to OBL, 2) NOL (not on the NWPL and too little information to assign UPL to OBL, but often occurring in moist locations), or 3) UND (undetermined due to limited information).

Table 7-3. Wetland Indicator Status (WIS) definitions. OBL, FACW, FAC, FACU and UPL defined by Lichvar 2016. NOL and UND defined by NWCA. These seven WIS Categories are used in calculating Hydrophytic Status Metrics (**Section 6.8: Appendix E**). The Numeric Ecological Value (ECOIND2) for each indicator status (UPL to OBL) is used in calculating indices describing the hydrophytic status of the vegetation at each sampled site.

Wetland Indicator Status (WIS)	Qualitative Description	Numeric Ecological Value (ECOIND2)
OBL - Obligate	Almost always occur in wetland	5
FACW - Facultative Wetland	Usually occur in wetlands, but may occur in non-wetlands	4
FAC - Facultative	Occur in wetlands and non-wetlands	3
FACU - Facultative Upland	Usually occur in non-wetlands, but may occur in wetlands	2
UPL - Upland	Almost never occur in wetlands	1
NOL - Not on National Wetland Plant List	Not on NWPL, but observed in NWCA wetlands under wet or moist conditions	
UND - Undetermined	Wetland status is undetermined	

Table 7-4. Wetland regions within which wetland indicator status for individual plant species are defined, and a crosswalk between USACE codes and NWCA codes for these regions is provided.



Wetland Regions Map [US Army Corps of Engineers, National Wetland Plant List Map (USACE 2016-2018)]	Wetland Region	USACE/NWPL Wetland Region Code	NWCA Wetland Region Code (COE_REG_ID)
	Atlantic and Gulf Coastal Plain	AGCP	CSTL_PLAIN
	Arid West	AW	ARID_W
	Eastern Mountains and Piedmont	EMP	E_MTNS
	Western Mountains, Valleys, and Coast	WMVC	W_MTS
	Great Plains	GP	GT_PLAINS
	Northcentral and Northeast	NCNE	NE
	Midwest	MW	MIDWEST

7.7.1 *Wetland Indicator Status Assignment Process*

All taxon-wetland region pairs observed (n = 9,584) in the 2011 or 2016 NWCA Surveys were assigned a wetland indicator status (WIS) category (**Table 7-3**): OBL – obligate (n = 2088), FACW – facultative wetland (n = 2,011), FAC – facultative (n =1,622), FACU – facultative upland (n = 1,794), UPL – upland (n = 1,409), NOL – not on NWPL list but considered by NWCA to occur in wetlands some of the time (n = 94), or UND – undetermined (n = 566). The process used for making these category assignments is outlined in Steps 1 through 3 below. Step 4 explains how the origin of the WIS value for each NWCA taxon-wetland region pair was documented.

Step 1: WIS available directly from NWPL for 6631 species-region pairs – Where available, the WIS category from the National Wetland Plant List (NWPL) (USACE 2016-2018) was assigned to the corresponding NWCA taxon-wetland region pair. Assignments were made based on nomenclatural and wetland region matches between the NWPL and observed NWCA taxa. The NWPL provides taxon names as binomials (genus and species) only. WIS values were assigned to all NWCA names that were binomials and direct matches to the NWPL names. Some NWCA names represented lower taxonomic levels (e.g., subspecies or varieties). For NWCA names with subspecies or variety designations where the genus and species name matched a binomial on the NWPL, the NWPL WIS category for that binomial was assigned to the NWCA taxon.

Step 2: *WIS assigned from multiple sources for 1875 species-region pairs* – Each NWCA taxon-wetland region pair representing a taxonomic level of species, subspecies, variety, or hybrid and not assigned a WIS category in Step1 was evaluated to determine whether a WIS category could be assigned. This was a two-step process:

- *Step 2a* – First each of these NWCA taxon-wetland region pairs was evaluated to see if it was a synonym for a binomial included on the NWPL. If so, the taxon was assigned an NWPL WIS category following the procedures in Step 1 (n =554).

- *Step 2b* – The taxon-wetland region pairs in the species and lower taxonomic level group that were not synonyms for taxa on the NWPL list (n = 1,321), were reviewed using a variety of sources of ecological information (e.g., primary floras, distributional databases, and expertise of the NWCA vegetation analysis team) to determine if a WIS category might reasonably be assigned. Based on this review, each of these taxon-wetland region pairs was assigned a WIS category with the majority assigned to the UPL and NOL categories:
    - OBL (n = 19)
    - FACW (n = 11)
    - FAC (n = 15)
    - FACU (n = 13)
    - UPL (n = 1,160)
    - NOL (n = 94)
    - UND (n = 9)

Step 3: *WIS assigned for 1,078 higher level taxon-wetland region pairs* – Finally 1,078 taxon-wetland region pairs that were identified only to growth form, family, or genus, or that were nonvascular plants were assigned a WIS category. The few nonvascular taxon-wetland region pairs (n = 18) included in the NWCA taxa list were classified as UND. Most NWCA taxon-wetland region pairs identified only to family or growth habit were assigned an undetermined (UND, n = 202) WIS. Aquatic growth form-region pairs were assigned OBL (n = 9) status. Genus-level taxon-wetland region pairs (n = 849) were evaluated as to whether species in those genera for a given wetland region tended to predominantly occur in wetlands or uplands. Genera that had species that were predominantly a particular WIS category were assigned that category; those for which species spanned a wide range of categories were assigned UND:

- OBL (n = 129)
- FACW (n = 161)
- FAC (n = 128)
- FACU (n = 71)
- UPL (n = 23)
- UND (n = 337)

Step 4: Documentation of WIS Value Origin for 9,584 observed NWCA taxon-wetland region pairs – In addition to the WIS assignment for each of the 9,584 NWCA taxon-wetland region pairs, a source or reason for each assignment was included in the WIS_SOURCE column of the wetland indicator status trait table (*nwca_2016_plant_wis.csv*) to provide documentation of its origin. WIS_SOURCE codes, definitions, and included WIS categories are provided below:

- **NWPL:** WIS value directly from NWPL [OBL, FACW, FAC, FACU, UPL]
- **NWPL-NOMEN**: WIS value from NWPL synonym of NWCA_NAME [OBL, FACW, FAC, FACU, UPL]
- **NWPL-UPL**: no WIS value listed on NWPL, but likely UPL based on habitat descriptions [UPL]
- **NWPL-ADJREG:** WIS value from NWPL for the same taxon from an adjacent wetland region [OBL, FACW, FAC, FACU]
- **NWCA-WIS:** NWCA assigned WIS value based on other wetland indicator information or habitat descriptions from floras pertinent to region [OBL, FACW, FAC, FACU]
- **NWCA-EPIPAR:** Taxon-wetland region pair is an epiphyte or parasite that occurs on wetland species [NOL]
- **NWCA-MOIST:** Habitat descriptions indicate that taxon-wetland region pair often occurs under moist to wet conditions [NOL]
- **NWCA-GENUS:** UPL- OBL assignment based on predominant wetland status for species in a genus for a wetland region, or if too little information was available or a wide range of WIS values were present in the genus it was assigned UND. [OBL, FACW, FAC, FACU, UPL, UND]
- **NWCA-NI:** Insufficient information for a WIS assignment for taxon-wetland region pair [UND]
- **NONVASCULAR:** 18 nonvascular taxa that were included non NWCA taxa list [UND]

7.8 Species Traits – Native Status

The number, proportion, or abundance of native vs. nonnative flora at a given location can help inform assessment of ecological condition and stress (Magee et al. 2019b). To calculate metrics describing native and nonnative components of the flora, it was first necessary to determine the native status of the vascular plant taxa observed in the NWCA (USEPA 2016a, Magee et al. 2019b). Here, the state-level native status was determined for the approximately 21,360 taxon-state pairs observed in the 2011 or 2016 NWCA surveys across various states of the conterminous US.

Assigning state-level native status for such a large number of taxon-state pairs across the scale of the NWCA was a demanding task. First, there is currently no comprehensive national standard for native status of plant species at the local or state level. Next, existing native status designations can be ambiguous, and the understanding of indigenous species distributions is incomplete. In addition, defining the concepts for native and nonnative is not always straightforward. Nonnative species may originate from other countries or continents. Some species are native in one part of the United States, but nonnative in another. Other taxa may both have alien and native components (e.g., genotypes, subspecies, varieties, or hybrids).

Consequently, our first step in determining native status for the observed taxa-state pairs was to define several concepts describing native status for the NWCA (Table 7-5).

Table 7-5. Definition of state-level native status designations for NWCA taxon-state pairs.

Native Status Designations
Native **(NAT):** Indigenous to specific states in the conterminous US
Alien **(ALIEN):** Introduced + Adventive
Introduced **(INTR):** Indigenous outside of, and not native in, the conterminous US
Adventive **(ADV):** Native to some areas or states of the conterminous US, but introduced in the location of occurrence
Cryptogenic **(CRYP):** Includes both Native and Alien genotypes, varieties, or subspecies
Undetermined **(UND):** Taxa identified at level of growth form, most families, or genera with both native and alien species
Definitions from Magee et al. 2019b

Note: NWCA defines ***nonnative plants*** to include both *alien and cryptogenic taxa* (Magee et al. 2019b) Cryptogenic species include taxa with both introduced (often aggressive) and native (generally less prevalent) genotypes, varieties, or subspecies. Many cryptogenic species are invasive or act as ecosystem engineers (Magee et al. 2019b), so we grouped them with alien species and considered them nonnative for the purpose of indicating ecological stress. For example, see the Nonnative Plant Indicator (NNPI, **Chapter 10:)** and metrics ending in _AC (**Section 8.8, Appendix E**).

Using the definitions from **Table 7-5** to determine state-level native status for each of the NWCA taxon-state pairs, we reviewed existing native status designations for all NWCA taxon-state pairs from a variety of taxonomic and ecological sources:

1) Floristic Databases (state and national levels)
2) State and Regional Floras and Checklists
3) PLANTS Database (USDA, NRCS 2020): Native status and species distribution (conterminous US)
4) Consultation with the PLANTS nomenclatural team

Items 1 through 3 above were used in the primary review of native status for the NWCA taxon-state pairs and included numerous floristic sources (> 85). Final NWCA native status assignments for individual taxon-state pairs were based on the body of evidence from relevant reviewed sources. The native status review process was conducted by the NWCA Lead Ecologist/Botanist and another member of the Vegetation Analysis Team with strong botanical expertise. One key element of the review was to search native status designations based on the NWCA accepted name (see **Section 7.5**) and where needed, on its synonyms. Many native status determinations were clear-cut, but others were more complex and required extensive review of distributions and floristic sources. For taxa with particularly complex origins, the nomenclature team at the PLANTS Database provided input based on their expertise and access to resources describing species distributions and first collections to inform native status designations.

Native Status determinations for NWCA observed taxa were made for all species-state pairs, and wherever possible for taxa identified only to genus-state pairs. Family- and growth form-state pairs were designated 'Undetermined'. The native status designations are compiled in the native status trait table (*nwca_2106_plant_native_status.csv*). The approximately 21,360 taxon-state pairs were distributed as Native = 17,403, Introduced = 2,195, Adventive = 99, Cryptogenic = 297, and Undetermined = 1,354. The distribution of native status among taxon-state pairs are presented as percentages in **Figure 7-6**.

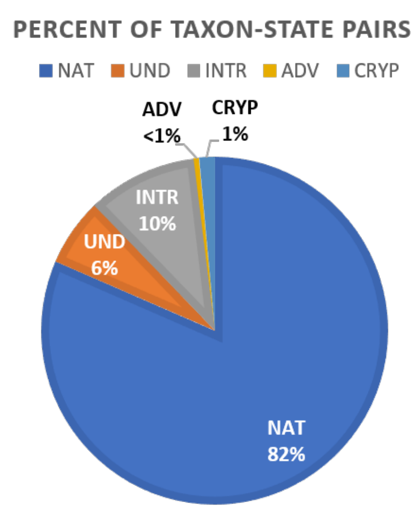


Figure 7-6. Distribution of native status among taxon-state pairs presented as percentages.

Native status was used in conjunction with validated field collected vegetation data and with other species trait information to calculate numerous candidate metrics (**Section 8.8: Appendix E**).

7.9 Species Traits – Coefficients of Conservatism

Coefficients of Conservatism (C-values, also called CCs) describe the tendency of individual plant species to occur in disturbed versus near pristine conditions. C-values for individual species are state or regionally specific and scaled from 0 to 10.

- A C-value of 1 indicates a widespread generalist species that thrives under disturbed conditions.
- A C-value of 10 indicates a species that occurs in specific habitats that are minimally disturbed (i.e., largely unaltered).
- For the NWCA, nonnative taxa were assigned a C-value of 0.

C-values are the primary building blocks of 1) floristic quality indices and 2) metrics describing vegetation sensitivity or tolerance to disturbance. Coefficients of Conservatism (C-values) for individual plant taxa in particular locations reflect a taxon's response to anthropogenic disturbance and its habitat specificity. C-values are applied to taxa by state, region, or habitat, so the C-value for a particular species often varies by location. Typically, C-values are assigned by panels of expert botanists/ecologists and have proven to be powerful tools in describing vegetation condition.

Floristic Quality (FQ) indices can be stand-alone indicators of condition or used as a component of a VMMI (e.g., see **Section 9.4**). Floristic quality describes the complement of plant species occurring at a site, and is based on summarization of species-specific, state or regional Coefficients of Conservatism that rank the responsiveness of each species to disturbance (Swink and Wilhelm 1979, Wilhelm and Ladd 1988). FQ indices have proven utility as indicators of wetland condition in many regions of the US (e.g., Lopez and Fennessy 2002, Cohen et al. 2004, Bourdaghs et al. 2006, Miller and Wardrop 2006, Milburn et al. 2007, Bried et al. 2013, Gara 2013, Bourdaghs 2014). Several kinds of FQ indices have been used to describe wetland condition; the two most common are Mean Coefficient of Conservatism (Mean C) and the Floristic Quality Assessment Index (FQAI). Both can be based on species presence only or weighted by species abundance.

Sensitivity and tolerance to disturbance are often key attribute categories used in MMIs for other biological assemblages and for some wetland VMMIs. For plants, sensitivity can be described based on presence or abundance of taxa with high C-values, whereas tolerance may be based on presence or abundance of taxa with low C-values.

See **Appendix E Metrics** (**Section 8.8**) for description of metrics based on C-values and for details of their calculation. Several versions of Floristic Quality Assessment Index (FQAI) and of Mean Coefficient of Conservatism (Mean C) were investigated in NWCA analyses as potential metrics for inclusion in one or more Vegetation VMMIs. Metrics describing sensitivity and tolerance to disturbance were also screened as of potential VMMI components.

C-values for individual plant species were not universally available for all states or regions, nor for all taxa observed across the 2011 and 2016 NWCAs. In addition, existing state or regional C-value lists were not compiled together in a readily accessible format. Thus, to use C-values as a plant trait and calculate C-value based metrics for the NWCA, it first was necessary to *obtain or develop* state or regional C-values for the plant taxa observed during the 2011 or 2016 NWCAs. A unique C-value was needed for each observed *NWCA taxon-region pair representing a specific plant taxon in either a specific state or a specific region within a state*.

This required:

- *Step 1* – Compiling and standardizing existing State and Regional C-Value Lists from across the Conterminous US (**Section 7.9.1**)

- *Step 2* – Assigning existing C-values, where available, to each taxon-region pair observed in the 2011 and 2016 NWCA surveys (**Section 7.9.2**)

- *Step 3* – Developing C-values for each NWCA taxon-region pair observed in the 2011 and 2016 NWCA surveys for which there was no existing C-value (**Section 7.9.3**)

- *Step 4* – Finalizing NWCA C-value trait table (**Section 7.9.4**)

The final C-value assignments for the taxon-region pairs observed in the 2011 and 2016 NWCAs are located in the NWCA C-value Trait Table (*nwca_2016_plant_cvalues.csv*) on the NWCA website.

7.9.1 *Compilation of Existing State and Regional C-Value Lists from Across the Conterminous US*

An initial compilation of C-value lists (*unpublished*) was developed for the 2011 NWCA and is described in the 2011 NWCA Technical Report (USEPA 2016a). C-value coverage for the western states was sparse; consequently, USEPA convened an expert panel to assign C-values to NWCA taxon-state pairs observed in the 2011 and 2016 NWCAs and occurring in Arizona, California, Idaho, New Mexico, Nevada, Oregon, Texas, and Utah (Fennessy & Great Lakes Environmental Center Inc., 2019, *unpublished*). These two sets of C-value lists served as the starting point for an updated, more extensive compilation of C-value lists.

For the 2016 NWCA analysis, the NWCA vegetation analysis team developed a standardized compilation of C-value lists available at the end of 2019, and applicable to plant taxa occurring in specific individual states or regions across the conterminous US. This unpublished compilation is hereon referred to as the Compiled C-value Lists (unpublished draft) or the CCL. Citations for the individual C-value lists included in the CCL are provided in Appendix D (**Section 7.13**).

The CCL ultimately contained C-values for over 124,000 taxon-region pairs, which were standardized for potential use with observed NWCA taxon-region pairs. The 124,000+ taxon-region pairs in the CCL were recorded under the parameter name C-VALUE_NWCA_USE and accompanying each of these taxon-region pair C-values was the source abbreviation (see **Appendix D, Section 7.13**) for the specific C-Value List from which it originated.

Because diverse approaches to list organization, data formats, and taxonomy were used across the various C-value lists, it was necessary to standardize a variety of elements in the CCL. This standardization was reflected in the C-values listed under C-VALUE_NWCA_USE so they could later be applied to observed NWCA taxon-region pairs. The original C-value for each these records was also retained in the CCL.

C-values in the C-VALUE_NWCA_USE field of the CCL were standardized as indicated in the bullet points below:

- *Standardization of nomenclature* – The component C-value lists within the CCL used diverse taxonomic nomenclatures, with scientific names for plant taxa derived from state or regional floristic resources. To ensure that each taxonomic entity was referred to by the same name and compatible with NWCA accepted names (see **Section 7.5**), taxonomy for the Compiled C-value Lists was standardized, wherever possible, to the PLANTS database (USDA, NRCS 2019) nomenclature. For each taxon-region pair, both the PLANTS name and the name or names from the original C-value list were included in the CCL. When two or more synonyms for a single taxon-region pair were subsumed under a single PLANTS name, a decision tree (see B in the text box in **Figure 7-7**) was used to select among the C-values for the synonyms to apply for the NWCA taxon-region pair based on the PLANTS name.

- *Selecting C-value when multiple values were available for a taxon-region pair* – In the CCL, there were sometimes multiple C-values lists available for the same state or region. Consequently, there could potentially be more than one C-value available for the same taxon in that state/region. Where this occurred, a decision-tree (see A in the text box in **Figure 7-7**) was used to choose the most update-to-date or most rigorous/comprehensive list source from which to select the C-value for a specific taxon-region pair.

- *Standardization of C-value formats* – The methods and formats used for presentation of C-values varied among the state and regional lists, with C-values sometimes expressed as whole numbers ranging from 0 to 10 and sometimes as decimal numbers, e.g., 2.1, 6.7. Consequently, NWCA standardized all C-values as whole numbers between 0 and 10. C-values originally expressed as decimals were rounded to the nearest integer; for example, a C-value of 5.5 or higher was rounded to 6.

- *Standardization of C-value scoring for nonnative plant species* – States and regional C-value lists did not treat alien plant species uniformly. Some included nonnative species and others did not. Among those that did, the methods used to assign C-values for alien species were not standardized. For example, many states assigned a C-value of zero to all nonnative taxa, but occasionally alien taxa were ranked on a gradient of invasiveness using a range of negative integers for C-values to indicate increasing potential impact. To address this issue, NWCA standardized C-values for taxon-region pairs indicated as nonnative species by the CCL to zero.

- *Native taxon-region pairs listed in the CCL without C-values* – were designated undetermined (‘UND’).

Finally, we note that the specific criteria for C-value assignment varies somewhat across different state or regional lists, and this is likely to introduce some variability in C-values for taxon-region pairs listed in the CCL that is not strictly related to taxon responses to disturbance or natural conditions. However, floristic quality metrics calculated from C-values tend to be robust to many sources of noise.

Decision Tree for selecting C-value for potential use in the NWCA (*C-VALUE_NWCA_USE*)) when more than one C-value existed for a taxon-region pair in the *Compiled C-value Lists (unpublished)*

Definitions:

- ***C-VALUE_NWCA_USE* –** C-value for a taxon-region pair that has been standardized for potential use with observed NWCA taxon-region pairs
- ***2011NWCA_CVALUE*** – interim C-values used in 2011 NWCA analysis for observed taxon-region pairs (nwca2011_planttaxa_cc_natstat.csv on NWCA website)
- ***SOURCE 1*** – for a state or region: 1) only one list exists, or 2) the oldest list if two lists exist
- ***SOURCE2*** – for a state or region: Where two C-value lists exist for a state or region, the most recently completed one.

A. Decision points for selection of taxon-region pair for which the accepted PLANTS name in the CCL relates to only one taxon name from a C-value list(s) for a state or region

1. Are there multiple C-values for the taxa-location pair?
   a. NO -> Use the available C-value
   b. YES -> 2.
2. How many and which sources are there?
   a. Only one source is available (**2011NWCA_CVALUE**[1] or **Source 1**[2] or **Source 2**[3]) -> Use the available C-value
   b. **2011NWCA_CValue** and **Source 1** -> 3.
   c. **Source 1** and **Source 2** -> 4.
   d. **2011NWCA_CValue**, **Source 1** and **Source 2** -> 5.
3. Are **2011NWCA_CValue** and **Source 1** equal?
   a. NO -> Prioritize **Source 1** where available. Use **2011NWCA_CValue** when there is no **Source 1** value, or **Source 1** has no value for a specific taxon.
   b. YES -> Use matching C-value
4. How do **Source 1** and **Source 2** compare?
   a. **Source 1** and **Source 2** are equal -> Use matching -value
   b. **Source 1** and **Source 2** differ by only one value -> Use **Source 2**
   c. **Source 1** and **Source 2** differ by more than one value -> Review & decision by NWCA lead botanist
   d. **Source 1** and **Source 2** disagree on Nativity -> Review & decision by NWCA lead botanist
5. 2011NWCA_CValue, Source 1 and Source 2 are all available
   a. Use Source 1 or Source2 -> 4

B. Decision points where the accepted PLANTS name is applied to two to several names from an original C-value list (synonyms of the PLANTS name)[1]

1. If C-values among synonyms for the accepted name differ by 2 values or less -> Choose the higher C-value as the C-VALUE_NWCA_USE
2. If C-values among synonyms differ by more than 2 values -> Review and C-value decision by NWCA lead botanist
3. If there is a difference in native status between listed synonym names -> Review and C-value decision by NWCA lead botanist

[1]**Note:** The steps listed in B were completed for all taxon-region pairs observed in the 2011 and 2016 NWCAs that occurred in the CCL, but due to time limitations may not have been completed for all records in the CCL.

Figure 7-7. Text box outlining C-value selection decision tree when multiple C-values were available for one taxon-region pair

7.9.2 *Assigning Existing C-values to Taxon-Region Pairs Observed in the NWCA Surveys*

Each available C-value list included in the CCL was assigned a geography (GEOG) which reflected the areas to which that list was applicable, typically this was an individual state, or an EPA Level III Ecoregion (USEPA 2013) falling within part of one or more adjacent states. To facilitate assigning C-values from the Compiled C-value Lists (CCL) to observed NWCA taxa, each NWCA site sampled was assigned to one of 84 NWCA C-value Regions (see NWCA_CREG16, in the 2011 and 2016 site information files). Individual NWCA C-value Regions were defined as one of the following: an entire individual state, the portion of a state described by a specific Level III Ecoregion, or, in one case, the portions of a state falling on the east vs. west side of a mountain divide. Thus, a given NWCA C-value Region could represent an entire state or a part of state.

Existing standardized C-values (see **Section 7.9.1**) were assigned to NWCA taxon-region pairs (where region = NWCA C-value Region) with C-values for a particular region selected from one or more applicable lists of the CCL. Often both a regional and a state C-value list were pertinent to a particular NWCA C-value Region. In some instances, C-value coverage was incomplete for an NWCA C-value Region. When this was the case, C-values were considered from nearby geographies, i.e., adjacent or nearby states with the same or similar Level III Ecoregions. For each NWCA C-value Region, the NWCA lead botanist/ecologist prioritized the applicable CCL lists in order of best geographic/ecoregional fit and availability of C-values.

R-code was developed to assign C-values from the CCL to taxa in each NWCA C-value Region based on the prioritized order of the specific applicable C-value lists. Each NWCA C-value Region had two to four CCL geographies, from which C-values could be drawn. The CCL geographies (and their accompanying C-value lists) that were applicable to each NWCA C-value Region were given Priority 1, Priority 2, Priority 3, or Priority 4 for order of use. C-values were assigned from the CCL to the 2011 and 2016 NWCA taxon-region pairs in each NWCA C-value region using the following order:

- C-values were assigned first from the Priority 1 List.
- If no C-value for a taxon-region pair was available in the Priority 1 List, then C-value was assigned from the Priority 2 List.
- This process was continued sequentially through lists of subsequent priority levels until all available C-values from the CCL for relevant NWCA taxon-region pairs were assigned.

Using this approach, existing C-values from the CCL were assigned to nearly 22,000 NWCA taxon-region pairs. Of these taxon-region pairs, most were species or lower taxonomic-levels (i.e., subspecies, variety, hybrid). However, the CCL also included C-values for some genera, and, where available, they were applied to NWCA genus-region pairs.

7.9.3 *Defining C-values for NWCA Taxon-Region Pairs Where None Were Available*

After applying existing C-values from the CCL, a set of 2,245 NWCA taxon-region pairs still lacked C-values. These taxon-region pairs fell into three groups:

- Group 1 – 802 identified to species or lower taxonomic levels (e.g., species, subspecies, variety, or hybrid), hereafter species-region pairs
- Group 2 – 872 identified to only to genus
- Group 3 – 571 identified to only to high-level taxonomic categories (e.g., subfamily, family, growth form, or a few nonvascular taxa)

Group 1 – C-value Assignment for Species-Region Pairs – The 802 NWCA species-region pairs lacking C-values were evaluated to determine whether an existing C-value from a proximate geography that was not previously identified in the priority C-value lists for a particular NWCA C-value region might be available for use. Using this ecoregion extrapolation approach, the following steps were used in identifying C-values for these 802 NWCA species-region pairs:

- If a relevant C-value in an adjacent state and the same Level III ecoregion was available, it was applied to the NWCA species-region pair.
- If no such value was available, but a C-value from a nearby state and similar ecoregion was available, that C-value was selected.
- If multiple C-values from nearby geographies might apply, these were reviewed by the NWCA botanist/ecologist and the highest value (if there were 2 potential C-values) or the median value (if there were 3 or more potential C-values) was selected.
- If the NWCA species-region pair was considered introduced or adventive by NWCA, a C-value of 0 was assigned.
- If no C-value could be assigned, the NWCA species-region pair was assigned UND.

In all cases, the list in the CCL from which the C-value, assigned to a NWCA species-region pair, originated was noted (see Appendix D for source list abbreviations) in the final trait table. Where the C-value was derived from the median of several C-value source lists or was otherwise assigned by the NWCA botanist/ecologist, the C-value source was noted as NWCA16.

Using the above process, C-values were selected for 661 of the 802 NWCA species-region pairs that were not assigned values in the initial prioritization from the CCL.

Group 2 – Genus-Region Pair Assignments – The 872 NWCA genus-region pairs that were not initially assigned C-values from the CCL were evaluated in a two-step process to see if C-values could be developed. First, a tentative C-value was assigned based on the median C-value for species in the genus and occurring in the NWCA C-Region and also appearing on the priority 1, or priority 1 and 2 C lists in the CCL. Note, some C-lists include the flora of a state, but others include only a subset of the flora (e.g., sometimes only wetland species). The NWCA botanist/ecologist then reviewed these tentative genus-region C-values and accepted or rejected them using BPJ supported by information for the genus in the NWCA C-value region, e.g.:

- The number of C-values and species in the genus that the median C-value represented.
- How well was the genus represented on the C-value lists applicable to the NWCA C-value region? To address this question, PLANTS database maps or relevant floras were consulted to evaluate distribution of taxa in genus in the NWCA C-value region.
- Were nonnative species included in the genus, and if so, how many, and are they typically widespread invaders?
- Based on this review decide whether to accept median C-value or assign as undetermined. Record notes on decisions.

Using the above process, median C-values were selected for 665 of the 872 NWCA genus-region pairs not assigned values in the initial prioritization from the CCL.

Group 3 – High-Level Taxa or Growth Forms – The 571 taxon-region pairs in this group were assigned undetermined C-value (UND).

7.9.4 *Final NWCA C-value Trait Table*

The last step in finalizing the NWCA C-value Trait Table was ensuring that all taxa designated as introduced or adventive by the NWCA (see **Section 7.8**) received a C-value of zero.

The final C-value assignments for the taxon-region pairs observed in the 2011 and 2016 NWCAs are located in the NWCA C-value Trait Table (*nwca_2016_plant_cvalues.csv*) on the NWCA website. The source list from the CCL from which each NWCA taxon-region pair C-value originated is also noted in this table and designated by abbreviations defined in **Section 7.13, Appendix D**. C-values or UND status defined by NWCA are denoted by NWCA16 as the C-value source.

The NWCA C-value Trait Table includes C-values specific to 24,206 NWCA taxon-region pairs:

- 21,479 species-region pairs with C-values ranging from 0 to 10 (*here species includes*: species, subspecies, varieties, or hybrids)
- 1832 genus-region pairs with C-values ranging from 0 to 10
- 895 taxon-region pairs where C-value remained undetermined (UND)
    - 571 of these were family level or higher, taxa identified only to growth form, and a handful of nonvascular taxa
    - 183 of these were genus-region pairs
    - 141 of these were species-region pairs

The NWCA C-values were used in calculation of floristic quality indices (e.g., variations of FQAI and Mean C) and metrics describing sensitivity and tolerance to disturbance. See **Section 8.8, Appendix E Metrics** for a list of specific metrics. The NWCA adopted the standard practice of excluding taxon-region pairs with C-values = UND taxa from calculations of metrics of floristic quality and of disturbance sensitivity or tolerance. The NWCA taxon-region pairs with C-values = UND represented a very small proportion of NWCA taxa observed across all sites, and where these occurred, they typically had low abundance, so their exclusion was expected to have little impact on metric values.

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7.11 Appendix B: Vegetation Field Data Forms

FORM V-1: NWCA 2016 VEGETATION PLOT ESTABLISHMENT (Front)

Reviewed by (initial): ____

Site ID: NWCA16-

Date: ___ / ___ / 2 0 1 6

Vegetation Plot Layout - Fill in the bubble for the Vegetation Plot Layout configuration used in this AA (see Reference Card V-2 for descriptions of plot layout configurations).

○ Standard Veg Plot Layout - 1/2 ha Circular AA (Veg Plots on 2 axes, cardinal directions from AA Center)

Alternate Veg Plot Layouts

○ Wide Polygon AA Veg Plot Layout - 1/2 ha Polygon AA with width and length >30m (Veg Plots on 2 axes)

○ Narrow Polygon AA Veg Plot Layout - 1/2-ha Polygon AA ≤ 30m wide (Veg Plots on 1 axis)

○ Wetland Boundary AA Veg Plot Layout - AA <1/2-ha polygon equal to wetland boundary (Veg Plots distributed)

For alternate or obstacle vegetation plot layouts only: Coordinates for plot corner closest to the AA center.

○ **Obstacle Veg Plot Layout Used**

(Fill bubble if obstacles prevent placement of plot(s) as designated by the selected Veg Plot Layout).

Obstacle Type (mark all that apply):

○ Deep Water

○ Tide Channel

○ Safety Hazard

○ Other: ______

Plot	Latitude North (Decimal Degrees)	Longitude West (Decimal Degrees)
Plot 1	.	– .
Plot 2	.	– .
Plot 3	.	– .
Plot 4	.	– .
Plot 5	.	– .

Add Veg Plot locations to the annotated aerial photo. Number Veg Plots 1 through 5 using guidelines on Reference Card V-2. If needed, elaborate on plot layout or make notes about unique features or gradients in the vegetation or environment in the notes section on the back of this form.

Predominant NWCA Target Wetland Type	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Definitions:	○ EH	○ EH	○ EH	○ EH	○ EH
EH - Estuarine Emergent	○ EW	○ EW	○ EW	○ EW	○ EW
EW - Estuarine Shrub/Forest	○ PRL-EM	○ PRL-EM	○ PRL-EM	○ PRL-EM	○ PRL-EM
PRL-EM - Palustrine, Riverine, and Lacustrine Emergent	○ PRL-SS	○ PRL-SS	○ PRL-SS	○ PRL-SS	○ PRL-SS
PRL-SS - Palustrine, Riverine, and Lacustrine Scrub/Shrub	○ PRL-FO	○ PRL-FO	○ PRL-FO	○ PRL-FO	○ PRL-FO
PRL-FO - Palustrine, Riverine, and Lacustrine Forested	○ PRL-UBAB	○ PRL-UBAB	○ PRL-UBAB	○ PRL-UBAB	○ PRL-UBAB
PRL-UBAB - Palustrine, Riverine, and Lacustrine Unconsolidated	○ PRL-f	○ PRL-f	○ PRL-f	○ PRL-f	○ PRL-f
PRL-f - Palustrine, Riverine, and Lacustrine Farmed (not actively farmed)					
(See Reference Card AA-3, Side A for wetland type descriptions)					

Plant Species Nomenclature: Record citations for Floras/Field Guides/Databases used for plant identification

1. ______

2. ______

3. ______

4. ______

03/24/2016 V-1 NWCA 2016 Vegetation Plot Establishment

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FORM V-2: NWCA 2016 VASCULAR SPECIES PRESENCE AND COVER (Front)

Reviewed by (initial):______

Site ID: NWCA16-

Date: ___ / ___ / 2 0 1 6

Page 1 of ___

Instructions:

1. **General:** Print using ALL CAPITAL LETTERS. Write as neatly as possible, keeping all marks within data fields or workspace areas.
2. **Species Name:** List scientific name or pseudonym for each plant species observed in the Veg Plots (See the NWCA FOM for Pseudonym assignment rules).
3. **Presence Data:** For each species occurring in a quadrat nest (SW or NE corners of Veg Plot), **record the smallest quadrat/plot size in which it occurs by filling in the appropriate bubble (S (small) = 1-m² quadrat, M (medium) = 10-m² quadrat.) If a species does not occur in a particular nest (SW or NE), but occurs in the 100-m² Veg Plot, fill in the W (whole plot) bubble for that corner.**
4. **Predominant Height Class:** For each species observed, note its predominant height across each 100-m² Veg Plot by recording the appropriate height class code (defined below).
5. **Cover Data:** Estimate cover across each 100-m² Veg Plot (0 to 100%; See NWCA-FOM) for each species observed and record in the *Cover* data field. If necessary, use the gray workspace to make preliminary cover estimates for each species in each of the four quarters of the Veg Plot, and then combine preliminary estimates to obtain total cover for the species in the Veg Plot and record in the Cover data field.
6. **Collect Specimens and Assign Collection Numbers:** Follow procedures in NWCA FOM for specimen collection. Record the collection number for each specimen in the Coll # column. Label Unknown Specimens consecutively prefaced with the letter U, e.g., U1, U2, U3, etc. Label Quality Assurance (QA) Voucher Specimens consecutively prefaced with the letter Q, e.g., Q1, Q2, Q3, Q4, or Q5.

Total number of plots sampled: ___ of 5 | If less than 5 plots sampled, flag here & explain in comments ___ | **IMPORTANT:** Empty data cells or bubbles indicate absence or zero.

Complete if Collected

Height Classes (except E, which may occur in any vertical stratum):
1 = <0.5m, 2 = >0.5-2m, 3 = >2-5m, 4= >5-15m, 5 = >15-30m, 6 = >30m, and E = liana, vine or epiphyte species

		Plot 1					Plot 2					Plot 3					Plot 4					Plot 5					
Coll #	Species Name or Pseudonym	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	SW	NE	Ht. Class	% Cover	Work Space	Flag
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				
		S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				S M W	S M W				

Flag codes: K = No measurement made, U = Suspect measurement. F1,F2, etc. = misc. flags assigned by each field crew. Explain all flags in comment section on back side of form.

03/24/2016 V-2 NWCA 2016 Vascular Plant Species Presence & Cover (Front) 1848303096

FORM V-3: NWCA 2016 VEGETATION TYPES (Front)

Reviewed by (initial):______

Site ID: ________________ Date: ___/___/_____

Instructions:

1. Estimate the cover for each *Vascular Vegetation Stratum*.
2. Estimate cover and collect categorical data for *Non-Vascular Taxonomic Groups*.
3. Cover can range from 0 - 100% for each of the following groups: submerged aquatic vegetation, floating aquatic vegetation, lianas, vines, and epiphytes, each height class of other vascular vegetation and each Non-Vascular Group.

Total number of plots sampled: ___ of **5**

If less than 5 plots sampled, flag here & explain in comments ___

IMPORTANT: Empty data cells or bubbles indicate absence or zero.

% Cover Vascular Vegetation Strata	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Flag
COVER OF SUBMERGED AQUATIC VEGETATION (rooted in sediment, most plant cover submerged or floating on water) (0 - 100%)						
COVER OF FLOATING AQUATIC VEGETATION (not rooted in sediment) (0 - 100%)						
COVER OF LIANAS, VINES AND EPIPHYTES IN ANY HEIGHT CLASS (0 - 100%)						
COVER FOR ALL OTHER VASCULAR VEGETATION FOR EACH OF THE FOLLOWING HEIGHT CLASSES:						
>30m tall: e.g., very tall trees (0 - 100%)						
>15 to 30m tall: e.g., tall trees (0 - 100%)						
>5 to 15m tall: e.g., very tall shrubs; short to mid-sized trees (0 - 100%)						
>2 to 5m tall: e.g., tall shrubs; tree saplings (0 - 100%)						
0.5 to 2m tall: e.g., medium height shrubs; tree seedlings and saplings; tall aquatic emergent/terrestrial herbaceous species (0 - 100%)						
< 0.5m tall: e.g., low aquatic emergent/terrestrial herbaceous species; low shrubs; tree seedlings (0 - 100%)						

% Cover and Categorical Data for Non-Vascular Taxa	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Flag
COVER OF BRYOPHYTES (mosses and liverworts) growing on ground surfaces, logs, rocks, etc.) (0 - 100%)						
Fill bubble if Bryophytes are dominated by *Sphagnum* or other peat-forming mosses	○	○	○	○	○	
COVER OF LICHENS growing on ground surfaces, logs, rocks, etc. (0 - 100%)						
ABUNDANCE OF ARBOREAL EPIPHYTIC BRYOPHYTES AND LICHENS NONE: Absent. SPARSE: Less than 1/3 of woody surface area covered. COMMON: 1/3 to 3/4 of woody surface area covered. ABUNDANT: >3/4 of woody surface area covered, epiphytes often draping or pendant.	○ None ○ Sparse ○ Common ○ Abundant	○ None ○ Sparse ○ Common ○ Abundant	○ None ○ Sparse ○ Common ○ Abundant	○ None ○ Sparse ○ Common ○ Abundant	○ None ○ Sparse ○ Common ○ Abundant	
COVER OF FILAMENTOUS OR MAT FORMING ALGAE (0 - 100%)						
COVER OF MACROALGAE (freshwater species/seaweeds, living or wrack) (0 - 100%):						

Flag	Comments	Flag	Comments

Flag codes: K = No measurement made, U = Suspect measurement, F1,F2, etc. = misc. flags assigned by each field crew. Explain all flags in comment section.

03/24/2016 V-3 NWCA 2016 Vegetation Types

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FORM V-3: NWCA 2016 GROUND SURFACE ATTRIBUTES (Back) Reviewed by (initial):______

Site ID: ________ Date: __ / __ / ____

Instructions: For each ground surface attribute **carefully record the requested data**.

1. **Water Cover** – Estimate total percent of Veg Plot area covered by water.
2. **Water Depth** – Measure water depth with marked PVC pole or ruler to represent the predominant water level across the Veg Plot.
3. **Litter** – Estimate total cover of litter. Identify the predominant type. Measure litter depth in SW and NE most corners of Veg Plot in center of 1-m^2 quadrat.
4. **Bare ground** – Estimate cover for exposed a) soil/sediment, b) gravel/cobble, c) rock. (The sum of a+b+c ≤100%).
5. **Dead Woody Material Cover** – Estimate cover (0 to 100%) for each category of dead woody material.

Total number of plots sampled: ___ of 5

If less than 5 plots sampled, flag here & explain in comments ___

IMPORTANT: Empty data cells or bubbles indicate absence or zero.

Water Cover	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Flag
Total Cover of Water (0-100%)						
Water Depth	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
Predominant Depth (cm)						
Time of Day (24 hour clock)						
Cover of Bare ground = a+b+c ≤100%	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
a) Exposed soil/sediment						
b) Exposed gravel/cobble (~2mm to 25cm)						
c) Exposed rock (>25cm)						
Vegetative Litter	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
Total Cover Vegetative Litter (0-100%)						
Predominant Litter type (Select one per plot) G = Graminoid (e.g., grasses, sedges, rushes) C= Coniferous Tree F = Forb D = Deciduous Tree R = Fern E = Broadleaf Evergreen Tree	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	○G ○C ○F ○D ○R ○E	
Litter Depth (cm) in center of 1-m^2 quadrat at SW Veg Plot corner						
Litter Depth (cm) in center of 1-m^2 quadrat at NE Veg Plot corner						
Cover of Downed Dead Woody Material (angle of incline <45°)	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Flag**
Cover of Downed Coarse Woody debris (>5cm diameter) (0-100%)						
Cover of Downed Fine Woody debris (<5cm diameter) (0-100%)						

Flag	Comments

Flag codes: K = No measurement made, U = Suspect measurement, F1,F2, etc. = misc. flags assigned by each field crew. Explain all flags in comment section.

9075456264

03/24/2016 V-3 NWCA 2016 Ground Surface Attributes

FORM V-4: NWCA 2016 SNAG AND TREE COUNTS AND TREE COVER

Reviewed by (initial):______

Site ID: NWCA16-   Date: ___ / ___ / 2 0 1 6   Page 1 of ___

Total number of plots sampled: ___ of 5
If no trees were observed in plots, this counts as sampled.

If less than 5 plots sampled, flag here & explain in comments ___

IMPORTANT: Empty data cells equal zero

Instructions for Recording Data:

1. Fill out Header Information.

2. If either Live Trees or Snags are Present in a Veg Plot, collect data across the entire 100-m^2 area of each Veg Plot.

3. Small (<5cm DBH) Standing Dead Trees/Snags: Rapidly estimate approximate number.

4. Standing Dead (>5cm DBH) Trees and Snags (angle of incline > 45°): Count snags > 5cm DBH by diameter class and record the total number of snags for each DBH class in the white data column for the appropriate Veg Plot.

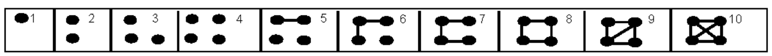
5. For Each Live Tree Species: Use one row for each plot in which each tree species is found. Be sure to indicate the Veg Plot number in the *Plot #* column next to each species name. Record species names or pseudonyms for each tree species. Ensure pseudonyms match those used on **Form V-2**.

6. Cover of trees in height classes: Record the percent cover (0-100%) for each tree species for each height class. (All trees, no minimum DBH).

7. Live Trees (>5cm DBH): Count trees in each Veg Plot by species in DBH classes and record the total number of trees for each diameter class in the white data column.

8. Counting Trees or Snags (>5cm DBH): If needed, for smaller DBH classes when many trees or snags are present, a running tally* of the numbers of all snags, or for each tree species, in each DBH class can be recorded in the gray shaded workspace in the DBH columns. Once all the snags or tree species are tallied for a plot, record the total number for each species in each DBH class in the white data field for each DBH column.

*Tally format



Estimate small standing dead trees/snags (<5cm DBH)

Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
○ None	○ None	○ None	○ None	○ None
○ Few(1-10)	○ Few(1-10)	○ Few(1-10)	○ Few(1-10)	○ Few(1-10)
○ Common(11-20)	○ Common(11-20)	○ Common(11-20)	○ Common(11-20)	○ Common(11-20)
○ Many(>20)	○ Many(>20)	○ Many(>20)	○ Many(>20)	○ Many(>20)

Standing Dead Tree/Snag Counts by DBH Class

(White box = data field, Gray box = tally workspace)

Plot	5 to 10cm		11 to 25cm		26 to 50cm		51 to 75cm		76 to 100cm	101 to 200cm	Flag
1											
2											
3											
4											
5											

Tree Cover by Height Class / Tree Counts by DBH Class

(White box = data field, Gray box = tally workspace) (DBH = diameter breast height)

Plot #	Live Tree Species Name/Pseudonym	<0.5m	>0.5-2m	>2-5m	>5-15m	>15-30m	>30m	5 to 10cm		11 to 25cm		26 to 50cm		51 to 75cm		76 to 100cm	101 to 200cm	>200 cm	Flag
○1 ○2 ○3 ○4 ○5																			
○1 ○2 ○3 ○4 ○5																			
○1 ○2 ○3 ○4 ○5																			
○1 ○2 ○3 ○4 ○5																			
○1 ○2 ○3 ○4 ○5																			
○1 ○2 ○3 ○4 ○5																			

Flag codes:K = No measurement made, U = Suspect measurement, F1, F2, etc = misc.flags assigned by each field crew. Explain all flags in comment section on the continuation page.

03/24/2016   V-4 NWCA 2016 Snag & Tree Counts (Front)   2766277681

7.12 Appendix C: Parameter Names for Field Collected Vegetation Data

PARAMETER NAME	DESCRIPTION	RESULT	VALID RANGE/ LEGAL VALUES
Form V-1: NWCA 2016 Vegetation Plot Establishment			
Plot Predominant Wetland Type Data: Observations from each of five 100-m2 (10x10m) Veg Plots			
WETLAND_TYPE	NWCA Target Wetland Type dominating Veg Plot	**One Category: EH -** Estuarine Intertidal Emergent, **EW** - Estuarine Shrub/Forested, **PRL-EM** -Palustrine, Lacustrine, or Riverine Emergent, **PRL-SS -** Palustrine, Lacustrine, or Riverine Scrub/Shrub, **PRL-FO -** Palustrine, Lacustrine, or Riverine Forested, **PRL-UBAB** - Palustrine, Lacustrine, or Riverine Unconsolidated Bottom, **PRL-f** - Palustrine, Lacustrine, or Riverine previously farmed (not currently actively farmed)	EH, EW, PRLEM, PRLSS, PRLFO, PRLUBAB, or PRLF
Form V-2a and V-2b: NWCA Vascular Species Presence and Cover			
***Plant Species Data*:** Cover, presence, and height data for each vascular plant species observed in each of five 100-m^2 (10x10m) Veg Plots. Presence of each species in four component nested quadrats for each Veg Plot.			
SPECIES	Scientific Name for each species (taxon) encountered in the Veg Plot.	Typically, the binomial genus and species name. In some cases: lower taxonomic levels (e.g., subspecies, varieties) or higher taxonomic levels (e.g., genus, family, growth form) or pseudonyms for unknowns	Taxon name
SW	For each species present, the smallest scale at which it is first observed: 1-m^2 or 10-m^2 quadrat in SW corner or in larger 100-m^2 Veg Plot	**One of:** S = 1-m^2 quadrat, M = 10-m^2 quadrat, or W = the whole 100-m^2 Veg Plot	S, M, or W
NE	For each species present, the smallest scale at which it is first observed: 1-m2 or 10-m2 quadrat in NE corner or in larger 100-m^2 Veg Plot	**One of:** S = 1-m^2 quadrat, M = 10-m^2 quadrat, or W = the whole 100-m^2 Veg Plot	S, M, or W
HEIGHT	Predominant height class for each species present across a Veg Plot	**One Height Class:** 1 = < 0.5m, 2 = > 0.5m-2m, 3 = > 2-5m, 4 = > 5-15m, 5 = > 15-30m, 6 = > 30m, or E = Liana, vine, or epiphyte species	1, 2,3, 4, 5, 6, or E
COVER	Percent cover of each species across a Veg Plot	Cover value for each individual species present is estimated as a direct percentage of the spatial area of the plot overlain by that species and can range from 0 to 100%.	0-100%
Form V-3: NWCA Vegetation Types (Front) and Ground Surface Attributes (Back)			
% Cover Vascular Vegetation Strata			

PARAMETER NAME	DESCRIPTION	RESULT	VALID RANGE/ LEGAL VALUES
SUBMERGED_AQ	% Cover Submerged Aquatic Vegetation	0-100 % Cover	0-100%
FLOATING_AQ	% Cover Floating Aquatic Vegetation	0-100 % Cover	0-100%
LIANAS	% Cover Lianas, vines, and vascular epiphytes	0-100 % Cover	0-100%
Cover for other vascular vegetation in height classes indicated below:			
VTALL_VEG	% Cover Vegetation > 30m tall	0-100 % Cover	0-100%
TALL_VEG	% Cover Vegetation > 15m to 30m tall	0-100 % Cover	0-100%
HMED_VEG	% Cover Vegetation > 5m to 15m tall	0-100 % Cover	0-100%
MED_VEG	% Cover Vegetation >2m to 5 tall	0-100 % Cover	0-100%
SMALL_VEG	% Cover Vegetation 0.5 to 2m tall	0-100 % Cover	0-100%
VSMALL_VEG	% Cover Vegetation < 0.5m tall	0-100 % Cover	0-100%
% Cover and Categorical Data for Non-Vascular Taxa			
BRYOPHYTES	% Cover of Bryophytes growing on ground surfaces, logs, rocks, etc.	0-100 % Cover	0-100%
PEAT_MOSS	Bryophytes dominated by Sphagnum or other peat forming moss	Y (yes) if present	Y
LICHENS	% Cover of Lichens growing on ground surfaces, logs, rocks, etc.	0-100 % Cover	0-100%
ARBOREAL	Abundance of Arboreal Bryophytes and Lichens	Categorical classes: ABUNDANT, COMMON, SPARSE, NONE	ABUNDANT, COMMON, SPARSE, or NONE
ALGAE	% Cover of filamentous or mat forming algae	0-100 % Cover	0-100%
MACROALGAE	% Cover of macroalgae (freshwater species/seaweeds)	0-100 % Cover	0-100%
Water Cover and Depth			
TOTAL_WATER	Total percent cover of water across Veg Plot area	% Cover	0-100%
PREDOMINANT_DEPTH	Predominant water depth	depth in cm	Investigate if >200 cm
TIME	Time water depth measurements were made	time on 24 hour clock	500 to 2100 (investigate if outside this range)
Bare ground and Litter			
Cover of bare ground = a + b + c ≤ 100%			
EXPOSED_SOIL	a) Cover exposed soil/sediment	% Cover	≤ 100%
EXPOSED_GRAVEL	b) Cover exposed gravel/cobble (~2mm to 25cm)	% Cover	≤ 100%

PARAMETER NAME	DESCRIPTION	RESULT	VALID RANGE/ LEGAL VALUES
EXPOSED_ROCK	c) Cover exposed rock (>25cm)	% Cover	≤ 100%
Vegetation Litter			
TOTAL_LITTER	Total cover of vegetation litter	% Cover	≤ 100%
PREDOMINANT_LITTER	Predominant litter type	G=Graminoid (e.g., grasses, sedges, rushes), F=Forb, R=Fern, C=Coniferous Tree/shrub, D=Deciduous Tree/shrub, E=Broadleaf Evergreen Tree/shrub	CONIFEROUS, DECIDUOUS, GRAMINOID, FORB, FERN, BROADLEAF
DEPTH_SW	Litter depth (cm) in center of 1-m^2 quadrat at SW corner of Veg Plot	depth in cm	Investigate if >100 cm
DEPTH_NE	Litter depth (cm) in center of 1-m^2 quadrat at NE corner of Veg Plot	depth in cm	Investigate if >100 cm
Cover of Downed Dead Woody Material (angle of incline < 45°)			
WD_FINE	Cover of fine woody debris (<5cm diameter)	% Cover	0-100%
WD_COARSE	Cover of coarse woody debris (> 5cm diameter)	% Cover	0-100%
Form V-4a and V-4b: NWCA Snag and Tree Counts and Tree Cover			
Standing Dead trees/snags (<5cm DBH)			
STANDING	Estimate of small standing trees/snags on plot	Abundance Class: None (0), Few (1-10), Common (11-20), Many (>20)	NONE, FEW, COMMON, MANY
Standing Dead Tree/Snag Counts by DBH Class			
XXTHIN_SNAG	Dead trees/snags 5 to 10 cm DBH (diameter breast height)	Counts	Investigate if > 200
XTHIN_SNAG	Counts of dead trees/snags 11 to 25cm DBH	Counts	Investigate if > 200
THIN_SNAG	Counts of dead trees/snags 26 to 50cm DBH	Counts	Investigate if > 100
JR_SNAG	Counts of dead trees/snags 51 to 75cm DBH	Counts	Investigate if > 20
THICK_SNAG	Counts of dead trees/snags 76 to 100cm DBH	Counts	Investigate if > 20
XTHICK_SNAG	Counts of dead trees/snags 101 to 200 cm DBH	Counts	Investigate if > 20
Tree Data			
Tree Species Name			

PARAMETER NAME	DESCRIPTION	RESULT	VALID RANGE/ LEGAL VALUES
TREE_SPECIES	Scientific Name for each tree species (taxon) encountered in the Veg Plot.	Typically, the binomial genus and species name. In some cases: lower taxonomic levels (e.g., subspecies, varieties) or higher taxonomic levels (e.g., genus, family, growth form) or pseudonyms for unknowns	Taxon Name
Tree Species Cover by Height Class			
VSMALL_TREE	For each tree species, cover of trees < 0.5m tall	0-100 % Cover	0-100%
SMALL_TREE	For each tree species, cover of trees 0.5m to 2m tall	0-100 % Cover	0-100%
LMED_TREE	For each tree species, cover of trees > 2 to 5m tall	0-100 % Cover	0-100%
HMED_TREE	For each tree species, cover of trees > 5m to 15m tall	0-100 % Cover	0-100%
TALL_TREE	For each tree species, cover of trees > 15m to 30m tall	0-100 % Cover	0-100%
VTALL_TREE	For each tree species, cover of trees > 30m tall	0-100 % Cover	0-100%
Tree Species Counts by DBH Class			
XXTHIN_TREE	For each tree species, counts of trees 5 to 10 cm DBH (diameter breast height)	Counts	Investigate if > 200
XTHIN_TREE	For each tree species, counts of trees 11 to 25cm DBH	Counts	Investigate if > 100
THIN_TREE	For each tree species, counts of trees 26 to 50cm DBH	Counts	Investigate if > 50
JR_TREE	For each tree species, counts of trees 51 to 75cm DBH	Counts	Investigate if > 20
THICK_TREE	For each tree species, counts of trees 76 to 100cm DBH	Counts	Investigate if > 10
XTHICK_TREE	For each tree species, counts of trees 101 to 200 cm DBH	Counts	Investigate if > 5
XXTHICK_TREE	For each tree species, counts of trees > 200 cm DBH	Counts	Investigate if > 5

7.13 Appendix D: Existing Coefficient of Conservatism Lists included in the *Compiled C-value Lists* (*unpublished draft*) assembled by NWCA

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
All 48 Individual Conterminous United States	**NWCA11**	USEPA (2016) US Environmental Protection Agency. National Aquatic Resource Surveys. National Wetland Condition Assessment 2011 (NWCA 2011 Plant CC and Native Status Values - Data (CSV) and NWCA 2011 Plant CC and Native Status Values - Metadata (TXT)). [Includes (for observed plant species) state-level trait information for: C-Values, Native Status Designations, and Disturbance Sensitivity Categories]. Available from USEPA website: https://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys.
AZ	**EPA19_AZ**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019, unpub.). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
CA	**EPA19_CA**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
CO	**ROCC_07**	Rocchio, J. (2007). Floristic quality assessment indices for Colorado plant communities. Fort Collins, Colorado: Colorado Natural Heritage Program, Colorado State University.
CT	**NEIW13_CT**	New England Interstate Water Pollution Control Commission (NEIWPCC). (2013) Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: Connecticut.
DE	**MCAV12**	McAvoy, W.A. (2011) The Flora of Delaware Online Database. Delaware Division of Fish and Wildlife, Natural Heritage and Endangered Species Program, Smyrna, Delaware. http://www.wra.udel.edu/de-flora. Current URL (28 August 2019): http://www.wrc.udel.edu/de-flora/

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
FL (Source 1)	**LANE03**	Lane, C.R., Brown, M., Murray-Hudson, M. and Vivas, M. B. (2003) The Wetland Condition Index (WCI): Biological indicators for Isolated Depressional Herbaceous Wetlands in Florida, Report Submitted to the Florida Department of Environmental Protection under Contract #WM-683
FL (Source 2)	**REIS05**	A) Reiss, K.C.& Brown, M.T. (2005a) The Florida Wetland Condition Index (FWCI): Developing Biological Indicators for Isolated Depressional Forested Wetlands. B) Reiss, K.C.& Brown, M.T. (2005) Pilot Study - The Florida Wetland Condition Index (FWCI): Preliminary Development of Biological Indicators for Forested Strand and Floodplain Wetlands. Report Submitted to the Florida Department of Environmental Protection Under Contract #WM-683
FL_South	**MORT09**	Mortellaro, S., Barry, M., Gann, G., Zahina, J., Channon, S., Hilsenbeck, C., Scofield, D., Wilder, G., & Wilhelm, G. (2009). Coefficients of Conservatism Values and the Floristic Quality Index for the Vascular Plants of South Florida. Southeastern Naturalist, 11(mo3), 1-62, 62.
GA	**ZOML13**	Zomlefer, W. B., Chafing. L.G., Carter, J.R. and Giannasi, D.E. (2013) Coefficient of Conservatism Rankings for the Flora of Georgia: Wetland Indicator Species. Southeastern Naturalist 12:790–808.
IA	**DROB01**	Drobney, P.D., Wilhelm, G.S., Horton, D., Leoschke, M., Lewis, D., Pearson, J., Roosa, D., and Smith, D. (2001) Floristic quality assessment for the state of Iowa. Unpublished report.
ID	**EPA19_ID**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
IL	**TAFT03**	Taft, J.B., Wilhelm, G.S., & Masters, L.A. (2003) Floristic quality assessment for vegetation in Illinois a method for assessing vegetation integrity. Illinois Native Plant Society
IN	**ROTH19**	Rothrock, P.E. (2019) The Floristic quality assessment of Indiana concepts, use and development of coefficients of conservatism. Final Report for ARN A305-4-53 EPA Wetland Program Development Report Grant CD975586-01

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
IN	**ROTH04**	Rothrock, P.E. (2004) The Floristic quality assessment of Indiana concepts, use and development of coefficients of conservatism. Final Report for ARN A305-4-53 EPA Wetland Program Development Report Grant CD975586-01.
KS	**FREE12**	Freeman, C. C. (2012) Coefficients of Conservatism for Kansas Vascular Plants (2012) and Selected Life History Attributes. Kansas Biological Survey, University of Kansas. http://ksnhi.ku.edu/media/ksnhi/public-data-resources/Coefficients%20of%20Conservatism%20for%20Kansas%20Vascular%20Plants%20%282012%29.pdf
KY	**WHIT97**	White, D., Shea, M., Ladd, D. and Evans, M. (1997) Floristic quality assessment for Kentucky. The Kentucky Chapter of The Nature Conservancy, Kentucky State Nature Preserves Commission, The Missouri Chapter of The Nature Conservancy
LA	**CRET12**	Cretini, K.F., Visser, J.M., Krauss, K.W., & Steyer, G.D. (2012) Development and use of a floristic quality index for coastal Louisiana marshes. *Environmental Monitoring and Assessment*. 184:2389–2403. List included as supplement to paper. An updated list with a few added species was provided to Nicole Kirchner in July 2012.
MA	**NEIW13_MA**	New England Interstate Water Pollution Control Commission (NEIWPCC). (2013). Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: Massachusetts.
ME	**NEIW13_ME**	New England Interstate Water Pollution Control Commission (NEIWPCC). (2013). Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: Maine.
ME	**MENA14**	Maine Natural Areas Program. (2014) Coefficient of Conservatism Scores for Maine. Maine Natural Areas Program, Augusta, Maine, USA. Current URL (8-28-2019: https://www.maine.gov/dacf/mnap/features/coc.htm
MI	**REZN14**	Reznicek, A.A., Penskar, M.R., Walters, B.S. and Slaughter, B.S. (2014) Michigan Floristic Quality Assessment Database. Herbarium, University of Michigan, Ann Arbor, MI and Michigan Natural Features Inventory, Michigan State University, Lansing, MI. (http://michiganflora.net/home.aspx)
MI	**HERM01**	Herman, K.D., Masters, L.A., Penskar, M.R., Reznicek, A.A., Wilhelm, G.S., Brodovich, W.W. and Gardiner, K.P. (2001) Floristic quality assessment with wetland categories and examples of computer applications for the state of Michigan. 2nd Edition. Michigan Dept. of Natural Resources, Lansing, MI. 19 pp. + appendices.

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
		http://www.michigandnr.com/publications/pdfs/HuntingWildlifeHabitat/FQA_text.pdf
MN	**MILB07**	Milburn, S. A., Bourdaghs, M. and Husveth (2007) Floristic Quality Assessment for Minnesota Wetlands. Minnesota Pollution Control Agency, St. Paul, Minn. Accessed at www.pca.state.mn.us/water/biomonitoring/bio-wetlands.html
MO	**LADD93**	Ladd, D. (1993) Coefficients of conservatism for the Missouri vascular flora: a database of the flora of missouri with species conservatism coefficients, wetness ratings, physiognomy, standardized acronyms, and common names. Missouri chapter of the Nature conservancy.
MO	**LADD15**	Ladd, D. and Thomas, J.R. (2015) Ecological checklist of the Missouri flora for Floristic Quality Assessment. Phytoneuron. 2015-12: 1–274. Published 12 February 2015. ISSN 2153 733X
MS	**HERM06**	Herman, B.D., Madsen, J. D. and Ervin, G.D. (2006) Development of coefficients of conservatism for wetland vascular flora of north and central Mississippi. Mississippi State University, GeoResources Institute Report 4001 (Water Resources)
MT	**PIPP15_16**	Pipp, A. (2015) Coefficient of Conservatism Rankings for the Flora of Montana: Part I. Report to the Montana Department of Environmental Quality, Helena, Montana. Prepared by the Montana Natural Heritage Program, Helena, Montana. 73 pp
MT	**PIPP15_16**	Pipp, A. (2016) Coefficient of Conservatism Rankings for the Flora of Montana: Part II. Report to the Montana Department of Environmental Quality, Helena, Montana. Prepared by the Montana Natural Heritage Program, Helena, Montana. 75 pp.
MT	**JONE05**	Jones, W.M. (2005) A vegetation index of biotic integrity for small order streams in southwestern Montana and floristic quality assessment for western Montana wetlands. Report to the Montana Department of Environmental Quality and US Environmental Protection Agency, Montana Natural Heritage program, Helena Montana. 29 pp. plus appendices.

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
ND	**TNGP01**	The Northern Great Plains Floristic Quality Assessment Panel. (2001) Coefficients of conservatism for the vascular flora of the Dakotas and adjacent grasslands: US Geological Survey, Biological Resources Division, Information and Technology Report USGS/ BRD/ITR—2001-0001, 32 p.
NE	**ROLF11**	Rolfsmeier, S. & Steinauer, G. (2003, 2011) Vascular plants of Nebraska (Version I -July 2003). Nebraska Game and Parks Commission. Lincoln, NE 57 pp. List was updated in 2011 and forwarded via email from G. Steinaur to Nicole Kirchner in 2011.
NH	**NEIW13_NH**	New England Interstate Water Pollution Control Commission (NEIWPCC). (2013) Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: New Hampshire.
NJ	**WALZ17**	Walz, K. S., Kelly, L. and Anderson, K. (2017) Floristic Quality Assessment Index for Vascular Plants of New Jersey: Coefficient of Conservancy (CoC) Values for Species and Genera. New Jersey Department of Environmental Protection, New Jersey Forest Service, Office of Natural Lands Management, Trenton, NJ, 08625. Submitted to United States Environmental Protection Agency, Region 2, for State Wetlands Protection Development Grant, Section 104(B)(3); CFDA No. 66.461, CD97225809.
NJ	**KELL13**	Kelly, L., Anderson, K. & Walz, K.S. (2013) New Jersey floristic quality assessment: coefficients of conservatism for vascular taxa
NM	**EPA19_NM**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
NV	**EPA19_NV**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
NY	**NEIW13_NY**	New England Interstate Water Pollution Control Commission (NEIWPCC) (2013) Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: New York.
OH	**ANDR04**	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.
OK	**EWIN12**	Ewing, A.K., and Hoagland, B. (2012) Development of floristic quality index approaches for wetland plant communities in Oklahoma. USEPA Final Report, FY201, 104(b)(3), CD-00F074, Project 2.
OR	**EPA19_OR**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
OR	**MAGE01**	Magee, T.K. and Bollman, M.A. (2013, unpublished). C-values for ~500 Streamside plant species in eastern Oregon.
RI	**NEIW13_RI**	New England Interstate Water Pollution Control Commission (NEIWPCC). (2013) Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: Rhode Island.
SD	**TNGP01**	The Northern Great Plains Floristic Quality Assessment Panel, (2001) Coefficients of conservatism for the vascular flora of the Dakotas and adjacent grasslands: US Geological Survey, Biological Resources Division, Information and Technology Report USGS/ BRD/ITR—2001-0001, 32 p.
TN	**TN_CC**	Compiled from:1) Willis, K. and Estes, L. unpub. 2013. Floristic Quality Assessment for Tennesee Vascular Plants, 2) Gianopulos, K. (2014) Coefficient of Conservatism Database Development for Wetland Plants Occurring in the Southeast United States: Summary Document. North Carolina Dept. of Environment and Natural Resources, Division of Water Resources. See: USEPA (2016) National Wetland Condition Assessment: 2011 Technical Report. EPA-843-R-15-006. Section 5.9 Species Traits – Coefficients of Conservatism.

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
TX	**EPA19_TX**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
UT	**EPA19_UT**	Fennessy, M. S., & Great Lakes Environmental Center, Inc (2019). Project to assign C-values to western states for use in the USEPA National Wetland Condition Assessment (NWCA): C-values for taxon-state pairs observed in AZ, CA, ID, NV, NM, OR, TX, UT during the 2011 and 2016 NWCA Surveys. Funded by USEPA Office of Wetlands, Oceans, and Watersheds to the Great Lakes Environmental Center, Traverse City, MI. EP-C-16-008: Task Order #08. Unpublished Report and Excel File (NWCA_C_Values__Western States_11-6-2018_Draft) Submitted to USEPA.
VA	**VDEP05**	Virginia Department of Environmental Quality (2005) Determining coefficient of conservatism values (C-Values) for vascular plants frequently encountered in tidal and nontidal wetlands in Virginia. Report prepared for US Environmental Protection Agency-Region III. Wetlands Program Development Grant #CD983380-01
VT	**NEIW13_VT**	New England Interstate Water Pollution Control Commission (NEIWPCC). (2013) Northeast Regional Floristic Quality Assessment. Current URL (27 August 2019): https://neiwpcc.org/our-programs/wetlands-aquatic-species/nebawwg/nqa/. Individual State CoC lists: Vermont.
WA	**ROCC13**	Roccio, F.J. & Crawford, R.C. (2013) Floristic quality assessment for Washington vegetation. Washington Natural Heritage Program Washington Department of Natural Resources. Natural Heritage Report 2013-03. USEPA Wetland Program Development Grant Assistance Agreements: 1) CD-00J26301 and CD-00J49101
WI	**BERN03**	Bernthal, T.W. (2003) Development of a Floristic Quality Assessment methodology for Wisconsin. Report to the USEPA (Region V). Wisconsin Department of Natural Resources: Bureau of Fisheries Management and Habitat Protection. USEPA Wetland Grant # CD975115-01-0
WI	**CHUN17**	Chung-Gibson, M., Bernthal T., Doyle K., Wetter, M., Haber, E. (2017). Wisconsin Department of Natural Resources, Water Quality Bureau. From WDNR_FQA_Calculator_v1.5.17. Nomenclature from Wisconsin State Herbarium, University of Wisconsin-Madison (2016). COFC values from

State or Region	Source Abbreviation	Coefficient of Conservatism Lists included in the Compilation of Existing C-values
		Bernthal, TW. Development of a Floristic Quality Assessment Methodology for Wisconsin. Wisconsin Department of Natural Resources, 2003. Note that regions differ only in Wetland Indicator Status.
WI	**PARK14**	Parker, E.C., Curran, M., Waechter, Z.S. and Grosskopf, E.A. (2014) Wisconsin FQA (Floristic Quality Assessment) Databases for Midwest and Northcentral-Northeast Regions for Universal FQA Calculator.
WV	**RENT06**	Rentch, J.S.& Anderson, J.T. (2006) A floristic quality index for West Virginia wetland and riparian plant communities. Division of Forestry and Natural Resources, West Virginia University. US Department of Agriculture CREES, Award No. 2004-38874-02133.
WV	**WVHP15**	West Virginia Natural Heritage Program (2015) Coefficients of Conservatism for the Vascular Flora of West Virginia. Wildlife Diversity Unit, West Virginia Division of Natural Resources, Elkins, West Virginia, USA.
WY	**WASH15**	Washkoviak L, Heidel, B, and Jones, G (2017). Floristic Quality Assessment for Wyoming Flora: Developing Coefficients of Conservatism. Prepared for the US Army Corps of Engineers. The Wyoming Natural Diversity Database, Laramie, Wyoming. 13 pp. plus appendices.
Mid-Atlantic (Mid_Atl) Region	**CHAM12**	Chamberlin J, Ingram H (2012) Developing coefficients of conservatism to advance floristic quality assessment in the Mid-Atlantic region.
Northeast (NEngl) Region	**FABE18**	Faber-Langendoen, D. (2018) Northeast Regional Floristic Quality Assessment Tools for Wetland Assessments. NatureServe, Arlington VA
Southeast (SEast) Region	**GIAN14**	Gianopulos, K. (2014) Coefficient of Conservatism Database Development for Wetland Plants Occurring in the Southeast United States: Summary Document. North Carolina Dept. of Environment and Natural Resources, Division of Water Resources.

Chapter 8: Vegetation Analyses and Candidate Metric Evaluation Prerequisite to Multimetric Index Development

8.1 Overview

In the 2011 NWCA, a national-scale Vegetation Multimetric Index (VMMI) was developed with thresholds for good, fair, and poor based on VMMI values observed in least-disturbed sites (USEPA 2016a, Magee et al. 2019a). However, with the additional data from the 2016 survey, it was possible to consider developing more specific VMMIs, e.g., for broad wetland groups or broad geographic regions.

Therefore, we used data from both the 2011 and 2016 NWCA surveys (**Figure 8-1**) to develop updated VMMIs. For sites that had repeat sampling events, the data from the Index Visit (see **Section 6.1**) to that site were used for developing the disturbance gradient (**Chapter 6:**) and for developing the VMMIs (this chapter and **Chapter 9**:). 1,987 unique sites were used in setting the disturbance gradient (see **Table 6-1**); however, at two of these sites, vegetation data were not collected.

Consequently, the Index Visit data from 1985 NWCA sites where vegetation was sampled in 2011 or 2016 (**Table 8-1**) were used in calculating and evaluating candidate vegetation metrics (**Sections 8.4** and **8.5**) and developing four Wetland Group VMMIs (**Chapter 9:**).

Several initial analysis steps were needed to support development of the NWCA VMMIs:

Step 1: Definition of anthropogenic disturbance gradients by identifying least- and most-disturbed sites (**Section 8.2** and **Chapter 6:**).
Step 2: Consideration of sample sizes and variability in species composition across regions and wetland types to determine potential scales (e.g., national, wetland type, ecoregion) for metric evaluation and VMMI development (**Section 8.3**).
Step 3: Calculation (**Section 8.4**) of candidate vegetation metrics.
Step 4: Evaluation of candidate vegetation metrics (**Section 8.5**) for use in VMMI development.

In addition to the Index Visit data, where unique sites also had a sampling revisit (Visit 2) during the same field season, these revisit data were compared to data of the Index Visit to calculate signal:noise (S:N) ratios, which were used in aspects of metric (**Section 8.5.2**) and VMMI (**Section 9.3.2**) screening.

Analyses were completed with R Statistical Software, ver. 3.6.1 (R Core Team 2019), except detrended correspondence analysis for which PC-ORD, ver. 7.8 (McCune and Mefford 2018) was used.

Table 8-1. Numbers of unique NWCA 2011 and 2016 sampled sites. NWCA_REF (Disturbance): L = Least, I = Intermediate, M = Most, ? = Undetermined. Revisit = site sampled twice in same field season.

ALL SITES	n Numbers of Unique Sites by Type							
	Total	L	I	M	?	Revisit	Calibration	Validation
	1985	439	1061	474	11	104	1587	398

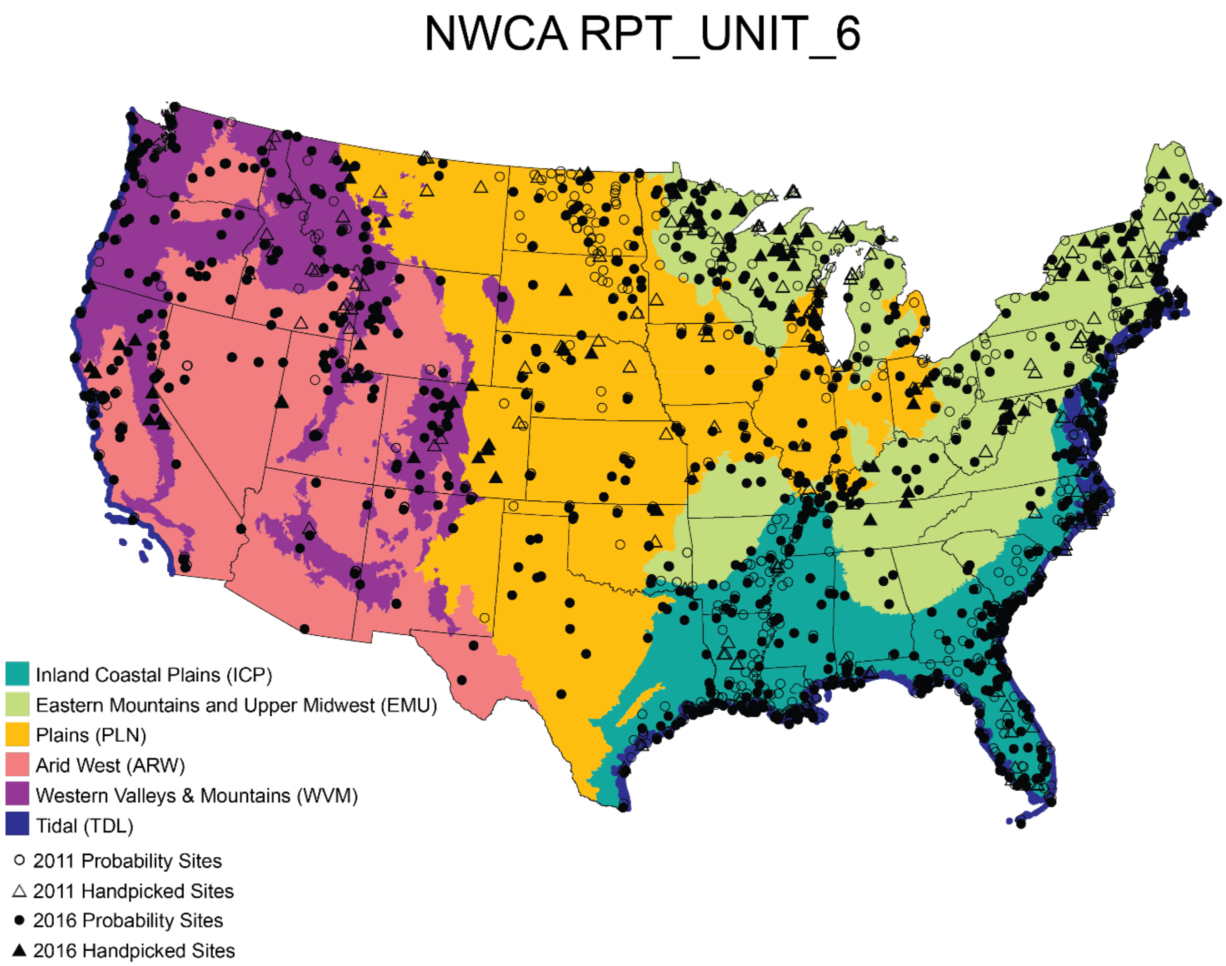


Figure 8-1. Distribution of probability and hand-picked sites sampled in the 2011 and 2016 NWCA surveys within Six Reporting Units (RPT_UNIT_6). TDL = coastal areas where tidally-influenced estuarine wetlands occur. Inland wetlands are mapped within five geographic regions.

8.2 Anthropogenic Disturbance

Both the evaluation of candidate metrics for utility in reflecting ecological condition and the development of VMMIs require least- and most-disturbed sites to anchor the ends of an anthropogenic disturbance gradient (USEPA 2016a, Magee et al. 2019a). In addition, least-disturbed sites are used in setting thresholds for good, fair, and poor condition based on VMMI values (Magee et al. 2019a, Herlihy et al. 2019).

The multi-step process for screening and assigning least-disturbed, intermediate-disturbed, or most-disturbed status to NWCA sites is detailed in Chapter 6: and summarized in **Appendix A: Illustrative Guide to Assigning Disturbance Class in Six Steps**. In brief, a stepwise process was used in which sites were first screened for abiotic disturbance using physical indices (Section 6.3), then by chemical indices (Section 6.4) to assign abiotic disturbance classes. Least-disturbed sites passing the physical and chemical screens (Section 6.5), were further screened with a biological metric (XRCOV_AC, (Section 6.6), the relative percent cover of nonnative (alien and cryptogenic, **Table 7-5**) plants. The final set of least-, intermediate-, and most-disturbed sites (REF_NWCA) was used for evaluation of vegetation candidate metrics and for VMMI development based on the Index Visit data from 1985 unique NWCA sites where vegetation was sampled in 2011 or 2016 (Table 8-1).

8.3 Considering Regional and Wetland Type Differences

To account for physical and biotic diversity across the national scale, finer scales are often needed to facilitate development of the most effective MMIs (Stoddard et al. 2008, USEPA 2006, Herlihy et al. 2019). Plant species composition in wetlands varies widely across the conterminous United States, both with environmental conditions and wetland type (Herlihy et al. 2019, USEPA 2016a, Magee et al. 2019a). We evaluated a series of potential subpopulation groups (Table 5-1) in an effort to minimize natural variation, while maintaining sample sizes sufficient to inform candidate metric evaluation and VMMI development. To identify scales relevant for VMMI development based on the plant data from NWCA 2011 and NWCA 2016 sampled sites, we examined the following groupings listed from finer to coarser scale:

- RPT_UNIT12 (Table 8-2, Figure 8-2): 12 subpopulations based on combining region (RPT_UNIT_6) and wetland group (WETCLS_GRP)
- RPT_UNIT_6 (Table 8-3): six subpopulations including tidally-influenced estuarine wetlands in coastal areas and inland wetlands in 5 aggregated ecoregions
- WETCLS_GRP (Table 8-4): four subpopulations describing broad Wetland Groups

Table 8-2 through Table 8-4 include, for each subpopulation: 1) the total number of unique sampled sites; 2) the numbers of sites identified as "least disturbed", "intermediate disturbed", and "most disturbed"; 3) the number of revisit sites (sites sampled twice during the same sampling season to quantify within-year sampling variability); and 4) the number of calibration and validation sites used in analyses. Ordination analysis of the plant species data was used to evaluate how species composition (presence and abundance) varied in relation to these broad ecoregional and wetland group subpopulations (Figure 8-3).

Table 8-2. Numbers of unique NWCA 2011 and NWCA 2016 sampled sites by RPT_UNIT12 (RPT_UNIT_6 x WETCLS_GRP). RPT_UNIT_6 is defined in **Figure 6-2** and **Table 6-3**. WETCLS_GRP is defined in **Table 6-4**. REF_NWCA (Disturbance): L = Least, I = Intermediate, M = Most, ? = undetermined. Revisit = site sampled twice in same field season.

RPT_UNIT12 (RPT_UNIT_6 x WETCLS_GRP)	RPT_GRP_12*	n Numbers of Sites by Type							
		Total	L	I	M	?	Revisit	Calibration	Validation
TDL-H	ALL-EH	374	134	158	81	1	18	298	76
TDL-W	ALL-EW	87	15	43	27	2	4	70	17
ICP-H	CPL-PRLH	104	21	48	34	1	3	83	21
ICP-W	CPL-PRLW	307	65	168	71	3	11	247	60
EMU-H	EMU-PRLH	116	29	61	26	0	11	90	26
EMU-W	EMU-PRLW	234	72	115	46	1	17	181	53
PLN-H	IPL-PRLH	210	19	124	65	2	15	169	41
PLN-W	IPL-PRLW	141	34	84	23	0	4	121	20
ARW-H	XER-PRLH	109	7	70	32	0	2	86	23
ARW-W	XER-PRLW	59	3	43	13	0	3	40	19
WVM-H	WMT-PRLH	113	20	63	30	0	8	94	19
WVM-W	WMT-PRLW	131	20	84	26	1	8	108	23

**Note: membership of sites in subpopulations of RPT_UNIT12 and of RPT_GRP_12 is the same*. RPT_UNIT12 codes were created to allow matching with codes in RPT_UNIT_6 and WETCLS_GRP.

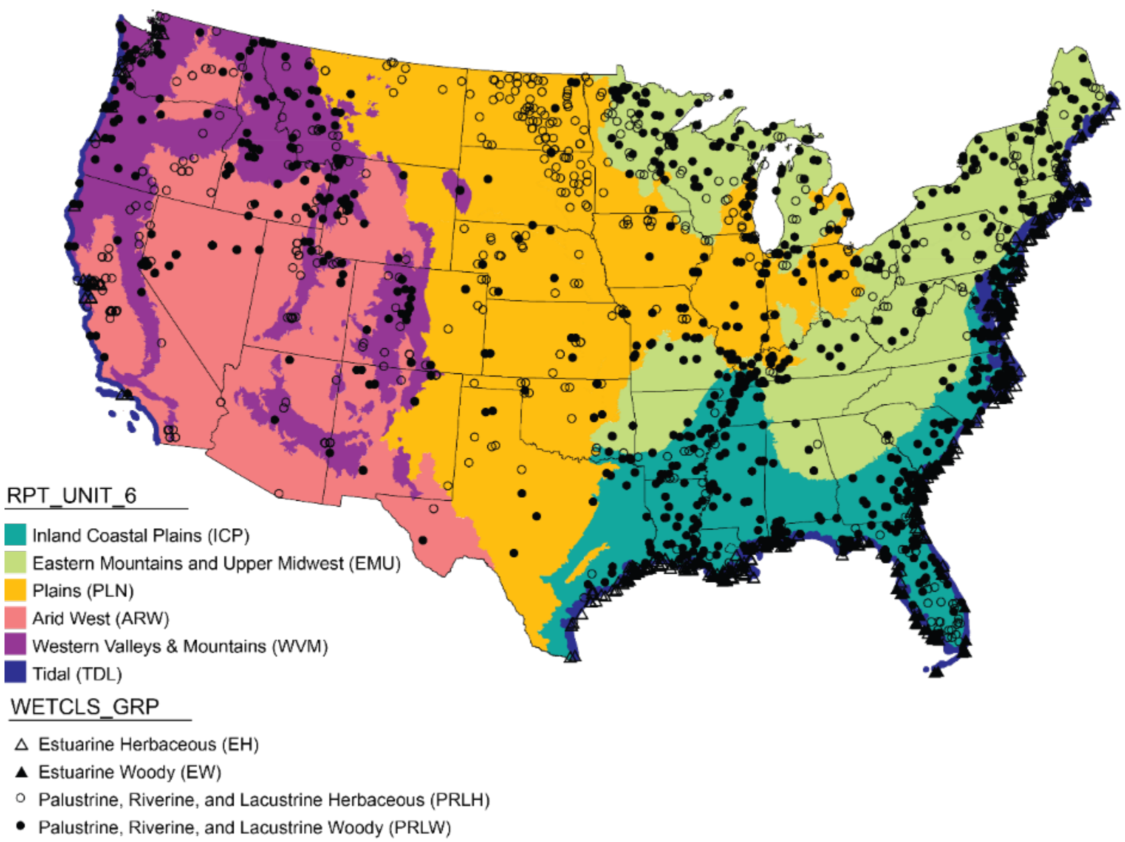


Figure 8-2. Six Reporting Units and four Wetland Groups: TDL = coastal areas where tidally-influenced estuarine wetlands occur. Inland wetlands are mapped within 5 NWCA Aggregated Ecoregions.

Table 8-3. Numbers of unique NWCA 2011 and 2016 sampled sites by six reporting units (RPT_UNIT_6). REF_NWCA (Disturbance): L = Least, I = Intermediate, M = Most, ? = undetermined. Revisit = site sampled twice in same field season. Tidal (TDL) = tidally-influenced estuarine wetlands occurring in near coastal areas. The other five groups represent inland wetlands within five ecoregional areas. See **Table 8-4** for description of include wetland types.

RPT_UNIT_6		n Numbers of Sites by Type							
		Total	L	I	M	?	Revisit	Calibration	Validation
TDL	Tidal	461	149	201	108	3	22	368	93
ICP	Inland Coastal Plains	411	86	216	105	4	14	330	81
EMU	Eastern Mtns & Upper Midwest	350	101	176	72	1	28	271	79
PLN	Interior Plains	351	53	208	88	2	19	290	61
ARW	Arid West	168	10	113	45	0	5	126	42
WVM	Western Valley & Mountains	244	40	147	56	1	16	202	42

Table 8-4. Numbers of unique NWCA 2011 and 2016 sampled sites by Wetland Groups (WETCLS_GRP). REF_NWCA (Disturbance): L = Least, I = Intermediate, M = Most, ? = undetermined. Revisit = site sampled twice in same field season. EH and EW are tidally-influenced estuarine wetlands. PRLH and PRLW are inland wetlands.

WETCLS_GRP[1] (Wetland Groups)		n Numbers of Sites by Type							
		Total	L	I	M	?	Revisit	Calibration	Validation
EH	Estuarine Herbaceous	374	134	158	81	1	18	298	76
EW	Estuarine Woody	87	15	43	27	2	4	70	17
PRLH	Palustrine, Riverine or Lacustrine Herbaceous	654	96	366	187	3	39	522	130
PRLW	Palustrine, Riverine or Lacustrine Woody	872	194	494	179	5	43	697	175

[1]Wetland types included in each WETCLS_GRP category listed above are defined below

	WETCLS_GRP	Description of wetland types included	NWCA Wetland Type	USFWS Status & Trends Code
Estuarine	EH	Estuarine intertidal (E) emergent (H = herbaceous)	EH	E2EM
	EW	Estuarine intertidal (E) forested and shrub (W= woody)	EW	E2SS
Inland	PRLH	Emergent wetlands (EM) in palustrine, shallow riverine, or shallow lacustrine littoral settings (PRL)	PRL-EM	PEM
		Farmed wetlands (f) in palustrine, shallow riverine, or shallow lacustrine littoral settings (PRL); only subset previously farmed, but not currently in crop production	PRL-f	Pf
		Open-water ponds and aquatic bed wetlands	PRL-UBAB[2]	PUBPAB[2]
	PRLW	Shrub-dominated wetlands (SS) in palustrine, shallow riverine, or shallow lacustrine littoral settings (PRL)	PRL-SS	PSS
		Forested wetlands in palustrine (FO), shallow riverine, or shallow lacustrine littoral settings (PRL)	PRL-FO	PFO

[2]PUBPAB covered S&T Wetland Categories: PAB (Palustrine Aquatic Bed), PUBn (Palustrine Unconsolidated Bottom, natural), PUBa (aquaculture), PUBf (agriculture use), PUBi (industrial), PUBu (PBU urban).

Ideally, for VMMI development, each subpopulation or analysis group would have at least 100 total sites, with 30 of these meeting least-disturbed criteria. Not all of these potential analysis groups (**Table 8-2** through **Table 8-4**) had the recommended number of total sites or of least-disturbed sites for VMMI development. For example, among the RPT_UNIT12 categories (**Table 8-2**) the tidally-influenced Estuarine Woody wetlands (TDL-W) and the inland Arid West woody wetlands (ARW-PRLW) each had fewer than 100 sites, and several region-Wetland Group combinations had fewer than 30 least-disturbed sites. At the coarser scale of RPT_UNIT_6 subpopulations, only 10 least-disturbed sites were available for the Arid West (ARW) (**Table 8-3**). In the WETCLS_GRP classification (**Table 8-4**), there were only 87 Estuarine Woody (EW) wetland sites and only 15 of these were least-disturbed.

Ordination using detrended correspondence analysis (DCA) (McCune and Mefford 2018) illustrated how species composition, based on species identity and abundance (estimated as percent cover), at the site-level varied in relation to broad wetland type and ecoregional subpopulations. The DCA was based on the percent cover of 4,798 observed taxa (native and nonnative) observed in one or more of the sampled sites and was run with down-weighting of uncommon taxa and axis rescaling (segments = 30). Eigenvalues for axes 1 and 2 were 0.949 and 0.803, respectively, with a Monte Carlo randomization test (999 permutations) having p = 0.0001 for both axes. Total variance in the species data was 113.3. The ordination (**Figure 8-3**) was plotted using raw site scores and unrotated axes (McCune and Mefford 2018), with sites coded to represent the 12-Ecoregion x Wetland Group (RPT_UNIT12) subpopulations.

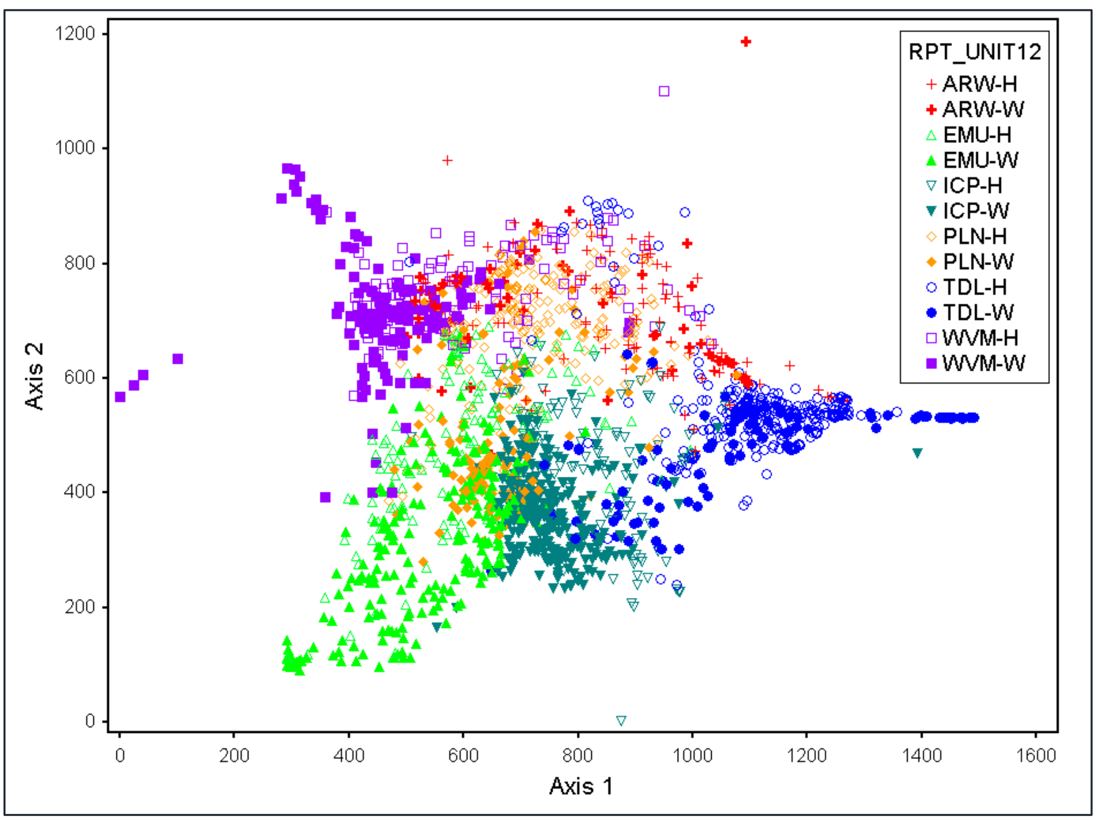


Figure 8-3. Detrended correspondence analysis for NWCA 2011 and 2016 sampled sites. Sites are color- and symbol-coded by RPT_UNIT12. Blue and TDL = Tidally-influenced, estuarine wetland sites. Other codes and colors = Inland wetland sites by geographic region. Open symbols = herbaceous (H) wetlands. Filled symbols = woody (W) wetlands. Note: Among the unique 1985 sampled sites, 208 were resampled sites (sampled in 2011 and 2016), (**Section 6.1**), and for these resampled sites the data from 2011 visit were used in this DCA.

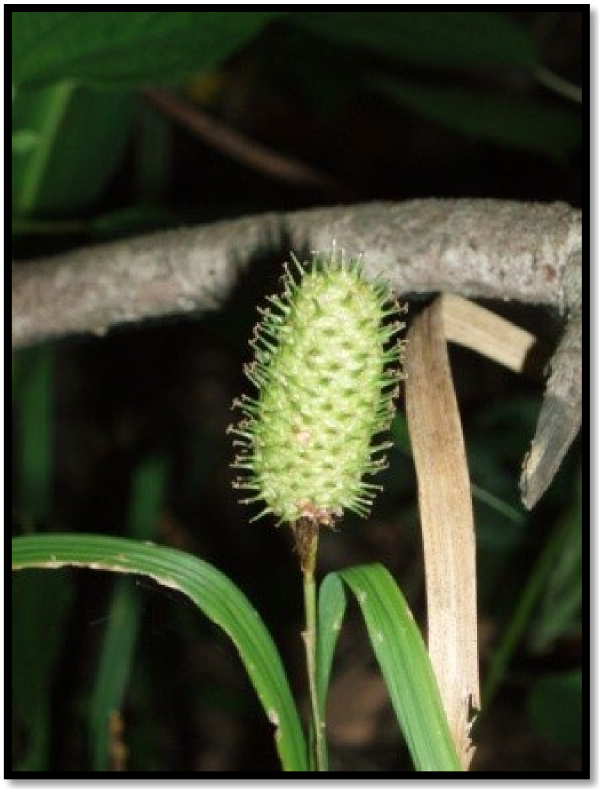
DCA axis gradient length reflects the standard deviations (SD) in species composition along an axis; and sites with scores that differ by more than 4 SD are expected to have no species in common (McCune and Grace 2002, Jongman et al. 1995). Gradient length for Axis 1 was 14.9 and for Axis 2 was 11.8. This means that from one edge of Axis 1 to the other (i.e., moving from left to right across the ordination), there are 3.7 complete turnovers in species composition. Similarly, for Axis 2 (i.e., moving from top to bottom of the ordination), there are nearly 3 turnovers in species composition. This level of beta diversity is not surprising given the geographic scope of the study area (conterminous US) and the diversity of wetland plant communities that are represented in each 12-Ecoregion x Wetland Group subpopulation.

The ordination plot (**Figure 8-3**) shows distinct to intergrading groups of sites associated with wetland subpopulations along gradients described by the axes. Tidal (EH, EW) vs. inland (PRLH, PRLW) wetlands separate distinctly along Axis 1. Inland herbaceous and woody wetlands tend to separate within ecoregional groups along both Axes 1 and 2. Axis 2 appears to be related to longitude, with sites from the western half of the US (e.g., WVM, ARW, PLNS) tending to occur in the top half of the ordination and those from the eastern half (EMU, ICP) occurring in the bottom half. Within the ecoregional groups the woody sites separate more distinctly than the herbaceous sites, and woody wetlands tend to be distributed along the outer edges/portions of the ordination by their ecoregional groups. The woody (PRLW) wetlands in the PLNS tend to intermix at the interface between EMU-PRLW and ICP-PRLW Some Inland Herbaceous wetlands (PRLH in the WMV, ARW, and PLNS), tend to intermix in the center and upper right of the ordination and to intergrade more among regions than do the woody wetlands. Intermixing of these herbaceous Wetland Groups may be related in part to the presence of widespread native species and to nonnative species with wide ecological amplitude (Magee et al 2019b).

The ordination of these 12-Ecoregion x Wetland Type (RPT_UNIT12) subpopulations was useful in describing variation in wetland vegetation at a continental scale, with wetland type (WETCLS_GRP) appearing to be primary and ecoregion (RPT_UNIT_6) to be secondary drivers of species composition. Given these patterns and the available sample sizes for least-disturbed sites in the various classifications (**Table 8-1** through **Table 8-4**), we evaluated metrics (**Section 8.5**) and developed candidate VMMIs (**Section 9.3**) at the national scale, and for subpopulations in WETCLS_GRP and in RPT_UNIT_6:

- National scale – all sampled wetlands (**Table 8-1**)
- Five subpopulations based on RPT_UNIT_6 groups (**Figure 8-2** and **Table 8-3**):
    - TDL – tidally-influenced estuarine wetlands in coastal areas
    - Inland wetlands in Four NWCA Aggregated Ecoregions
        - ICP – Inland Coastal Plains
        - EMU – Eastern Mountains and Upper Midwest
        - PLNS_ARW – Plains (PLN) and Arid West (ARW); note the PLN and ARW groups were combined because there were few least-disturbed sites in ARW
        - WVM – Western Mountains and Valleys
- Four Wetland Group subpopulations (WETCLS_GRP) (**Table 8-4**)

Candidate VMMIs for all these groups were developed and evaluate to identify which might have the most robust performance.



8.4 Calculating Candidate Metrics

Validated vegetation data (see **Sections 7.4** and **7.5**), along with species trait information, (see **Sections 7.6 through 7.9**) were used to calculate numerous candidate metrics representing several major Metric Groups (**Table 8-5**). These ecologically important Metric Groups and their component metrics are commonly recognized as potential indicators of condition or stress (USEPA 2016a, Magee et al 2019).

The Metric Groups listed in **Table 8-5** are comprised of a variety of broad metric types, and for each metric type, several-to-many specific candidate metrics with potential relationships to ecological condition or stress were calculated. NWCA candidate vegetation metrics included descriptors that were likely to have broad applicability across regions and wetland types, as well as metrics expected to have more restricted utility for specific broad wetland groups. **Section 8.8, Appendix E** lists: 1) the name and a short description of each metric, 2) how each metric was calculated, 3) the field data and species trait groups on which each metric is based, and 4) whether the metric is used primarily to describe ecological condition or stress in the NWCA.

The metric information specified in **Section 8.8, Appendix E** was used in updating R code to calculate 556 candidate vegetation metrics for each sampled site. The original, accuracy-tested, R code that was developed for metric calculation for the 2011 survey (USEPA 2016a) was updated, here, for the joint analysis of the 2011 and 2016 data. The calculated metrics can be found on the NWCA website (*nwca_2016_veg_metrics.csv*).

Most of the metric types described in **Table 8-5** include versions of metrics that incorporate all species, only native species, or only nonnative species. Vegetation metrics based on all species or on only native species were considered as potential descriptors of wetland condition (n = 426). Metrics based on only nonnative species (alien and cryptogenic species, see **Section 7.8**) (n = 130) were viewed as indicators of wetland stress (USEPA 2016a). Only the former group of metrics was considered in VMMI development.

The 426 candidate condition metrics were used in developing candidate VMMIs (see **Chapter 9**:). In previous work, the Nonnative Plant Indicator (NNPI) was developed based on data from the 2011 NWCA (Magee et al. 2019a). Here, the NNPI was applied in analysis of the combined 2011 and 2016 data (**Chapter 10:**). The NNPI uses exceedance values for three nonnative plant metrics to assign categorical classes (good, fair, poor, and very poor) to describe wetland condition in relation to impact from nonnative plants.

Table 8-5. Metric Groups and component Metric Types for characterizing vegetation condition.

Metric Groups	Major Metric Types for each Metric Group
Taxa Composition[a]	Richness, diversity, frequency, cover, importance of vascular plant species, genera, families, etc.
Floristic Quality[a]	Mean Coefficient of Conservatism, Floristic Quality Assessment Index (versions based on species presence or frequency and cover-weighted versions)
Tolerance and Sensitivity to Disturbance	Richness and abundance of sensitive, insensitive, tolerant, highly tolerant species
Hydrophytic Status[a]	Richness and abundance by Wetland Indicator Status; Wetland Indices
Life History[a]	Richness and abundance by growth-habit type, duration/longevity category, vascular plant category (e.g., ferns, dicots, etc.)
Vegetation Structure	Frequency, cover, importance, diversity, by structural (height) vegetation groups
Nonvascular	Frequency, cover, importance for ground or arboreal bryophytes or lichens, algae
Ground Surface Attributes	Frequency, cover, importance, depth of water, litter, bare ground
Woody Debris and Snags	Frequency, cover, importance for woody debris, counts for snags
Trees[a]	Richness, counts, or frequency, cover or importance by height or diameter classes

[a]Individual metrics in a group often included versions based on all species or native species only. Note: All importance metrics combine frequency and cover.

Only a small number of the calculated metrics were ultimately incorporated in NWCA vegetation indices (VMMIs, **Chapter 9:**) or (NNPI, **Chapter 10:**, Magee et al. 2019b). However, many of the other metrics are expected to be useful in describing other characteristics of wetlands or for addressing ecological questions related to diversity, structure, functional traits, or relationships to environmental conditions or ecological processes. For example, the nonnative plant metrics (n =130) are likely to inform questions related to the impacts of nonnative plants, which can 1) reflect condition of the vegetation, 2) be indicators of anthropogenic disturbance, or 3) behave as direct stressors to vegetation and ecosystem properties (e.g., Kuebbing et al. 2015, Magee et al. 2008, 2010, 2019b, Pyšek et al. 2020, Riccardi et al. 2020, Ruaro et al 2020, Simberloff 2011).

8.5 Evaluating Candidate Vegetation Metrics

Data from all 1,985 unique 2011 and 2016 sampled sites were used to evaluate 426 individual NWCA candidate vegetation metrics of condition for their potential utility in development of candidate VMMI(s). The NWCA metric screening approach was adapted and expanded for wetlands (Magee et al. 2019a) from metric evaluation methods used in other NARS (e.g., Stoddard et al. 2008, Pont et al. 2009, VanSickle 2010). Most of the wetland vegetation metrics were strongly non-normal (Magee et al. 2019a, USEPA 2016a); consequently, nonparametric statistical (e.g., Kruskal-Wallis test) approaches were used in the screening analyses where appropriate. Specific criteria for range, repeatability, responsiveness, and redundancy were defined. R code was written to implement these screening tests.

8.5.1 *Range Tests*

Metrics with limited range, too many zero values, or highly skewed distributions have been shown to generally be poor indicators of ecological condition. Thus, sufficient range in values to permit signal detection is important. We used two tests to define sufficient (PASS), marginal (PASS-), and insufficient (FAIL) range for metric values.

- **Test 1** – Identifies metrics with large proportion of 0 values or highly skewed distributions:
    - If the 75th percentile = 0, i.e., more than 75% of values are 0, then FAIL
    - If the 75th percentile = the minimum OR the 25th percentile = max (indicating 75% of values identical), then FAIL (ensures that a majority of values are not the same as the minimum or maximum to help eliminate variables that are highly skewed and mostly a single non-zero value)
    - If the median = 0, then PASS-

- **Test 2** – Identifies metrics with very narrow ranges
    - If the metric is a percent variable and (max-25th percentile) < 15%, then FAIL
    - If the metric is not a percent variable and (max-25th) < (max/3), then FAIL

If either Test 1 or 2 resulted in a FAIL, the final assignment for the metric was FAIL. If the first two screens in Test 1 resulted in a PASS, but the third screen a PASS-, the result was PASS-. To pass the range screen, each metric had to receive a PASS or PASS-.

8.5.2 *Repeatability (S:N)*

Useful metrics tend to have high repeatability, that is, the among-site variability will be greater than within-year sampling variability based on repeat sampling during the same field season at a subset of sites (see **Table 8-1** through **Table 8-4**, revisit sites). To quantify repeatability, NARS uses ***Signal-to-Noise Ratio (S:N)***, that is, the ratio of variance associated with a sampling site (signal) to the variance associated with repeated visits to the same site (noise) (Kaufmann et al. 1999). All sites are included in the signal, whereas only revisit sites contribute to the noise component. Metrics with high S:N are more likely to show consistent responses to human-caused disturbance, and S:N values ≤ 1 indicate that sampling a site twice yields as much or more metric variability as sampling two different sites (Stoddard et al. 2008).

In the NWCA, we set an initial criterion of S:N ≥ 4 (Magee et al. 2019a). In practice, however, the observed S:N values for the vegetation metrics were much higher, so we ultimately set the metric retention criterion to S:N ≥ 10, or ≥ 5 if metric type was as yet unrepresented in the suite of metrics passing all selection criteria. For the NWCA, S:N for individual metrics was calculated using the R package "lme4" (version 1.1-7, Bates et al. 2014). Each metric was used as a response variable with SITE_ID (a site identifier) as the main factor in a random effects model. Then the variance components from the resulting model were used to calculate S:N.

Note, that among the analysis groups for which metric screening was conducted (**Section 8.5.5**), two subpopulations had ≤ 5 revisit sites (ARW, EW). For these, two groups S:N values were given little consideration compared to other screening criteria.

8.5.3 *Responsiveness*

The most fundamental test of the efficacy of a candidate metric is its capacity to discriminate degraded from relatively undisturbed ecosystems. Responsive candidate metrics effectively distinguish least-disturbed from most-disturbed sites (Stoddard et al. 2008). In the NWCA, the ability to differentiate least- from most-disturbed sites was evaluated based on p-values and Chi-squared values from a Kruskal-Wallis test (large sample approximation). The assessment of the discriminatory capability of individual metrics was also supported by ranking the separation of least- and most-disturbed sites based on box plot comparisons, where the degree of overlap of medians and interquartile ranges (IQRs) between least- and most-disturbed sites provides a signal of the metric responsiveness (Klemm et al. 2002).

We developed R code to automate a process to simulate comparison of box plots for least and most disturbed sites, for each vegetation metric, and to rank the separation levels. Using the approach developed by Barbour et al. (1996) and outlined in Klemm et al. (2002), the medians and IQRs of the least and most disturbed sites were compared, and metrics were scored as follows:

- Score of 0 (lowest discriminatory power) – Complete overlap of each group's IQRs with the median of the other group
- Score of 1 – Only one median was overlapping with the IQRs of the other group
- Score of 2 – Neither median overlapped with the IQR of the other group, but the IQRs overlapped
- Score of 3 (highest discriminatory power) – IQRs did not overlap

Metric responsiveness was evaluated using three acceptance thresholds:

- Kruskal-Wallis $p \leq 0.05$
- Chi-square value from Kruskal-Wallis test ≥10, or ≥5 if metric type was as yet unrepresented in the suite of metrics passing all selection criteria
- Box plot separation score > 0
    - A zero-value box plot did not disqualify if the metric passed the other screens and was not represented in the suite of metrics passing all other selection criteria
    - Higher box plot separation scores received greater preference (3 > 2 > 1) in selecting among related metrics

Among metrics passing the responsiveness screen, the Kruskal-Wallis p-values were often much lower and Chi-square values were often much higher than acceptance thresholds. In some cases where other screening criteria were high, a metric with Chi-square < 5 might be retained.

8.5.4 *Redundancy*

Step 1 – During metric screening, a subset of metrics that passed the range, repeatability, and responsiveness tests, but which conveyed information similar to other metrics, were dropped. Dropped metrics typically included those that were very similar (e.g., absolute versus relative cover for trait-based metrics) or individual metrics that were also represented as a component of another metric. In such cases, the metric that was considered most ecologically meaningful, performed best on screening tests, or was easiest to collect or calculate was selected.

Step 2 – Additional redundancy screening was handled during the process of VMMI development. It is generally agreed that metrics included in a MMI should not be strongly correlated, and $r \leq 0.75$ is often a cut off point for correlation among metrics included in the same MMI (e.g., Stoddard et al. 2008, Pont et al 2009, Van Sickle 2010). Candidate VMMIs were screened to ensure that correlations among their component metrics were less than this threshold. If this threshold was exceeded the candidate VMMI was disqualified (see **Section 9.3**).

8.5.5 *Application of Metric Screening Criteria*

Screening criteria were applied nationally and to subpopulations of the RPT_UNIT_6 or WETCLS_GRP subpopulation groups, that is to:

- All Wetlands – Conterminous US (**Table 8-1**)
- RPT_UNIT_6 subpopulations: TDL, ICP, EMU, PLN-ARW, WVM (**Table 8-3**)
- WETCLS_GRP subpopulations: EH, EW, PRLH, PRLW (**Table 8-4**)

The metrics passing screening tests (range, repeatability, responsiveness criteria, and Step 1 of the redundancy criteria) for a given subpopulation were retained for consideration in VMMI development.

8.6 Metric Screening Results

Candidate vegetation metrics that passed screening tests (**Section 8.5**) for the national scale, for five subpopulations based on RPT_UNIT_6, or the subpopulations of WETCLS_GRP were retained for further analysis. Passing metrics for each subpopulation were used in developing potential VMMIs for that subpopulation. In the VMMI development process (described in **Chapter 9:**), four final VMMIs were ultimately selected as the best performing, one for each WETCLS_GRP subpopulation: Estuarine Herbaceous (EH), Estuarine Woody (EW), Inland Herbaceous (PRLH), and Inland Woody (PRW). These Wetland Group VMMIs were used for population estimates of condition for the 2016 survey and for change analysis between 2011 and 2016. *Therefore, in this section we report metric screening results only for the Wetland Group subpopulations* (**Table 8-6** through **Table 8-9**).

Table 8-6. Metrics (n = 40) that passed screening criteria for the Estuarine Herbaceous (EH) wetland subpopulation. Kruskal-Wallis statistics: Chi square and p-value. Metrics defined in **Section 8.8** (Appendix E).

Estuarine Herbaceous Wetland (EH) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
TOTN_SPP	PASS	26.18	41.15	0.0000	2	All or Native Species
TOTN_FAM	PASS	24.3	34.87	0.0000	2	All or Native Species
H_ALL	PASS	47.24	29.66	0.0000	2	All or Native Species
XBCDIST_SPP	PASS	21.6	26.99	0.0000	2	All or Native Species
TOTN_NATSPP	PASS	29.6	30.05	0.0000	1	All or Native Species
PCTN_NATSPP	PASS	18.26	59.64	0.0000	1	All or Native Species
RFREQ_NATSPP	PASS	27.6	64.49	0.0000	1	All or Native Species
H_NAT	PASS	18.98	25.23	0.0000	2	All or Native Species
XBCDIST_NATSPP	PASS	16.39	27.64	0.0000	2	All or Native Species
XC_NAT	PASS	57.23	18.79	0.0000	1	Floristic Quality
XC_ALL	PASS	60.34	40.06	0.0000	2	Floristic Quality
FQAI_COV_NAT	PASS	11.87	45.56	0.0000	2	Floristic Quality
FQAI_COV_ALL	PASS	14.06	61.41	0.0000	2	Tolerance
N_TOL	PASS	25.31	43.8	0.0000	2	Tolerance

Estuarine Herbaceous Wetland (EH) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
PCTN_SEN	PASS	38.06	39.08	0.0000	2	Tolerance
PCTN_TOL	PASS	59.19	49.27	0.0000	2	Tolerance
XRCOV_SEN	PASS	115.37	46.9	0.0000	2	Tolerance
XRCOV_TOL	PASS	56.52	57.21	0.0000	2	Tolerance
XRCOV_HTOL	PASS-	21.98	56.07	0.0000	1	Tolerance
PCTN_OBL	PASS	14.82	41.74	0.0000	2	Hydrophytic Status
PCTN_OBL_FACW	PASS	37.3	35.26	0.0000	1	Hydrophytic Status
XRCOV_OBL	PASS	67.43	27.68	0.0000	1	Hydrophytic Status
WETIND_COV_ALL	PASS	39.45	31.28	0.0000	2	Hydrophytic Status
WETIND2_COV_ALL	PASS-	39.45	31.28	0.0000	2	Hydrophytic Status
N_FORB	PASS	22.15	55.93	0.0000	2	Growth Habit
XRCOV_FORB	PASS	79.94	41.43	0.0000	2	Growth Habit
PCTN_GRAMINOID_NAT	PASS	8.04	37.81	0.0000	2	Growth Habit
XRCOV_GRAMINOID_NAT	PASS	35.55	46.85	0.0000	2	Growth Habit
N_HERB	PASS	24.94	48.72	0.0000	2	Growth Habit
XRCOV_HERB_NAT	PASS	22.74	24.26	0.0000	2	Growth Habit
N_ANNUAL	PASS-	3.08	42.3	0.0000	1	Duration
N_PERENNIAL	PASS	20	35.05	0.0000	1	Duration
N_PERENNIAL_NAT	PASS	20.44	26.05	0.0000	1	Duration
PCTN_PERENNIAL_NAT	PASS	8.27	62.92	0.0000	2	Duration
N_DICOT	PASS	23.02	39.67	0.0000	2	Category
N_MONOCOT	PASS	13.63	27.1	0.0000	2	Category
PCTN_MONOCOTS_NAT	PASS	7.61	37.05	0.0000	2	Category
XRCOV_DICOT	PASS	44.16	28.45	0.0000	2	Category
XRCOV_MONOCOT	PASS	40.53	28.13	0.0000	2	Category
XRCOV_MONOCOTS_NAT	PASS	36.39	45.87	0.0000	2	Category

Table 8-7. Metrics (n = 21) that passed screening criteria for the Estuarine Woody (EW) wetland subpopulation. Kruskal-Wallis statistics: Chi square and p-value. Metrics defined in **Section 8.8** (Appendix E).

Estuarine Woody Wetland (EW) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
XTOTABCOV	PASS	2.74	4.14	0.0419	2	All or Native Species
PCTN_NATSPP	PASS	9.15	7.44	0.0064	2	All or Native Species
RIMP_NATSPP	PASS-	122.29	8.97	0.0027	2	All or Native Species
FQAI_ALL	PASS	17.73	3.57	0.0587	1	Floristic Quality
PCTN_ISEN	PASS	6.26	4.2	0.0405	2	Tolerance
PCTN_HTOL	PASS	22.33	4.47	0.0345	1	Tolerance
PCTN_GRAMINOID_NAT	PASS	10.68	8.38	0.0038	2	Graminoid
XABCOV_GRAMINOID	PASS	61.84	5.21	0.0225	2	Graminoid
XABCOV_GRAMINOID_NAT	PASS	115.16	7.34	0.0068	2	Graminoid

Estuarine Woody Wetland (EW) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
XRCOV_GRAMINOID	PASS	72.74	4.07	0.0436	2	Graminoid
XRCOV_GRAMINOID_NAT	PASS	44.94	5.85	0.0156	2	Graminoid
XCOV_WD_FINE	PASS	40.88	4.69	0.0303	2	Woody
XRCOV_SHRUB_COMB	PASS	80.27	3.63	0.0568	1	Woody
XRCOV_SHRUB_COMB_NAT	PASS	80.76	4.04	0.0445	1	Woody
PCTN_DICOT	PASS	13.93	4.1	0.0429	2	Dicots
XRCOV_DICOT	PASS	74.9	4.31	0.0378	1	Dicots
XRCOV_DICOTS_NAT	PASS	70.83	3.58	0.0584	1	Dicots
PCTN_MONOCOT	PASS	8.86	5.91	0.015	2	Monocots
PCTN_MONOCOTS_NAT	PASS	7.94	9.77	0.0018	3	Monocots
XABCOV_MONOCOT	PASS	67.64	7.62	0.0058	3	Monocots
XRCOV_MONOCOTS_NAT	PASS	49.56	8.34	0.0039	3	Monocots

Table 8-8. Metrics (n = 42) that passed screening criteria for the Inland Herbaceous (PRLH) wetland subpopulation. Kruskal-Wallis statistics: Chi square and p-value. Metrics defined in **Section 8.8** (Appendix E).

Inland Herbaceous Wetland (PRLH) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
PCTN_NATSPP	PASS	8.14	79.11	0.0000	3	Native Species
RFREQ_NATSPP	PASS	10.61	82.2	0.0000	3	Native Species
XRCOV_NATSPP	PASS	8.37	86.26	0.0000	3	Native Species
RIMP_NATSPP	PASS	11.84	92.83	0.0000	3	Native Species
XC_NAT	PASS	23.06	62.01	0.0000	2	Floristic Quality
XC_ALL	PASS	37.2	94.31	0.0000	3	Floristic Quality
XC_COV_ALL	PASS	28.62	45.66	0.0000	2	Floristic Quality
FQAI_NAT	PASS	30.81	30.74	0.0000	2	Floristic Quality
FQAI_ALL	PASS	38.13	40.38	0.0000	2	Floristic Quality
FQAI_COV_ALL	PASS	14.7	69.77	0.0000	2	Floristic Quality
N_SEN	PASS	25.5	38.99	0.0000	1	Sensitive
PCTN_SEN	PASS	18.17	53.79	0.0000	2	Sensitive
PCTN_ISEN	PASS	9.09	24.95	0.0000	2	Sensitive
XRCOV_SEN	PASS	24.21	37.16	0.0000	1	Sensitive
XRCOV_ISEN	PASS	7.32	24.08	0.0000	1	Sensitive
N_TOL	PASS	8.85	35.94	0.0000	1	Tolerant
N_HTOL	PASS	6.51	58.06	0.0000	2	Tolerant
PCTN_TOL	PASS	17.36	66.16	0.0000	2	Tolerant
PCTN_HTOL	PASS	18.1	71.48	0.0000	3	Tolerant
XRCOV_TOL	PASS	8.68	57.34	0.0000	2	Tolerant
XRCOV_HTOL	PASS	12.83	66.44	0.0000	2	Tolerant
PCTN_FAC_FACU	PASS	11.77	47.19	0.0000	2	Hydrophytic Status
PCTN_OBL_FACW	PASS	20.25	47.64	0.0000	2	Hydrophytic Status

Inland Herbaceous Wetland (PRLH) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
PCTN_OBL_FACW_FAC	PASS	9.95	33.08	0.0000	2	Hydrophytic Status
XRCOV_OBL	PASS	23.08	51.97	0.0000	2	Hydrophytic Status
XRCOV_FAC_FACU	PASS	9.23	42.47	0.0000	2	Hydrophytic Status
XRCOV_OBL_FACW	PASS	25.31	40.06	0.0000	2	Hydrophytic Status
WETIND2_COV_ALL	PASS-	30.75	51.2	0.0000	2	Hydrophytic Status
WETIND2_COV_NAT	PASS-	15.29	30.7	0.0000	1	Hydrophytic Status
PCTN_FORB_NAT	PASS	6.7	28.73	0.0000	2	Herbaceous
XRCOV_GRAMINOID_NAT	PASS	17.3	12.02	0.0005	0	Herbaceous
PCTN_HERB_NAT	PASS	6.63	30.75	0.0000	1	Herbaceous
XRCOV_HERB_NAT	PASS	8.98	41.62	0.0000	2	Herbaceous
PCTN_SHRUB_COMB	PASS	19.96	17.36	0.0000	1	Shrub
PCTN_SHRUB_COMB_NAT	PASS	14.52	16.81	0.0000	1	Shrub
XRCOV_SHRUB_COMB	PASS	24.64	10.57	0.0011	0	Shrub
XRCOV_SHRUB_COMB_NAT	PASS	24.57	9.87	0.0017	0	Shrub
PCTN_ANNUAL	PASS	7.8	14.51	0.0001	0	Category
PCTN_PERENNIAL	PASS	11.06	24.6	0.0000	2	Category
PCTN_PERENNIAL_NAT	PASS	13.41	60.92	0.0000	2	Category
XRCOV_PERENNIAL_NAT	PASS	10.8	62.87	0.0000	2	Category
XRCOV_MONOCOTS_NAT	PASS	9.04	18.53	0.0000	1	Category

Table 8-9. Metrics (n = 47) that passed screening criteria for the Inland Woody (PRLW) wetland subpopulation. Kruskal-Wallis statistics: Chi square and p-value. Metrics defined in **Section 8.8** (Appendix E).

Inland Woody Wetland (PRLW) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
PCTN_NATSPP	PASS	7.11	51.39	0.0000	2	Native Species
RFREQ_NATSPP	PASS	12.63	56.12	0.0000	2	Native Species
XRCOV_NATSPP	PASS-	18.29	65.53	0.0000	2	Native Species
RIMP_NATSPP	PASS	20.14	64.77	0.0000	2	Native Species
XC_NAT	PASS	49.34	27.37	0.0000	1	Floristic Quality
XC_ALL	PASS	62.91	47.61	0.0000	2	Floristic Quality
FQAI_COV_ALL	PASS	49.62	30.81	0.0000	0	Floristic Quality
PCTN_SEN	PASS	34.53	37.56	0.0000	1	Tolerance
PCTN_TOL	PASS	39.68	32.01	0.0000	1	Tolerance
PCTN_HTOL	PASS	28.94	35.93	0.0000	1	Tolerance
XRCOV_HTOL	PASS	25.05	37.11	0.0000	1	Tolerance
PCTN_FAC_FACU	PASS	13.71	12.09	0.0005	0	Hydrophytic Status
PCTN_OBL_FACW	PASS	16.23	18.3	0.0000	0	Hydrophytic Status
XRCOV_UPL	PASS	35.16	11.68	0.0006	0	Hydrophytic Status
XRCOV_FAC_FACU	PASS	20.36	11.47	0.0007	0	Hydrophytic Status

Inland Woody Wetland (PRLW) Metrics	Range Test	S:N Ratio	Chi Square	p Value	Box plot Score	Metric Type
XRCOV_OBL_FACW	PASS	18.13	15.56	0.0001	0	Hydrophytic Status
WETIND2_COV_ALL	PASS	24.24	14.54	0.0001	0	Hydrophytic Status
PCTN_HERB	PASS	24.74	6.38	0.0115	0	Vine
PCTN_VINE_ALL	PASS	16.29	7.5	0.0062	0	Vine
XRCOV_VINE_ALL	PASS	28.36	9.92	0.0016	0	Vine
XRCOV_VINE_ALL_NAT	PASS	30.92	8.26	0.0041	0	Vine
PCTN_SHRUB_COMB	PASS	32.05	18.1	0.0000	0	Shrub
PCTN_SHRUB_COMB_NAT	PASS	11.11	10.44	0.0012	0	Shrub
XRCOV_SHRUB_COMB_NAT	PASS	41.98	26.03	0.0000	0	Shrub
PCTN_TREE_COMB	PASS	25.43	8.25	0.0041	0	Tree
XRCOV_TREE_COMB_NAT	PASS	20.59	5.72	0.0168	0	Tree
XRCOV_GYMNOSPERM	PASS	24.45	20.89	0.0000	1	Tree
IMP_TREE_GROUND	PASS	2.12	7.15	0.0075	0	Tree
IMP_TREE_UPPER	PASS	6.23	7.01	0.0081	0	Tree
TOTN_TREES	PASS	10.42	11.63	0.0007	0	Tree
TOTN_MID	PASS	11.59	7.88	0.005	0	Tree
TOTN_SMALL	PASS	9.24	10.81	0.001	0	Tree
TOTN_SNAGS	PASS	11.96	20.25	0.0000	0	Tree
XN_SNAGS	PASS	11.94	20.39	0.0000	0	Tree
PCTN_PERENNIAL	PASS	7.99	38.6	0.0000	2	Duration
PCTN_PERENNIAL_NAT	PASS	9.29	56.34	0.0000	2	Duration
XRCOV_ANNUAL	PASS	29.94	11.47	0.0007	0	Duration
XRCOV_ANNUAL_NAT	PASS	31.48	11.77	0.0006	0	Duration
XRCOV_PERENNIAL_NAT	PASS	24.97	56.17	0.0000	1	Duration
XRCOV_MONOCOTS_NAT	PASS	14.99	8.07	0.0045	0	Duration
PCTN_FERN	PASS	15.36	10.11	0.0015	0	Non-seed Plants
PCTN_FERNS_NAT	PASS	14.95	10.86	0.001	0	Non-seed Plants
XRCOV_FERN	PASS	14.56	7.86	0.005	0	Non-seed Plants
FREQ_BRYOPHYTES	PASS	2.42	29.2	0.0000	1	Non-seed Plants
IMP_BRYOPHYTES	PASS	5.88	26.81	0.0000	0	Non-seed Plants
XCOV_LICHENS	PASS	4.26	33.36	0.0000	1	Non-seed Plants
IMP_LICHENS	PASS	5.53	13.91	0.0002	0	Non-seed Plants

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8.8 Appendix E: NWCA 2016 Candidate Vegetation Metrics[6]

READ THIS: Key Information for Reading and Using This Appendix

- ***Important:*** *This Appendix is **a descriptive overview** of Candidate Vegetation Metrics. Exact methods/formulas for calculations, specific field data, and trait information used for each metric were defined in the Vegetation Metric R Code.*

- Unless otherwise indicated, vegetation metrics are summarized to site level. Metrics are calculated based on data from five 100-m^2 plots in the Assessment Area (AA) for the site (or if fewer than 5 plots were sampled, the total number plots sampled). In the metric descriptions or formulas provided in this appendix, the phrase 'five 100-m^2 plots' can be assumed to mean the 5 plots in the AA or the total number of plots sampled if less than 5. Rarely were fewer than 5 vegetation plots sampled at the AA.

- The term '*Species*' as typically used in this appendix refers to taxonomic species or lowest identifiable taxonomic unit (e.g., variety, genus, family, growth-habit).

- **BLACK BANNER** with column headings is repeated at the top of each page.
- **GRAY BANNER,** heading each *major group of metrics*, lists the NWCA Field Data Form from which the validated field data that is used in metrics originated.
- **COLORED BANNERS**, under each major metric group, provide section and subsection headings for *sets of metrics that describe related ecological components*.
- **METRIC NAME column** the *metric name* used in the NWCA vegetation metrics data set.
- **DESCRIPTION column** gives narrative description of each metric.

- **CALCULATION/TRAIT INFORMATION column** provides:
  - ***In white metric rows:***
    - A general formula for calculation of the metric, if not evident in the DESCRIPTION column, is provided. PARAMETER NAMES representing raw data included in calculations are highlighted in **GRAY-BLUE and** are defined in **Section 5.12, Appendix C**.
    - Some calculated metrics listed in the METRIC NAME column are, in turn, used as components of other calculated metrics.
    - Some calculated metrics use species trait information to aggregate species level data. Where traits are used, trait names are indicated in the calculation column using GREEN font.
  - ***In colored banner rows defining metric sets*** – General categories of species trait information used in calculating a particular series of metrics are listed, if applicable. Codes for specific traits are indicated in GREEN font. ***For metrics that use species traits, trait designations are applied as follows:***
    - Growth-habit, Duration, and Taxonomic Category are applied by species (see **Section 5.6**)
    - Wetland Indicator Status is applied to taxon-wetland region pairs (see **Section 5.7**)
    - Native status designations for taxon-site pairs are based on state-level status (see **Section 5.8**)
    - Coefficients of Conservatism (CCs, aka C-values) are applied to taxon-site pairs based on state or regional specific C-values for each species (see **Section 5.9**)

- **METRIC TYPE column** indicates whether the candidate metric is to reflect ecological condition or stress.

- **METRICS INCLUDED IN NWCA VEGETATION INDICES** are indicated in the **METRIC TYPE column** in **bold color-coded font:** the four ***2016 Wetland Type Vegetation Multimetric Indices (VMMIs)*** in **light blue (EH), dark blue (EW)**, **purple (PRLH), forest green (PRLW)**, respectively; the ***Nonnative Plant Indicator (NNPI)*** in red; and the previously used ***2011 National (VMMI***) in rose.

[6] Most metrics developed for analysis of the 2011 NWCA vegetation data (USEPA 2016a) were considered here. A few (n = 11) metrics were dropped because the 2016 field protocols were simplified and requisite data for those specific metrics were unavailable for 2016 data. Also, several new metrics that described additional characteristics of hydrophytic vegetation (n =16), vines (n = 12), and summaries of tree counts by three major size (dbh) ranges (n = 6) were added.

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
SECTIONS 1 - 5	**Metrics based on field data: FORM V-2 – NWCA 2016 VASCULAR SPECIES PRESENCE AND COVER**		
SECTION 1	**TAXA COMPOSITION (RICHNESS, FREQUENCY, COVER, DIVERSITY)**		
Section 1.1	**All Species/Taxonomic Groups**		
TOTN_SPP	Richness - Total number of unique species across all 100-m^2 plots	Count unique species across all plots	C
XN_SPP	Mean number of species across all 100-m^2 plots		C
MEDN_SPP	Median number of species across all 100-m^2 plots		C
SDN_SPP	Standard deviation in number of species across all 100-m^2 plots		C
TOTN_GEN	Total number of unique genera across all 100-m^2 plots	Count unique genera across all plots	C
XN_GEN	Mean number of unique genera across all 100-m^2 plots		C
MEDN_GEN	Median number of genera across all 100-m^2 plots		C
SDN_GEN	Standard deviation in number of genera across 100-m^2 plots		C
TOTN_FAM	Total number of families across 100-m^2 plots	Count unique families observed across all plots	C
XN_FAM	Mean number of families across 100-m^2 plots		C
MEDN_FAM	Median number of families across 100-m^2 plots		C
SDN_FAM	Standard deviation in number of families across 100-m^2 plots		C
XTOTABCOV (summary data used in calculation of other metrics)	Mean total absolute cover summed across all species across 100-m^2 plots	Σ COVER of all individual taxa across 5 plots/5 plots	
H_ALL	Shannon-Wiener Diversity Index - All species *s* = number of species observed, *i* = species *i, p* = proportion of individuals (relative cover) belonging to species *i*	$H' = -\sum_{i}^{s} p_i \ln p_i$	C
J_ALL	Evenness (Pielou) - All species *S* = number of species observed	$J = \frac{H'}{\ln S}$	C

METRIC NAME	METRIC DESCRIPTION	CALCULATION (listed in Metric Row), SPECIES TRAIT TYPE (indicated in Banner if applicable)	METRIC TYPE (C = condition, S = stress)
D_ALL	Simpson Diversity Index - All species *s* = number of species observed, *i* = species *i*, *p* = proportion of individuals (relative cover) belonging to species *i*	$D = 1 - \sum_{i}^{s} p_i^2$	C
XBCDIST_SPP	Within Assessment Area dissimilarity based on species composition = Mean of between-plot Bray-Cutis (BC) Distance (Dissimilarity) based on all species.	Calculate between-plot Bray Curtis Distance for all plot pairs based on species and plot level cover values. Calculate mean of these values to get mean within AA distance: $BC_{ih} = 1 \frac{2 \sum_{j=1}^{p} MIN(a_{ij}, a_{hj})}{\sum_{j=1}^{p} a_{ij} + \sum_{j=1}^{p} a_{hj}}$	C
SECTIONS 1.2 - 1.3	**NATIVE STATUS**	**Trait Information = Native Status (see Table 5-5)**	
Section 1.2	**Native (NAT) Species/Taxonomic Groups**		
TOTN_NATSPP	Native Richness: Total number of unique native species across all 100-m² plots	Count unique native (NAT) species across all plots	C
XN_NATSPP	Mean number of native species across 100-m² plots		C
MEDN_NATSPP	Median number of native species across 100-m² plots		C
SDN_NATSPP	Standard deviation in number of native species across 100-m² plots		C
PCTN_NATSPP ■, ■	Percent richness of native species observed across 100-m² plots	(TOTN_NATSPP/TOTN_SPP) x 100	C, in **EH-VVMI**, **EW-VMMI**
RFREQ_NATSPP	Relative frequency of occurrence for native species as a percent of total frequency (sum of all species)	∑ Frequencies of all (NAT species/∑ Frequencies of all species) x 100; Frequency for individual species = % of 100-m² plots in which it occurs.	C, in **PRLW-VMMI**
XABCOV_ NATSPP	Mean total absolute cover of native species across 100-m² plots	∑ COVER of all individual native (NAT) taxa across 5 plots/5 plots	C
XRCOV_NATSPP ■, ■	Mean relative cover of native species across 100-m² plots as a percentage of total cover	(XABCOV_NATSPP/XTOTABCOV) x 100	C, in **PRLH-VMMI, PRLW-VMMI**
RIMP_NATSPP ■, ■	Mean relative importance of all native species	(RFREQ_NATSPP + XRCOV_NATSPP)/2	**C, in EW-VMMI, 2011 National VMMI**
H_NAT	Shannon-Wiener Diversity Index – Native species only	See H_ALL	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
J_NAT	Evenness (Pielou) – Native species only	See J_ALL	C
D_NAT	Simpson Diversity Index – Native species only	See D_NAT	C
XBCDIST_ NATSPP	Within AA dissimilarity based on native species only composition = Mean of between plot Bray-Cutis Distance (Dissimilarity) based on native species only	See XBCDIST_SPP	C
Section 1.3	**Introduced (INTR), Adventive (ADV), ALIEN (INTR + ADV), Cryptogenic (CRYP)**	**Trait Information = Native Status (see Table 5-5)**	
TOTN_INTRSPP	Introduced Richness: Total number of unique introduced species across all 100-m^2 plots	Count unique introduced (INTR) species across all plots	S
XN_INTRSPP	Mean number of introduced species across 100-m^2 plots		S
MEDN_INTRSPP	Median number of introduced species across 100-m^2 plots		S
SDN_INTRSPP	Standard deviation in number of introduced species across 100-m^2 plots		S
PCTN_INTRSPP	Percent richness introduced species observed across 100-m^2 plots	(TOTN_INTRSPP/TOTN_SPP) x 100	S
RFREQ_INTRSPP	Relative frequency of occurrence for introduced species as a percent of total frequency (sum of all species)	(∑ Frequencies of all introduced (INTR) species/∑ Frequencies of all species) x 100; Frequency for individual species = % of 100-m^2 plots in which it occurs.	S
XABCOV_ INTRSPP	Mean total absolute cover of all introduced species across 100-m^2 plots	∑ **COVER of al**l individual INTR taxa across 5 plots/5 plots	S
XRCOV_INTRSPP	Mean relative cover of all INTR species across 100-m^2 plots as a percentage of total cover	(XABCOV_INTRSPP/XTOTABCOV) x 100	S
RIMP_INTRSPP	Mean relative importance of all introduced species	(RFREQ_INTRSPP + XRCOV_INTRSPP)/2	S
TOTN_ADVSPP	Adventive Richness: Total number of adventive species across 100-m^2 plots	Count unique adventive (ADV) species across all plots	S
XN_ADVSPP	Mean number of adventive species across 100-m^2 plots		S
MEDN_ADVSPP	Median number of adventive species across 100-m^2 plots		S
SDN_ADVSPP	Standard deviation in number of adventive species across 100-m^2 plots		S

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
PCTN_ADVSPP	Percent richness adventive species observed across all 100-m^2 plots	(TOTN_ADVSPP/TOTN_SPP) x 100	S
RFREQ_ADVSPP	Relative frequency of adventive species occurrence across 100-m^2 plots	(∑ Frequencies of all adventive (ADV) species/∑ Frequencies of all species) x 100; Frequency for individual species = % of 100-m^2 plots in which it occurs.	S
XABCOV_ ADVSPP	Mean total absolute cover of all ADV species across 100-m^2 plots	Σ COVER of all individual ADV taxa across 5 plots/5 plots	S
XRCOV_ADVSPP	Mean relative cover of all ADV species or lowest taxonomic unit across 100-m^2 plots as a percentage of total cover	(XABCOV_ADVSPP/XTOTABCOV) x 100	S
RIMP_ADVSPP	Mean relative importance of all adventive species	(RFREQ_ADVSPP + XRCOV_ADVSPP)/2	S
TOTN_ALIENSPP	Alien Richness: Total number of unique alien (INTR + ADV) species across 100-m^2 plots	TOTN_ADVSPP + TOTN_INTRSPP	S
XN_ALIENSPP	Mean number of alien (INTR + ADV) species across 100-m^2 plots		S
MEDN_ALIENSPP	Median number of alien (INTR + ADV) species across 100-m^2 plots		S
SDN_ALIENSPP	Standard deviation in number of alien (INTR + ADV) species		S
PCTN_ALIENSPP	Percent richness alien species across 100-m^2 plots	(TOTN_ALIENSPP/TOTN_SPP) x 100	S
RFREQ_ ALIENSPP	Relative frequency of alien (INTR + ADV) species occurrence across 100-m^2 plots	(∑ Frequencies of all ALIEN species/∑ Frequencies of all species) x 100; Frequency for individual species = % of 100-m^2 plots in which it occurs.	S
XABCOV_ ALIENSPP	Mean total absolute cover of ALIEN (INTR + ADV) species across 100-m^2 plots	Σ COVER of all individual ALIEN taxa across 5 plots/5 plots	S
XRCOV_ ALIENSPP	Mean relative cover of all ALIEN (INTR + ADV) species across 100-m^2 plots as a percentage of total cover	(XABCOV_ALIENSPP/XTOTABCOV) x 100	S
RIMP_ALIENSPP	Mean relative importance of all ALIEN (INTR + ADV) species	(RFREQ_ALIENSPP + XRCOV_ALIENSPP)/2	S
H_ALIEN	Shannon-Wiener Diversity Index	See H_ALL	S
J_ALIEN	Evenness (Pielou)	See J_ALL	S
D_ALIEN	Simpson Diversity Index	See D_NAT	S
TOTN_CRYPSPP	Cryptogenic Richness: Total number of unique cryptogenic species across 100-m^2 plots	Count unique cryptogenic (CRYP) species across all plots	S
XN_CRYPSPP	Mean number of cryptogenic species across 100-m^2 plots		S

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
MEDN_CRYPSPP	Median number of cryptogenic species across 100-m^2 plots		S
SDN_CRYPSPP	Standard deviation in number of cryptogenic species across 100-m^2 plots		S
PCTN_CRYPSPP	Percent richness cryptogenic species across 100-m^2 plots	(TOTN_CRYPSPP/TOTN_SPP) x 100	S
RFREQ_CRYPSPP	Relative frequency of cryptogenic species occurrence across 100-m^2 plots	(∑ Frequencies of all cryptogenic (CRYP) species/∑ Frequencies of all species) x 100; Frequency for individual species = % of 100-m^2 plots in which it occurs.	S
XABCOV_ CRYPSPP	Mean total absolute cover of all CRYP species across 100-m^2 plots	∑ COVER of all CRYP taxa across 5 plots/5 plots	S
XRCOV_CRYPSPP	Mean relative cover of all CRYP species across 100-m^2 plots as a percentage of total cover	(XABCOV_CRYPSPP/XTOTABCOV) x 100	S
RIMP_CRYPSPP	Mean relative importance of all CRYP species	(RFREQ_CRYPSPP + XRCOV_CRYPSPP)/2	S
TOTN_AC	AC Richness: Total number of unique alien and cryptogenic species across 100-m^2 plots	TOTN_CRYPSPP + TOTN_ALIENSPP	**S, Used in NNPI**
XN_AC	Mean number of AC (ALIEN + CRYP) species across 100-m^2 plots		S
MEDN_AC	Median number of AC (ALIEN + CRYP) species across 100-m^2 plots		S
SDN_AC	Standard deviation number of AC (ALIEN + CRYP) species across 100-m^2 plots		S
PCTN_AC	Percent Richness AC species (ALIEN + CRYP) across 100-m^2 plots	(TOTN_CRYPSPP + TOTN-ALIENSPP/TOTN_SPP) x 100	S
RFREQ_AC	Relative frequency of alien and cryptogenic species occurrence in flora based on five 100-m^2 plots	(∑ Frequencies of all ALIEN + CRYP species/∑ Frequencies of all species) x 100; Frequency for individual species = % of 100-m^2 plots in which it occurs.	**S, Used in NNPI**
XABCOV_AC	Mean total absolute cover of all AC (ALIEN + CRYP) species across 100-m^2 plots	∑ COVER of all ALIEN + CRYP taxa across 5 plots/5 plots	S
XRCOV_AC	Mean relative cover of all AC (ALIEN + CRYP) species across 100-m^2 plots as a percentage of total cover	(XABCOV_AC/XTOTABCOV) x 100	**S, Used in NNPI**
RIMP_AC	Mean relative importance of all AC (ALIEN + CRYP) species	(RFREQ_AC + XRCOV_AC)/2	S
H_AC	Shannon-Weiner Diversity Index	See H_ALL	S
J_AC	Evenness (Pielou)	See J_ALL	S
D_AC	Simpson Diversity Index	See D_NAT	S

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
Section 2	**FLORISTIC QUALITY**	**Trait Information = Coefficients of Conservatism (see Section 5.9); Native Status (see Table 5-5)**	
Equation 1	**General formula for Mean C** CC_{ij} – coefficient of conservatism for each unique species *i* at site *j*, N = number of species at site *j*	$\overline{C} = \left(\sum cc_{ij}\right)/N_j$	
Equation 2	**General formula for FQAI** CC_{ij} – coefficient of conservatism for each unique species *i* at site *j*, N = number of species at site *j*	$FQAI = \sum CC_{ij}/\sqrt{N_j}$	
Equation 3	**For weighted Mean C or FQAI** Replace CC_{ij} with wCC_{ij}, where p_{ij} = relative frequency or relative cover	$wCCij = p_{ij}CC_{ij}$	
XC_NAT	Mean Coefficient of Conservatism with native species only	Equation 1	C
XC_ALL	Mean Coefficient of Conservatism with all species	Equation 1	**C, in PRLW-VMMI**
XC_FREQ_NAT	Relative frequency-weighted Mean Coefficient of Conservatism with native species only	Equation 1, Equation 3	C
XC_FREQ_All	Relative frequency-weighted Mean Coefficient of Conservatism with all species only	Equation 1, Equation 3	C
XC_COV_NAT	Relative cover-weighted Mean Coefficient of Conservatism with native species only	Equation 1, Equation 3	C
XC_COV_All	Relative cover-weighted Mean Coefficient of Conservatism with all species	Equation 1, Equation 3	C
FQAI_NAT	Floristic Quality Index with native species only	Equation 2	C
FQAI_ALL ■, ■	Floristic Quality Index with all species	Equation 2	**C, in PRLH-VMMI, 2011 National VMMI**
FQAI_FREQ_NAT	Proportional frequency-weighted Floristic Quality Assessment Index with native species only	Equation 2, Equation 3	C
FQAI_FREQ_ALL	Proportional frequency-weighted Floristic Quality Assessment Index with all species only	Equation 2, Equation 3	C
FQAI_COV_NAT	Proportional cover-weighted Floristic Quality Assessment Index with native species only	Equation 2, Equation 3	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
FQAI_COV_ALL	Proportional cover-weighted Floristic Quality Assessment Index with all species	Equation 2, Equation 3	C
Section 3	**STRESS TOLERANCE/SENSITIVITY**	**Trait Information = Coefficients of Conservatism (Section 5.9)**	
N_HSEN	Number (Richness) Highly Sensitive Species; C-value >= 9	Count unique species that meet criterion across 100-m^2 plots	C
N_SEN	Number (Richness) Sensitive Species; C -value >= 7	Count unique species that meet criterion across 100-m^2 plots	C
N_ISEN	Number (Richness) Intermediate Sensitivity Species; C-value = 5 to 6	Count unique species that meet criterion across 100-m^2 plots	C
N_TOL ■, ■	Number (Richness) Tolerant Species; C -value <= 4	Count unique species that meet criterion across 100-m^2 plots	**C, in PRLH-VMMI, 2011 National VMMI**
N_HTOL	Number (Richness) Highly Tolerant Species; C-value <= 2	Count unique species that meet criterion across 100-m^2 plots	C
PCTN_HSEN	Percent Richness Highly Sensitive Species; C-value >= 9	(N_HSEN/TOTN_SPP) x 100	C
PCTN_SEN	Percent Richness Sensitive Species; C-value >= 7	(N_SEN/TOTN_SPP) x 100	C
PCTN_ISEN	Percent Richness Intermediate Sensitivity Species; C-value = 5 to 6	(N_ISEN/TOTN_SPP) x 100	C, **in EW-VMMI**
PCTN_TOL	Percent Richness Tolerant Species; C-value <= 4	(N_TOL/TOTN_SPP) x 100	C
PCTN_HTOL	Percent Richness Highly Tolerant Species; C-value <= 2	(N_HTOL/TOTN_SPP) x 100	C
XABCOV_HSEN	Absolute Mean Cover Highly Sensitive Species; C-value >= 9	Σ COVER of species with C-value >= 9 across 5 plots/5 plots	C
XABCOV_SEN	Absolute Mean Cover Sensitive Species; C-value >= 7	Σ COVER of species with C-value >= 7 across 5 plots/5 plots	C
XABCOV_ISEN	Absolute Mean Cover Intermediate Sensitivity Species; C-value= 5 to 6	Σ COVER of species with C-value = 5 or 6 across 5 plots/5 plots	C
XABCOV_TOL	Absolute Mean Cover Tolerant Species; C-value <= 4	Σ COVER of species with C-value <= 4 across 5 plots/5 plots	C
XABCOV_HTOL	Absolute Mean Cover Highly Tolerant Species; C-value <= 2	Σ COVER of species with C-value <= 2 across 5 plots/5 plots	C
XRCOV_HSEN	Relative Mean Cover Highly Sensitive Species; C >= 9	(XABCOV_HSEN/XTOTABCOV) x 100	C
XRCOV_SEN	Relative Mean Cover Sensitive Species; C-value >= 7	(XABCOV_SEN/XTOTABCOV) x 100	C, **in EH-VMMI**
XRCOV_ISEN	Relative Mean Cover Intermediate Sensitivity Species; C-value = 5 to 6	(XABCOV_ISEN/XTOTABCOV) x 100	C
XRCOV_TOL	Relative Mean Cover Tolerant Species; C-value <= 4	(XABCOV_TOL/XTOTABCOV) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XRCOV_HTOL	Relative Mean Cover Highly Tolerant Species; C-value <= 2	(XABCOV_HTOL/XTOTABCOV) x 100	C, **in EH-VMMI**
SECTION 4	**HYDROPHYTIC CHARACTERISTICS OF VEGETATION**	**Trait Information =** Wetland Indicator Status (WIS): Obligate (**OBL**), Facultative Wetland (**FACW**), Facultative (**FAC**), Facultative Upland (**FACU**), Upland (**UPL**) (Table 5-3); Native Status (Table 5-5)	
N_OBL	Richness (number) of Obligate species	Count unique OBL species across 100-m^2 plots	C
N_FACW	Richness (number) of Facultative Wetland species	Count unique FACW species across 100-m^2 plots	C
N_FAC	Richness (number) of Facultative species	Count unique FACU species across 100-m^2 plots	C
N_FACU	Richness (number) of Facultative Upland species	Count unique FAC species across 100-m^2 plots	C
N_UPL	Richness (number) of UPL species = UPL	Count unique UPL species across 100-m^2 plots	C
N_OBL_FACW	Richness (number) of Obligate + Facultative Wetland species	Count unique OBL + FACW species across 100-m^2 plots	C
N_OBL_FACW_FAC	Richness (number) of Obligate + Facultative Wetland species	Count unique OBL + FACW + FAC species across 100-m^2 plots	C
N_FAC_FACU	Richness (number) of Facultative + Facultative Upland species	Count unique FAC + FACU species across 100-m^2 plots	C
PCTN_OBL	Percent richness of Obligate species	(N_OBL/TOTN_SPP) x 100	C
PCTN_FACW	Percent richness of Facultative Wetland species	(N_FACW/TOTN_SPP) x 100	C
PCTN_FAC	Percent richness of Facultative species	(N_FAC/TOTN_SPP) x 100	C
PCTN_FACU	Percent richness of Facultative Upland species	(N_FACU/TOTN_SPP) x 100	C
PCTN_UPL	Percent richness of UPL (= UPL + NL) species	(N_UPL/TOTN_SPP) x 100	C
PCTN_OBL_FACW	Percent richness (number) of Obligate + Facultative Wetland species	(N_OBL_FACW/TOTN_SPP) x 100	C, in **PRLH-VMMI**
PCTN_OBL_FACW_FAC	Percent richness (number) of Obligate + Facultative Wetland species	(N_OBL_FACW_FAC/TOTN_SPP) x 100	C
PCTN_FAC_FACU	Percent richness (number) of Facultative + Facultative Upland species	(N_FAC_FACU/TOTN_SPP) x 100	C
XABCOV_OBL	Mean Absolute Cover of Obligate species	Σ **COVER of OBL** species across 5 plots/5 plots	C
XABCOV_FACW	Mean Absolute Cover of Facultative Wetland species	Σ **COVER of FACW** species across 5 plots/5 plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XABCOV_FAC	Mean Absolute Cover of Facultative species	Σ COVER of FAC species across 5 plots/5 plots	C
XABCOV_FACU	Mean Absolute Cover of Facultative Upland species	Σ COVER of FACU species across 5 plots/5 plots	C
XABCOV_UPL	Mean Absolute Cover of UPL species	Σ COVER of UPL species across 5 plots/5 plots	C
XABCOV _OBL_FACW	Mean Absolute Cover of Obligate + Facultative Wetland species	Σ COVER of OBL and FACW species across 5 plots/5 plots	C
XABCOV _OBL_FACW_FAC	Mean Absolute Cover of Obligate + Facultative Wetland species	Σ COVER of OBL, FACW, and FAC species across 5 plots/5 plots	C
XABCOV FAC_FACU	Mean Absolute Cover of Facultative + Facultative Upland species	Σ COVER of FAC and FACU species across 5 plots/5 plots	C
XRCOV_OBL	Mean Relative Cover of Obligate species	(XABCOV_OBL/XTOTABCOV) x 100	C
XRCOV_FACW	Mean Relative Cover of Facultative Wetland species	(XABCOV_FACW/XTOTABCOV) x 100	C
XRCOV_FAC	Mean Relative Cover of Facultative species	(XABCOV_FAC/XTOTABCOV) x 100	C
XRCOV_FACU	Mean Relative Cover of Facultative Upland species	(XABCOV_FACU/XTOTABCOV) x 100	C
XRCOV_UPL	Mean Relative Cover of UPL (= UPL) species	(XABCOV_UPL/XTOTABCOV) x 100	C
XRCOV_OBL_FACW	Mean Relative Cover of Obligate + Facultative Wetland species	(XABCOV _OBL_FACW /XTOTABCOV) x 100	C
XRCOV_OBL_FACW _FAC	Mean Relative Cover of Obligate + Facultative Wetland + Facultative species	(XABCOV _OBL_FACW_FAC/ XTOTABCOV) x 100	C
XRCOV_FAC_FACU	Mean Relative Cover of Obligate + Facultative Wetland + Facultative species	(XABCOV _FAC_FACU/ XTOTABCOV) x 100	C
WETIND_COV_ ALL	Wetland Index, Cover Weighted - all species I_{ij} = Importance Value = Mean absolute cover species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 1, FACW = 2, FAC = 3, FACU = 4, UPL = 5)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C
WETIND_FREQ_ ALL	Wetland Index, Frequency Weighted - all species I_{ij} = Importance Value = Frequency for species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 1, FACW = 2, FAC = 3, FACU = 4, UPL = 5)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
WETIND_ COV_NAT	Wetland Index, Cover Weighted - native species only I_{ij} = Importance Value = Mean absolute cover for species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 1, FACW = 2, FAC = 3, FACU = 4, UPL = 5)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C
WETIND_ FREQ_NAT	Wetland Index, Frequency Weighted - native species only I_{ij} = Importance Value = Frequency for species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 1, FACW = 2, FAC = 3, FACU = 4, UPL = 5)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C
WETIND2_COV_ ALL	Wetland Index, Cover Weighted - all species I_{ij} = Importance Value = Mean absolute cover species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 5, FACW = 4, FAC = 3, FACU =2, UPL = 1)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C
WETIND2_FREQ_ ALL	Wetland Index, Frequency Weighted - all species I_{ij} = Importance Value = Frequency for species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 5, FACW = 4, FAC = 3, FACU =2, UPL = 1)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C
WETIND2_ COV_NAT	Wetland Index, Cover Weighted - native species only I_{ij} = Importance Value = Mean absolute cover for species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 5, FACW = 4, FAC = 3, FACU =2, UPL = 1)	$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
WETIND2_ FREQ_NAT	Wetland Index, Frequency Weighted - native species only I_{ij} = Importance Value = Frequency for species *i* in site *j*. E_i = Ecological score for species based on WIS (OBL = 5, FACW = 4, FAC = 3, FACU =2, UPL = 1)	$$WI = \sum_{i=1}^{p} I_{ij} E_i \Big/ \sum_{i=1}^{p} I_{ij}$$	C
N_OBLFACW_AC	Number of Alien + Cryptogenic Obligate and facultative wetland species	Count unique ALIEN and CRYP OBL and FACW species across 100-m^2 plots	S
XABCOV_ OBLFACW_AC	Mean Absolute Cover of Alien + Cryptogenic Obligate and Facultative Wetland species	Σ **COVER of** ALIEN and CRYP OBL and FACW species across 5 plots/5 plots	S
XRCOV_ OBLFACW_AC	Mean Relative Cover of Alien + Cryptogenic Obligate and Facultative Wetland species	(XABCOV_OBLFACW_AC/ XTOTABCOV) x 100	S
SECTION 5	**LIFE HISTORY**		
SECTION 5.1	***GROWTH-HABIT***	**Trait Information = Growth-habit (Table 5-1); Native Status (Table 5-5)**	
N_GRAMINOID	Graminoid richness	Count unique GRAMINOID species across 100-m^2 plots	C
N_GRAMINOID_ NAT	Native Graminoid richness	Count unique native (NAT) GRAMINOID species across 100-m^2 plots	C
N_GRAMINOID_ AC	Alien and cryptogenic Graminoid richness	Count unique ALIEN and CRYP GRAMINOID species across 100-m^2 plots	S
N_FORB	Forb richness	Count unique FORB species across 100-m^2 plots	C
N_FORB_NAT	Native Forb richness	Count unique native (NAT) FORB species across 100-m^2 plots	C
N_FORB_AC	Alien and cryptogenic Forb richness	Count unique ALIEN and CRYP FORB species across 100-m^2 plots	S
N_HERB	Herbaceous plant (FORB + GRAMINOID) species richness	N_FORB + N_GRAMINOID	C
N_HERB_NAT	Native Herbaceous species richness	N_FORB_NAT + N_GRAMINOID_NAT	C
N_HERB_AC	Alien and cryptogenic Herbaceous richness	N_FORB_AC + N_GRAMINOID_AC	S
N_SSHRUB_ FORB	Subshrub-forb richness	Count unique SUBSHRUB-FORB species across 100-m^2 plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
N_SSHRUB_ SHRUB	Subshrub-shrub richness	Count unique SUBSHRUB-SHRUB species across 100-m² plots	C
N_SHRUB	Shrub richness	Count unique SHRUB species across 100-m² plots	C
N_SHRUB_ COMB	Combined Shrub growth-habits richness	N_SHRUB + N_SSHRUB_SHRUB + N_SSHRUB-FORB	C
N_SHRUB_ COMB_NAT	Native richness of Combined Shrub growth-habits richness	Count unique native (NAT) SHRUB_COMB species across 100-m² plots	C
N_SHRUB_ COMB_AC	Alien and cryptogenic richness for Combined Shrub growth-habits	Count unique ALIEN and CRYP SHRUB_COMB species across 100-m² plots	S
N_TREE_SHRUB	Tree-Shrub richness	Count unique TREE-SHRUB species across 100-m² plots	C
N_TREE	Tree richness	Count unique TREE species across 100-m² plots	C
N_TREE_COMB	Combined Tree and Tree-Shrub richness	N_TREE_SHRUB + N_TREE	C
N_TREE_ COMB_NAT	Combined Tree and Tree-Shrub richness	Count unique native (NAT) TREE_COMB species across 100-m² plots	C
N_TREE_ COMB_AC	Combined Tree and Tree-Shrub richness	Count unique ALIEN and CRYP TREE_COMB species across 100-m² plots	S
N_VINE	Vine richness	Count unique VINE species across 100-m² plots	C
N_VINE_NAT	Vine richness	Count unique native (NAT) VINE species across 100-m² plots	C
N_VINE_AC	Vine richness	Count unique ALIEN and CRYP VINE species across 100-m² plots	S
N_VINE_SHRUB	Vine-Shrub richness	Count unique a VINE-SHRUB species across 100-m² plots	C
N_VINE_ SHRUB_NAT	Native Vine-Shrub richness	Count unique native (NAT) VINE-SHRUB species across 100-m² plots	C
N_VINE_ SHRUB_AC	Alien and cryptogenic Vine-Shrub richness	Count unique ALIEN and CRYP VINE-SHRUB species across 100-m² plots	S
N_VINE_ALL	Vine-All richness	Count unique a VINE_ALL species across 100-m² plots	C
N_VINE_ALL_NAT	Native Vine-All richness	Count unique native (NAT) VINE_ALL species across 100-m² plots	C
N_VINE_ALL_AC	Alien and cryptogenic Vine-Shrub richness	Count unique ALIEN and CRYP VINE_ALL species across 100-m² plots	S
PCTN_ GRAMINOID	Graminoid percent richness	(N_GRAMINOID/TOTN_SPP) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
PCTN_ GRAMINOID_NAT	Native Graminoid percent richness	(N_GRAMINOID_NAT/ TOTN_SPP) x 100	C
PCTN_ GRAMINOID_AC	Graminoid percent richness	(N_GRAMINOID_AC/TOTN_SPP) x 100	S
PCTN_FORB	Forb percent richness	(N_FORB/TOTN_SPP) x 100	C
PCTN_FORB_ NAT	Native Forb percent richness	(N_FORB_NAT/TOTN_SPP) x 100	C
PCTN_FORB_AC	Alien and cryptogenic Forb percent richness	(N_FORB_AC/TOTN_SPP) x 100	S
PCTN_HERB	Percent Herbaceous (FORB + GRAMINOID) richness	(N_HERB/TOTN_SPP) x 100	C
PCTN_HERB_ NAT	Percent native Herbaceous richness	(N_HERB_NAT/TOTN_SPP) x 100	C
PCTN_HERB_ AC	Percent alien and cryptogenic Herbaceous richness	(N_HERB_AC/TOTN_SPP) x 100	S
PCTN_SSHRUB_ FORB	Subshrub-Forb percent richness	(N_SSHRUB_FORB/TOTN_SPP) x 100	C
PCTN_SSHRUB_ SHRUB	Subshrub-Shrub percent richness	(N_SSHRUB/TOTN_SPP) x 100	C
PCTN_SHRUB	Shrub percent richness	(N_SHRUB/TOTN_SPP) x 100	C
PCTN_SHRUB_ COMB	Combined Shrub richness	(N_SHRUB_COMB/TOTN_SPP) x 100	C
PCTN_SHRUB_ COMB_NAT	Percent native richness of Combined Shrub growth-habits	(N_SHRUB_COMB_NAT/TOTN_SP P) x 100	C
PCTN_SHRUB_ COMB_AC	Percent alien and cryptogenic richness for Combined Shrub growth-habits	(N_SHRUB_COMB_AC/TOTN_SPP) x 100	S
PCTN_TREE_ SHRUB	Tree-Shrub percent richness	(N_TREE_SHRUB/TOTN_SPP) x 100	C
PCTN_TREE	Tree percent richness	(N_TREE/TOTN_SPP) x 100	C
PCTN_TREE_ COMB	Combined Tree and Tree-Shrub percent richness	(N_TREE_COMB/TOTN_SPP) x 100	C
PCTN_TREE_ COMB_NAT	Combined Tree and Tree-Shrub percent richness	(N_TREE_COMB_NAT/TOTN_SPP) x 100	C
PCTN_TREE_ COMB_AC	Combined Tree and Tree-Shrub percent richness	(N_TREE_COMB_AC/TOTN_SPP) x 100	S
PCTN_VINE	Vine percent richness	(N_VINE/TOTN_SPP) x 100	C
PCTN_VINE_NAT	Native Vine percent richness	(N_VINE_NAT/TOTN_SPP) x 100	C
PCTN_VINE_AC	Alien and cryptogenic Vine percent richness	(N_VINE_AC/TOTN_SPP) x 100	S
PCTN_VINE_ SHRUB	Vine-Shrub percent richness	(N_VINE_SHRUB/TOTN_SPP) x 100	C
PCTN_VINE_ SHRUB_NAT	Native Vine-Shrub percent richness	(N_VINE_SHRUB_NAT/TOTN_SPP) x 100	C
PCTN_VINE_ SHRUB_AC	Alien and Cryptogenic Vine-Shrub percent richness	(N_VINE_SHRUB_AC/TOTN_SPP) x 100	S

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
PCTN_VINE_ALL	All-Vine percent richness	(N_VINE_ALL/TOTN_SPP) x 100	C
PCTN_VINE_ALL_NAT	All-Vine native percent richness	(N_VINE_ALL_NAT/TOTN_SPP) x 100	C
PCTN_VINE_ALL_AC	All-Vine alien and cryptogenic percent richness	(N_VINE_ALL_AC/TOTN_SPP) x 100	S
XABCOV_ GRAMINOID	Mean absolute Graminoid cover	Σ **COVER of G**RAMINOID species across 5 plots/5 plots	C
XABCOV_ GRAMINOID_NAT	Mean absolute native Graminoid cover	Σ **COVER of G**RAMINOID NAT species across 5 plots/5 plots	C
XABCOV_ GRAMINOID_AC	Mean absolute alien and cryptogenic Graminoid cover	Σ **COVER of G**RAMINOID ALIEN and CRYP species across 5 plots/5 plots	S
XABCOV_FORB	Mean absolute FORB cover	Σ **COVER of F**ORB species across 5 plots/5 plots	C
XABCOV_FORB_ NAT	Mean absolute native FORB cover	Σ **COVER of N**AT FORB species across 5 plots/5 plots	C
XABCOV_FORB_ AC	Mean absolute alien and cryptogenic FORB cover	Σ **COVER of A**LIEN and CRYP FORB species across 5 plots/5 plots	S
XABCOV_HERB	Mean absolute Herbaceous species cover (FORB + GRAMINOID)	XABCOV_FORB + XABCOV_GRAMINOID	C
XABCOV_HERB_ NAT	Mean absolute native Herbaceous cover	XABCOV_FORB_NAT + XABCOV_GRAMINOID_NAT	C
XABCOV_HERB_ AC	Mean relative Herbaceous alien and cryptogenic cover	XABCOV_FORB_AC + XABCOV_GRAMINOID_AC	S
XABCOV_ SSHRUB_FORB	Mean absolute Subshrub-Forb cover	Σ **COVER of S**UBSHRUB-FORB species across 5 plots/5 plots	C
XABCOV_ SSHRUB_SHRUB	Mean absolute Subshrub-Shrub cover	Σ **COVER SUBS**HRUB-SHRUB species across 5 plots/5 plots	C
XABCOV_SHRUB	Mean absolute Shrub cover	Σ **COVER of S**HRUB species across 5 plots/5 plots	C
XABCOV_ SHRUB_COMB	Combined Shrub growth-habits absolute cover	Σ **COVER of S**HRUB_COMB species across 5 plots/5 plots	C
XABCOV_SHRUB_ COMB_NAT	Mean absolute native Combined Shrub growth-habits cover	Σ **COVER of N**AT SHRUB-COMB species across 5 plots/5 plots	C
XABCOV_SHRUB_ COMB_AC	Mean absolute alien and cryptogenic Combined Shrub growth-habits cover	Σ **COVER of A**LIEN and CRYP SHRUB_COMB species across 5 plots/5 plots	S
XABCOV_TREE_ SHRUB	Mean absolute Tree-Shrub cover	Σ **COVER of T**REE-SHRUB species across 5 plots/5 plots	C
XABCOV_TREE	Mean absolute Tree cover	Σ **COVER of T**REE species across 5 plots/5 plots	C
XABCOV_TREE_ COMB	Combined Tree and Tree-Shrub absolute cover	Σ **COVER of T**REE_COMB species across 5 plots/5 plots	C
XABCOV_TREE_ COMB_NAT	Combined native Tree and Tree-Shrub absolute cover	Σ **COVER of N**AT TREE_COMB species across 5 plots/5 plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XABCOV_TREE_ COMB_AC	Combined alien and cryptogenic Tree and Tree-Shrub absolute cover	Σ COVER of ALIEN and CRYP TREE_COMB species across 5 plots/5 plots	S
XABCOV_VINE	Mean absolute Vine cover	Σ COVER of VINE species across 5 plots/5 plots	C
XABCOV_VINE_ NAT	Mean native absolute Vine cover	Σ COVER of NAT VINE species across 5 plots/5 plots	C
XABCOV_VINE_ AC	Mean alien and cryptogenic absolute Vine cover	Σ COVER of ALIEN and CRYP VINE species across 5 plots/5 plots	S
XABCOV_VINE_ SHRUB	Mean absolute Vine-Shrub cover	Σ COVER of VINE-SHRUB species across 5 plots/5 plots	C
XABCOV_VINE_ SHRUB_NAT	Mean absolute native Vine-Shrub cover	Σ COVER of NAT VINE-SHRUB species across 5 plots/5 plots	C
XABCOV_VINE_ SHRUB_AC	Mean absolute alien and cryptogenic Vine-Shrub cover	Σ COVER of ALIEN and CRYP VINE-SHRUB species across 5 plots/5 plots	S
XABCOV_VINE_ ALL	Mean absolute Vine-ALL cover	Σ COVER of VINE-ALL species across 5 plots/5 plots	C
XABCOV_VINE_ ALL_NAT	Mean absolute native Vine-ALL cover	Σ COVER of NAT VINE-ALL species across 5 plots/5 plots	C
XABCOV_VINE_ ALL_AC	Mean absolute alien and cryptogenic Vine-ALL cover	Σ COVER of ALIEN and CRYP VINE-ALL species across 5 plots/5 plots	S
XRCOV_ GRAMINOID	Mean relative Graminoid cover	(XABCOV_GRAMINOID/ XTOTABCOV) x 100	C, **in EW-VMMI**
XRCOV_ GRAMINOID_NAT	Mean relative native Graminoid cover	(XABCOV_GRAMINOID_NAT/ XTOTABCOV) x 100	C
XRCOV_ GRAMINOID_AC	Mean relative alien and cryptogenic Graminoid cover	(XABCOV_GRAMINOID_AC/ XTOTABCOV) x 100	S
XRCOV_FORB	Mean relative Forb cover	(XABCOV_FORB/XTOTABCOV) x 100	C, **in EH-VMMI**
XRCOV_ FORB_NAT	Mean relative native Forb cover	(XABCOV_FORB_NAT/ XTOTABCOV) x 100	C
XRCOV_FORB_AC	Mean relative alien and cryptogenic Forb cover	(XABCOV_FORB_AC/XTOTABCOV) x 100	C
XRCOV_HERB	Mean relative Herbaceous (FORB + GRAMINOID) cover	(XABCOV_HERB/XTOTABCOV) x 100	C
XRCOV_ HERB_NAT	Mean relative native Herbaceous cover	(XABCOV_HERB_NAT/ XTOTABCOV) x 100	C
XRCOV_HERB_AC	Mean relative alien and cryptogenic Herbaceous cover	(XABCOV_HERB_AC/XTOTABCOV) x 100	S
XRCOV_SSHRUB_ FORB	Mean relative Subshrub-Forb cover	(XABCOV_SSHRUB_FORB/ XTOTABCOV) x 100	C
XRCOV_SSHRUB_ SHRUB	Mean relative Subshrub-Shrub cover	(XABCOV_SSHRUB_SHRUB/ XTOTABCOV) x 100	C
XRCOV_SHRUB	Mean relative Shrub cover	(XABCOV_SHRUB/XTOTABCOV) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XRCOV_SHRUB_COMB	Mean relative Combined Shrub growth-habits cover	(XABCOV_SHRUB_COMB/ XTOTABCOV) x 100	C
XRCOV_SHRUB_COMB_NAT	Mean relative native Combined Shrub growth-habits cover	(XABCOV_SHRUB_COMB_NAT/ XTOTABCOV) x 100	C
XRCOV_SHRUB_COMB_AC	Mean relative alien and cryptogenic Combined Shrub growth-habits cover	(XABCOV_SHRUB_COMB_AC/ XTOTABCOV) x 100	S
XRCOV_TREE_SHRUB	Mean relative Tree-Shrub cover	(XABCOV_TREE_SHRUB/ XTOTABCOV) x 100	C
XRCOV_TREE	Mean relative Tree cover	(XABCOV_TREE/XTOTABCOV) x 100	C
XRCOV_TREE_COMB	Mean relative Combined Tree and Tree-Shrub cover	(XABCOV_TREE_COMB/ XTOTABCOV) x 100	C
XRCOV_TREE_COMB_NAT	Mean relative Combined Tree and Tree-Shrub cover	(XABCOV_TREE_COMB_NAT/ XTOTABCOV) x 100	C
XRCOV_TREE_COMB_AC	Mean relative Combined Tree and Tree-Shrub cover	(XABCOV_TREE_COMB_AC/ XTOTABCOV) x 100	S
XRCOV_VINE	Mean relative Vine cover	(XABCOV_VINE/XTOTABCOV) x 100	C
XRCOV_VINE_NAT	Mean native relative Vine cover	(XABCOV_VINE_NAT/XTOTABCOV) x 100	C
XRCOV_VINE_AC	Mean alien and cryptogenic relative Vine cover	(XABCOV_VINE_AC/XTOTABCOV) x 100	S
XRCOV_VINE_SHRUB	Mean relative Vine-Shrub cover	(XABCOV_VINE_SHRUB/ XTOTABCOV) x 100	C
XRCOV_VINE_SHRUB_NAT	Mean native relative Vine-Shrub cover	(XABCOV_VINE_SHRUB_NAT/ XTOTABCOV) x 100	C
XRCOV_VINE_SHRUB_AC	Mean alien and cryptogenic relative Vine-Shrub cover	(XABCOV_VINE_SHRUB_AC/ XTOTABCOV) x 100	S
XRCOV_VINE_ALL	Mean relative Vine-ALL cover	(XABCOV_VINE_ALL/ XTOTABCOV) x 100	C
XRCOV_VINE_ALL_NAT	Mean native relative Vine-ALL cover	(XABCOV_VINE_ALL_NAT/ XTOTABCOV) x 100	C
XRCOV_VINE_ALL_AC	Mean alien and cryptogenic relative Vine-ALL cover	(XABCOV_VINE_ALL_AC/ XTOTABCOV) x 100	S
Section 5.2	***DURATION***	**Trait Information = Duration (Table 5-2); Native Status (Table 5-5)**	
N_ANNUAL	Annual species richness	Count unique ANNUAL species across 100-m^2 plots	C, **In EH-VMMI**
N_ANNUAL_NAT	Native Annual richness	Count unique NAT ANNUAL species across 100-m^2 plots	C
N_ANNUAL_AC	Alien and cryptogenic Annual richness	Count unique ALIEN and CRYP ANNUAL species across 100-m^2 plots	S
N_ANN_BIEN	Annual-Biennial richness	Count unique ANN_BIEN species across 100-m^2 plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
N_ANN_BIEN_NAT	Native Annual-Biennial richness	Count unique NAT ANN_BIEN species across 100-m^2 plots	C
N_ANN_BIEN_AC	Alien and cryptogenic Annual-Biennial richness	Count unique ALIEN and CRYP ANN_BIEN species across 100-m^2 plots	S
N_ANN_PEREN	Annual-Perennial richness	Count unique ANN_PEREN species across 100-m^2 plots	C
N_ANN_PEREN_NAT	Native Annual-Perennial richness	Count unique NAT ANN_PEREN species across 100-m^2 plots	C
N_ANN_PEREN_AC	Alien and cryptogenic Annual-Perennial richness	Count unique ALIEN and CRYP ANN_PEREN species across 100-m^2 plots	S
N_PERENNIAL	Perennial richness	Count unique PERENNIAL species across 100-m^2 plots	C
N_PERENNIAL_NAT	Native Perennial richness	Count unique NAT PERENNIAL species across 100-m^2 plots	C
N_PERENNIAL_AC	Alien and cryptogenic Perennial richness	Count unique ALIEN and CRYP PERENNIAL species across 100-m^2 plots	S
PCTN_ANNUAL	Percent Annual richness	(N_ANNUAL/TOTN_SPP) x 100	C
PCTN_ANNUAL_NAT	Percent native Annual richness	(N_ANNUAL_NAT/TOTN_SPP) x 100	C
PCTN_ANNUAL_AC	Percent alien and cryptogenic Annual richness	(N_ANNUAL_AC/TOTN_SPP) x 100	S
PCTN_ANN_BIEN	Percent Annual-Biennial richness	(N_ANN_BIEN/TOTN_SPP) x 100	C
PCTN_ANN_BIEN_NAT	Percent native Annual-Biennial richness	(N_ANN_BIEN_NAT/TOTN_SPP) x 100	C
PCTN_ANN_BIEN_AC	Percent alien and cryptogenic Annual-Biennial richness	(N_ANN_BIEN_AC/TOTN_SPP) x 100	S
PCTN_ANN_PEREN	Percent Annual-Perennial richness	(N_ANN_PEREN/TOTN_SPP) x 100	C
PCTN_ANN_PEREN_NAT	Percent native Annual-Perennial richness	(N_ANN_PEREN_NAT/TOTN_SPP) x 100	C
PCTN_ANN_PEREN_AC	Percent alien and cryptogenic Annual-Perennial richness	(N_ANN_PEREN_AC/TOTN_SPP) x 100	S
PCTN_PERENNIAL	Percent Perennial richness	(N_PERENNIAL/TOTN_SPP) x 100	C
PCTN_PERENNIAL_NAT	Percent native Perennial richness	(N_PERENNIAL_NAT/TOTN_SPP) x 100	C
PCTN_PERENNIAL_AC	Percent alien and cryptogenic Perennial richness	(N_PERENNIAL_AC/TOTN_SPP) x 100	S
XABCOV_ANNUAL	Mean absolute Annual cover	Σ COVER of ANNUAL species across 5 plots/5 plots	C
XABCOV_ANNUAL_NAT	Mean absolute native Annual cover	Σ COVER of NAT ANNUAL species across 5 plots/5 plots	C
XABCOV_ANNUAL_AC	Mean absolute alien and cryptogenic Annual cover	Σ COVER of ALIEN and CRYP ANNUAL species across 5 plots/5 plots	S

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XABCOV_ANN_ BIEN	Mean absolute Annual-Biennial cover	Σ **COVER of ANN**_BIEN species across 5 plots/5 plots	C
XABCOV_ANN_ BIEN_NAT	Mean absolute native Annual-Biennial cover	Σ **COVER of NAT** ANN_BIEN species across 5 plots/5 plots	C
XABCOV_ANN_ BIEN_AC	Mean absolute alien and cryptogenic Annual-Biennial cover	Σ **COVER of ALIEN** and CRYP ANN_BIEN species across 5 plots/5 plots	S
XABCOV_ANN_ PEREN	Mean absolute Annual-Perennial cover	Σ **COVER of ANN**_PEREN species across 5 plots/5 plots	C
XABCOV_ANN_ PEREN_NAT	Mean absolute native Annual-Perennial cover	Σ **COVER of NAT** ANN_PEREN species across 5 plots/5 plots	C
XABCOV_ANN_ PEREN_AC	Mean absolute alien and cryptogenic Annual-Perennial cover	Σ **COVER of ALIEN** and CRYP ANN_PEREN species across 5 plots/5 plots	S
XABCOV_ PERENNIAL	Mean absolute Perennial cover	Σ **COVER of P**ERENNIAL species across 5 plots/5 plots	C
XABCOV_ PERENNIAL_NAT	Mean absolute native Perennial cover	Σ **COVER of NAT** PERENNIAL species across 5 plots/5 plots	C
XABCOV_ PERENNIAL_AC	Mean absolute alien and cryptogenic Perennial cover	Σ **COVER of ALIEN** and CRYP PERENNIAL species across 5 plots/5 plots	S
XRCOV_ANNUAL	Mean relative annual cover	(XABCOV_ANNUAL/XTOTABCOV) x 100	C
XRCOV_ANNUAL_ NAT	Mean relative native Annual cover	(XABCOV_ANNUAL_NAT/ XTOTABCOV) x 100	C
XRCOV_ANNUAL_ AC	Mean relative alien and cryptogenic Annual cover	(XABCOV_ANNUAL_AC/ XTOTABCOV) x 100	S
XRCOV_ANN_ BIEN	Mean relative Annual-Biennial cover	(XABCOV_ANN_BIEN/ XTOTABCOV) x 100	C
XRCOV_ANN_ BIEN_NAT	Mean relative native Annual-Biennial cover	(XABCOV_ANN_BIEN_NAT/ XTOTABCOV) x 100	C
XRCOV_ANN_ BIEN_AC	Mean relative alien and cryptogenic Annual-Biennial cover	(XABCOV_ANN_BIEN_AC/ XTOTABCOV) x 100	S
XRCOV_ANN_ PEREN	Mean relative Annual-Perennial cover	(XABCOV_ANN_PEREN/ XTOTABCOV) x 100	C
XRCOV_ANN_ PEREN_NAT	Mean relative native Annual-Perennial cover	(XABCOV_ANN_PEREN_NAT/ XTOTABCOV) x 100	C
XRCOV_ANN_ PEREN_AC	Mean relative alien and cryptogenic Annual-Perennial cover	(XABCOV_ANN_PEREN_AC/ XTOTABCOV) x 100	S
XRCOV_ PERENNIAL	Mean relative Perennial cover	(XABCOV_PERENNIAL/ XTOTABCOV) x 100	C
XRCOV_ PERENNIAL_NAT	Mean relative native Perennial cover	(XABCOV_PERENNIAL_NAT/ XTOTABCOV) x 100	C
XRCOV_ PERENNIAL_AC	Mean relative alien and cryptogenic Perennial cover	(XABCOV_PERENNIAL_AC/ XTOTABCOV) x 100	S

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
Section 5.3	***PLANT CATEGORY***	**Trait Information = Plant Category (See Section 5.6.3); Native Status (Table 5-5)**	
N_DICOT	Dicot richness	Count unique DICOT species across 100-m^2 plots	C
N_DICOTS_NAT	Native Dicot richness	Count unique NAT DICOT species across 100-m^2 plots	C
N_DICOTS_ALIEN	Alien Dicot richness	Count unique ALIEN DICOT species across 100-m^2 plots	S
N_DICOTS_CRYP	Cryptogenic Dicot richness	Count unique CRYP DICOT species across 100-m^2 plots	C
N_DICOTS_AC	Alien and Cryptogenic richness	N_DICOT_ALIEN + N_DICOT_CRYP	S
N_FERN	Fern richness	Count unique FERN species across 100-m^2 plots	C
N_FERNS_NAT	Native Fern richness	Count unique native FERN species across 100-m^2 plots	C
N_FERNS_INTR	Introduced FERN species richness	Count unique introduced FERN species across 100-m^2 plots	S
N_GYMNOSPERM	Gymnosperm richness	Count unique GYMNOSPERM species across 100-m^2 plots	C
N_LYCOPOD	Lycopod richness	Count unique LYCOPOD species across 100-m^2 plots	C
N_HORSETAIL	Horsetail richness	Count unique HORSETAIL species across 100-m^2 plots	C
N_MONOCOT	Monocot richness	Count unique MONOCOT species across 100-m^2 plots	C
N_MONOCOTS_ NAT	Native Monocot richness	Count unique NAT MONOCOT species across 100-m^2 plots	C
N_MONOCOTS_ ALIEN	Alien Monocot richness	Count unique ALIEN MONOCOT species across 100-m^2 plots	S
N_MONOCOTS_ CRYP	Cryptogenic Monocot richness	Count unique CRYP MONOCOT species across 100-m^2 plots	S
N_MONOCOTS_ AC	Alien and cryptogenic Monocot richness	N_MONOCOT_ALIEN + N_MONOCOT_CRYP	S
PCTN_DICOT	Dicot percent richness	(N_DICOTS/TOTN_SPP) x 100	C
PCTN_DICOTS_ NAT	Native Dicot percent richness	(N_DICOTS_NAT/TOTN_SPP) x 100	C
PCTN_DICOTS_ ALIEN	Alien Dicot percent richness	(N_DICOTS_ALIEN/TOTN_SPP) x 100	S
PCTN_DICOTS_ CRYP	Cryptogenic Dicot percent richness	(N_DICOTS_CRYP/TOTN_SPP) x 100	S
PCTN_DICOTS_AC	Alien and cryptogenic Dicot percent richness	(N_DICOTS_AC/TOTN_SPP) x 100	S
PCTN_FERN	Fern percent richness	(N_FERNS/TOTN_SPP) x 100	C
PCTN_FERNS_ NAT	Native Ferns percent richness	(N_FERNS_NAT/TOTN_SPP) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
PCTN_FERNS_ INTR	Introduced Fern percent richness	(N_FERNS_INTR/TOTN_SPP) x 100	S
PCTN_ GYMNOSPERM	GYMNOSPERM Percent Richness	(N_GYNOSPERM/TOTN_SPP) x 100	C
PCTN_LYCOPOD	Lycopod percent richness	(N_LYCOPOD/TOTN_SPP) x 100	C
PCTN_HORSETAIL	Horsetail percent richness	(N_HORSETAIL/TOTN_SPP) x 100	C
PCTN_ MONOCOT	Monocot percent richness	(N_MONOCOTS/TOTN_SPP) x 100	C, **in EW-VMMI**
PCTN_ MONOCOTS_NAT	Native Monocot percent richness	(N_MONOCOTS_NAT/TOTN_SPP) x 100	C
PCTN_ MONOCOTS_ ALIEN	Alien Monocot percent richness	(N_MONOCOTS_ALIEN/ TOTN_SPP) x 100	S
PCTN_ MONOCOTS_ CRYP	Cryptogenic Monocot percent richness	(N_MONOCOTS_CRYP/TOTN_SPP) x 100	S
PCTN_ MONOCOTS_AC	Alien and cryptogenic monocot percent richness	(N_MONOCOTS_AC/TOTN_SPP) x 100	S
XABCOV_DICOT	Mean absolute cover Dicots	Σ COVER of DICOT species across 5 plots/5 plots	C
XABCOV_ DICOTS_NAT	Mean absolute cover native Dicots	Σ COVER of NAT DICOT species across 5 plots/5 plots	C
XABCOV_ DICOTS_ALIEN	Mean absolute cover Alien Dicots	Σ COVER of ALIEN DICOT species across 5 plots/5 plots	S
XABCOV_ DICOTS_CRYP	Mean absolute cover cryptogenic Dicots	Σ COVER of CRYP DICOT species across 5 plots/5 plots	S
XABCOV_ DICOTS_AC	Mean absolute cover of alien and cryptogenic Dicots	XABCOV_DICOTS_ALIEN + XABCOV_DICOTS_CRYP	S
XABCOV_FERN	Mean absolute cover of Ferns	Σ COVER of FERN species across 5 plots/5 plots	C
XABCOV_FERNS_ NAT	Mean absolute cover of native Ferns	Σ COVER of NAT FERN species across 5 plots/5 plots	C
XABCOV_FERNS_ INTR	Mean absolute cover of introduced Ferns	Σ COVER of introduced INTR FERN species across 5 plots/5 plots	S
XABCOV_ GYMNOSPERM	Mean absolute cover of Gymnosperms	Σ COVER of GYMNOSPERM species across 5 plots/5 plots	C
XABCOV_ LYCOPOD	Mean absolute cover of Lycopods	Σ COVER of LYCOPOD species across 5 plots/5 plots	C
XABCOV_ HORSETAIL	Mean absolute cover of Horsetails	Σ COVER of HORSETAIL species across 5 plots/5 plots	C
XABCOV_ MONOCOT	Mean absolute cover of Monocots	Σ COVER of MONOCOT species across 5 plots/5 plots	C
XABCOV_ MONOCOTS_NAT	Mean absolute cover of native Monocots	Σ COVER of NAT MONOCOT species across 5 plots/5 plots	C
XABCOV_ MONOCOTS_ ALIEN	Mean absolute cover of alien Monocots	Σ COVER of ALIEN MONOCOT species across 5 plots/5 plots	S

METRIC NAME	METRIC DESCRIPTION	CALCULATION (listed in Metric Row), SPECIES TRAIT TYPE (indicated in Banner if applicable)	METRIC TYPE (C = condition, S = stress)
XABCOV_ MONOCOTS_ CRYP	Mean absolute cover of cryptogenic Monocots	Σ COVER of CRYP MONOCOT species across 5 plots/5 plots	S
XABCOV_ MONOCOTS_AC	Mean absolute cover of alien and cryptogenic Monocots	XABCOV_MONOCOTS_ALIEN + XABCOV_MONOCOTS_CRYP	S
XRCOV_DICOT	Mean relative cover Dicots	(XABCOV_DICOTS/XTOTABCOV) x 100	C
XRCOV_DICOTS_ NAT	Mean relative cover native Dicots	(XABCOV_DICOTS_NAT/ XTOTABCOV) x 100	C
XRCOV_DICOTS_ ALIEN	Mean relative cover alien Dicots	(XABCOV_DICOTS_ALIEN/ XTOTABCOV) x 100	S
XRCOV_DICOTS_ CRYP	Mean relative cover cryptogenic Dicots	(XABCOV_DICOTS_CRYP/ XTOTABCOV) x 100	S
XRCOV_DICOTS_ AC	Mean relative cover of alien and cryptogenic Dicots	(XABCOV_DICOTS_AC/ XTOTABCOV) x 100	S
XRCOV_FERN	Mean relative cover of Ferns	(XABCOV_FERNS/ XTOTABCOV) x 100	C
XRCOV_FERNS_ NAT	Mean relative cover of native Ferns	(XABCOV_FERNS_NAT/ XTOTABCOV) x 100	C
XRCOV_FERNS_ INTR	Mean relative cover of introduced Ferns	(XABCOV_FERNS_INTR/ XTOTABCOV) x 100	S
XRCOV_ GYMNOSPERM	Mean relative cover of Gymnosperms	(XABCOV_GYMNOSPERMS/ XTOTABCOV) x 100	C
XRCOV_LYCOPOD	Mean relative cover of Lycopods	(XABCOV_LYCOPODS/ XTOTABCOV) x 100	C
XRCOV_ HORSETAIL	Mean relative cover of Horsetails	(XABCOV_HORSETAILS/ XTOTABCOV) x 100	C
XRCOV_ MONOCOT	Mean relative cover of Monocots	(XABCOV_MONOCOTS/ XTOTABCOV) x 100	C
XRCOV_ MONOCOTS_NAT ■, ■, ■	Mean relative cover of native Monocots	(XABCOV_MONOCOTS_NAT/ XTOTABCOV) x 100	**C, in EH-VMMI, PRLW-VMMI, 2011 National VMMI**
XRCOV_ MONOCOTS_ ALIEN	Mean relative cover of alien Monocots	(XABCOV_MONOCOTS_ALIEN/ XTOTABCOV) x 100	S
XRCOV_ MONOCOTS_ CRYP	Mean relative cover of cryptogenic Monocots	(XABCOV_MONOCOTS_CRYP/ XTOTABCOV) x 100	S
XRCOV_ MONOCOTS_AC	Mean relative cover of alien and cryptogenic Monocots	(XABCOV_MONOCOTS_AC/ XTOTABCOV) x 100	S
Sections 6 - 8	**METRICS BASED ON FIELD DATA FROM FORM V-1: NWCA 2016 VEGETATION PLOT ESTABLISHMENT AND FORM V-3: NWCA 2016 VEGETATION TYPES (FRONT) AND NWCA 2016 GROUND SURFACE ATTRIBUTES (BACK)**		

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
SECTION 6	**WETLAND TYPE HETEROGENEITY BASED ON PLOT-LEVEL NWCA WETLAND TYPES (*designated as 'Predominant NWCA Wetland Type' on Form V-1)***		
N_SANDT	Number of unique NWCA Wetland Types (**WETLAND_TYPE**) in AA	Count number of unique NWCA **WETLAND_TYPE** across the 5 plots	C
DOM_SANDT	Dominant NWCA **WETLAND_TYPE**(s) in AA	Select dominant NWCA **WETLAND_TYPE**: Most frequent (greatest number of plots), or in case of ties, the two most frequent hyphenated	C
D_SANDT	Simpson's Diversity - Heterogeneity of NWCA **WETLAND_TYPE** s in AA *s* = number of S&T classes present, *i* = class *i, p* = proportion of S&T Classes belonging to class *i*	$D = 1 - \sum_{i}^{s} p_i^2$	C
H_SANDT	Shannon-Wiener - Heterogeneity of NWCA **WETLAND_TYPE** s in AA *s* = number of S&T classes present, *i* = class *i, p* = proportion of S&T Classes belonging to class *i*	$H' = -\sum_{i}^{s} p_i \ln p_i$	C
J_SANDT	Pielou Evenness - Heterogeneity of NWCA **WETLAND_TYPE** s in AA *S* = number of S&T classes observed	$J = \frac{H'}{\ln S}$	C

SECTION 7	**VEGETATION STRUCTURE/TYPES**		
SECTION 7.1	***Vascular Strata***		
N_VASC_STRATA	Number of unique Vascular Vegetation Strata across AA	Count number of unique vascular vegetation strata across the 5 plots	C
XN_VASC_ STRATA	Mean number of vascular vegetation strata across plots		C
RG_VASC_ STRATA	Range in number of vascular vegetation strata found in all 100-m^2 plots	Maximum - minimum number of vegetation strata across five 100-m^2 plots	C
XTOTCOV_VASC_ STRATA	Mean total cover of all vascular strata	(Σ cover for all vascular strata across all 100-m^2 plots)/5 plots	C
FREQ_ SUBMERGED_AQ	Frequency Submerged Aquatic Vegetation	(# of 100-m^2 plots in which **SUBMERGED_AQ occu**rs/5 plots) x 100	C
FREQ_FLOATING_ AQ	Frequency Floating Aquatic Vegetation	(# of 100-m^2 plots in which **FLOATING_AQ occu**rs/5 plots) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
FREQ_LIANAS	Frequency Lianas, vines, and vascular epiphytes	(# of 100-m^2 plots in which LIANAS occurs/5 plots) x 100	C
FREQ_VTALL_VEG	Frequency Vegetation > 30m tall	(# of 100-m^2 plots in which VTALL_VEG occurs/5 plots) x 100	C
FREQ_TALL_VEG	Frequency Vegetation > 15m to 30m tall	(# of 100-m^2 plots in which TALL_VEG occurs/5 plots) x 100	C
FREQ_HMED_VEG	Frequency Vegetation > 5m to 15m tall	(# of 100-m^2 plots in which HMED_VEG occurs/5 plots) x 100	C
FREQ_MED_VEG	Frequency Vegetation >2m to 5 tall	(# of 100-m^2 plots in which MED_VEG occurs/5 plots) x 100	C
FREQ_SMALL_VEG	Frequency Vegetation 0.5 to 2m tall	(# of 100-m^2 plots in which SMALL_VEG occurs/5 plots) x 100	C
FREQ_VSMALL_VEG	Frequency Vegetation < 0.5m tall	(# of 100-m^2 plots in which VSMALL_VEG occurs/5 plots) x 100	C
XCOV_SUBMERGED_AQ	Mean absolute cover Submerged Aquatic Vegetation	Σ cover of SUBMERGED_AQ across 5 plots/5 plots	C
XCOV_FLOATING_AQ	Mean absolute cover Floating Aquatic Vegetation	Σ cover of FLOATING_AQ across 5 plots/5 plots	C
XCOV_LIANAS	Mean absolute cover Lianas, vines, and vascular epiphytes	Σ cover of LIANAS across 5 plots/5 plots	C
XCOV_VTALL_VEG	Mean absolute cover Vegetation > 30m tall	Σ cover of VTALL_VEG across 5 plots/5 plots	C
XCOV_TALL_VEG	Mean absolute cover Vegetation > 15m to 30m tall	Σ cover of TALL_VEG across 5 plots/5 plots	C
XCOV_HMED_VEG	Mean absolute cover Vegetation > 5m to 15m tall	Σ cover of HMED_VEG across 5 plots/5 plots	C
XCOV_MED_VEG	Mean absolute cover Vegetation >2m to 5 tall	Σ cover of MED_VEG across 5 plots/5 plots	C
XCOV_SMALL_VEG	Mean absolute cover Vegetation 0.5 to 2m tall	Σ cover of SMALL_VEG across 5 plots/5 plots	C
XCOV_VSMALL_VEG	Mean absolute cover Vegetation < 0.5m tall	∑cover of VSMALL_VEG across 5 plots/5 plots	C
IMP_SUBMERGED_AQ	Importance Submerged Aquatic Vegetation	(FREQ_SUBMERGED_AQ + XCOV_SUBMERGED_AQ)/2	C
IMP_FLOATING_AQ	Importance Floating Aquatic Vegetation	(FREQ_FLOATING_AQ + XCOV_FLOATING_AQ)/2	C
IMP_LIANAS	Importance Lianas, vines, and vascular epiphytes	(FREQ_LIANAS + XCOV_LIANAS)/2	C
IMP_VTALL_VEG	Importance Vegetation > 30m tall	(FREQ_VTALL_VEG + XCOV_VTALL_VEG)/2	C
IMP_TALL_VEG	Importance Vegetation > 15m to 30m tall	(FREQ_TALL_VEG + XCOV_TALL_VEG)/2	C
IMP_HMED_VEG	Importance Vegetation > 5m to 15m tall	(FREQ_HMED_VEG + XCOV_HMED_VEG)/2	C
IMP_MED_VEG	Importance Vegetation >2m to 5 tall	(FREQ_MED_VEG + XCOV_MED_VEG)/2	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
IMP_SMALL_VEG	Importance Vegetation 0.5 to 2m tall	(FREQ_SMALL_VEG + XCOV_SMALL_VEG)/2	C
IMP_VSMALL_VEG	Importance Vegetation < 0.5m tall	(FREQ_VSMALL_VEG + XCOV_VSMALL_VEG)/2	C
XRCOV_SUBMERGED_AQ	Relative mean cover Submerged Aquatic Vegetation	(XCOV_SUBMERGED_AQ/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_FLOATING_AQ	Relative mean cover Floating Aquatic Vegetation	(XCOV_FLOATING_AQ/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_LIANAS	Relative cover Lianas, Vines, and Vascular Epiphytes	(XCOV_LIANAS/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_VTALL_VEG	Relative cover Vegetation > 30m tall	(XCOV_VTALL_VEG/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_TALL_VEG	Relative cover Vegetation > 15m to 30m tall	(XCOV_TALL_VEG/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_HMED_VEG	Relative cover Vegetation > 5m to 15m tall	(XCOV_HMED_VEG/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_MED_VEG	Relative cover Vegetation >2m to 5 tall	(XCOV_MED_VEG/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_SMALL_VEG	Relative cover Vegetation 0.5 to 2m tall	(XCOV_SMALL_VEG/ XTOTCOV_VASC_STRATA) x 100	C
XRCOV_VSMALL_VEG	Relative cover Vegetation < 0.5m tall	(XCOV_VSMALL_/ XTOTCOV_VASC_STRATA) x 100	C
D_VASC_STRATA	Simpson's Diversity - Heterogeneity of Vertical Vascular Structure in AA based on occurrence and relative cover of all strata in all plots *s* = number of veg strata observed, *i* = veg stratum *i*, *p* = relative cover belonging to veg stratum *i*	$D = 1 - \sum_{i}^{s} p_i^2$	C
H_VASC_STRATA	Shannon-Wiener - Heterogeneity of Vertical Vascular Structure in AA based on occurrence and relative cover of all strata in all plots *s* = number of veg strata observed, *i* = veg stratum *i*, *p* = relative cover belonging to veg stratum *i*	$H' = -\sum_{i}^{s} p_i \ln p_i$	C
J_VASC_STRATA	Pielou Evenness - Heterogeneity of Vertical Vascular Structure in AA based on occurrence and relative cover of all strata in all plots *S*=number of strata observed	$J = \frac{H'}{\ln S}$	C
Section 7.2	***Non-Vascular Groups***		

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
N_PEAT_MOSS_DOM	Number of plots where bryophytes are dominated by Sphagnum or other peat forming moss	Count number of plots where **PEAT_MOSS = Y**	C
FREQ_PEAT_MOSS_DOM	Frequency of plots where bryophytes are dominated by Sphagnum or other peat forming moss	(N_PEAT_MOSS_DOM/5 plots) x 100	C
FREQ_BRYOPHYTES	Frequency of bryophytes growing on ground surfaces, logs, rocks, etc.	(# of 100-m^2 plots in which **BRYOPHYTES** occur/5 plots) x 100	C
FREQ_LICHENS	Frequency of lichens growing on ground surfaces, logs, rocks, etc.	(# of 100-m^2 plots in which **LICHENS** occur/5 plots) x 100	C
FREQ_ARBOREAL	Frequency of arboreal Bryophytes and Lichens	(# of 100-m^2 plots in which **ARBOREAL** occur/5 plots) x 100	C
FREQ_ALGAE	Frequency of filamentous or mat forming algae	(# of 100-m^2 plots in which **ALGAE** occurs/5 plots) x 100	C
FREQ_MACROALGAE	Macroalgae (freshwater species/seaweeds)	(# of 100-m^2 plots in which **MACROALGAE** occurs/5 plots) x 100	C
XCOV_BRYOPHYTES	Mean absolute cover bryophytes growing on ground surfaces, logs, rocks, etc.	Σ cover of **BRYOPHYTES** across 5 plots/5 plots	C
XCOV_LICHENS	Mean absolute cover lichens growing on ground surfaces, logs, rocks, etc.	Σ cover of **LICHENS** across 5 plots/5 plots	C
XCOV_ARBOREAL	Mean absolute cover arboreal Bryophytes and Lichens	∑ cover of **ARBOREAL** across 5 plots/5 plots	C
XCOV_ALGAE	Mean absolute cover filamentous or mat forming algae	∑ cover of **ALGAE** across 5 plots/5 plots	C
XCOV_MACROALGAE	Mean absolute cover macroalgae (freshwater species/seaweeds)	∑ cover of **MACROALGAE** across 5 plots/5 plots	C
IMP_BRYOPHYTES	Bryophytes growing on ground surfaces, logs, rocks, etc.	(FREQ_BRYOPHYTES + XCOV_BRYOPHYTES)/2	C
IMP_LICHENS	Lichens growing on ground surfaces, logs, rocks, etc.	(FREQ_LICHENS + XCOV_LICHENS)/2	C
IMP_ARBOREAL	Arboreal Bryophytes and Lichens	(FREQ_ARBOREAL + XCOV_ARBOREAL)/2	C
IMP_ALGAE	Filamentous or mat forming algae	(FREQ_ALGAE + XCOV_ALGAE)/2	C
IMP_MACROALGAE	Macroalgae (freshwater species/seaweeds)	(FREQ_MACROALGAE + XCOV_MACROALGAE)/2	C
Section 8	**Ground Surface Attributes**		
Section 8.1	***Water Cover and Depth***		
XH2O_DEPTH	Mean Predominant water depth in plots where water occurs	∑**PREDOMINANT_DEPTH** across plots where standing water occurs/number of plots where standing water occurs	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XH2O_DEPTH_AA	Mean Predominant water depth across AA	∑PREDOMINANT_DEPTH across plots all sampled 100-m^2 plots/5 plots	C
FREQ_H2O	Frequency of occurrence of water across 100-m^2 plots	(# of 100-m^2 plots in which TOTAL_WATER occurs/5 plots) x 100	C
MIN_COV_H2O	Minimum cover of water	Lowest value for TOTAL_WATER across five 100-m^2 plots	C
MAX_COV_H2O	Maximum cover of water	Highest value for TOTAL_WATER across five 100-m^2 plots	C
XCOV_H2O	Mean total cover of water (mean percent of Veg Plot area with water)	Σ cover of TOTAL_WATER across 5 plots/5 plots	C
IMP_H2O	Importance total cover of water across Veg Plot area	(FREQ_H2O + XCOV_H2O)/2	C
Section 8.2	***Bare ground and Vegetation Litter***		
LITTER_TYPE	Predominant litter type	PREDOMINANT_LITTER: CONIFEROUS, DECIDUOUS, GRAMINOID, FORB, FERN, BROADLEAF	C
XDEPTH_LITTER	Mean depth of litter across all 1-m^2 quadrats in AA	Sum DEPTH_SW and DEPTH_NE for all 1-m^2 quadrats/total number of sampled quadrats in AA (usually 10)	C
MEDDEPTH_ LITTER	Median depth of litter across all 1-m^2 quadrats in AA	Median DEPTH_SW and DEPTH_NE for all 1-m^2 quadrats/total number of sampled quadrats in AA (usually 10)	C
FREQ_LITTER	Frequency of litter	(# of 100-m^2 plots in which TOTAL_LITTER >0/5 plots) x 100	C
FREQ_BAREGD	Frequency of bare ground	(# of 100-m^2 plots in which any one of EXPOSED_SOIL; EXPOSED_GRAVEL; EXPOSED_ROCK occurs/5 plots) x 100	C
FREQ_EXPOSED_ SOIL	Frequency exposed soil/sediment	(# of 100-m^2 plots in which EXPOSED_SOIL occurs/5 plots) x 100	C
FREQ_EXPOSED_ GRAVEL	Frequency exposed gravel/cobble (~2mm to 25cm)	(# of 100-m^2 plots in which EXPOSED_GRAVEL occurs/5 plots) x 100	C
FREQ_EXPOSED_ ROCK	Frequency exposed rock (> 25cm)	(# of 100-m^2 plots in which EXPOSED_ROCK occurs/5 plots) x 100	C
FREQ_WD_FINE	Frequency of fine woody debris (< 5cm diameter)	(# of 100-m^2 plots in which WD_FINE occurs/5 plots) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
FREQ_WD_ COARSE	Frequency of coarse woody debris (> 5cm diameter)	(# of 100-m² plots in which WD_COARSE occurs/5 plots) x 100	C
XCOV_LITTER	Mean Cover of litter	Σ cover of TOTAL_LITTER across 5 plots/5 plots	C
XCOV_BAREGD	Mean cover of bare ground	Σ cover of EXPOSED_SOIL + EXPOSED_GRAVEL + EXPOSED_ROCK across 5 plots/5 plots	C
XCOV_EXPOSED_ SOIL	Mean Cover exposed soil/sediment	Σ cover of EXPOSED_SOIL across 5 plots/5 plots	C
XCOV_EXPOSED_ GRAVEL	Mean Cover exposed gravel/cobble (~2mm to 25cm)	Σ cover of EXPOSED_GRAVEL across 5 plots/5 plots	C
XCOV_EXPOSED_ ROCK	c) Cover exposed rock (> 25cm)	Σ cover of EXPOSED_ROCK across 5 plots/5 plots	C
XCOV_WD_FINE	Mean Cover of fine woody debris (< 5cm diameter)	Σ cover of WD_FINE across 5 plots/5 plots	C, **in EW-VMMI**
XCOV_WD_ COARSE	Mean Cover of coarse woody debris (> 5cm diameter)	Σ cover of WD_COARSE across 5 plots/5 plots	C
IMP_LITTER	Importance of litter	(FREQ_LITTER + XCOV_LITTER)/2	C
IMP_BAREGD	Importance of bare ground	(FREQ_BAREGD + XCOV_BAREGD)/2	C
IMP_EXPOSED_ SOIL	Importance exposed soil/sediment	(FREQ_EXPOSED_SOIL + XCOV_EXPOSED_SOIL)/2	C
IMP_EXPOSED_ GRAVEL	Importance exposed gravel/cobble (~2mm to 25cm)	(FRQ_EXPOSED_GRAVEL + XCOV_EXPOSED_GRAVEL)/2	C
IMP_EXPOSED_ ROCK	Importance exposed rock (> 25cm)	(FREQ_EXPOSED_ROCK + XCOV_EXPOSED_ROCK)/2	C
IMP_WD_FINE	Importance of fine woody debris (< 5cm diameter)	(FREQ_WD_FINE + XCOV_WD_FINE)/2	C
IMP_WD_ COARSE	Importance of coarse woody debris (> 5cm diameter)	(FREQ_WD_COARSE+ XCOV_WD_COARSE)/2	C

SECTIONS 9 - 11	**METRICS BASED ON RAW DATA FROM FORM V-4: NWCA 2016 SNAG AND TREE COUNTS AND TREE COVER** Snag and tree metrics are calculated as means/100-m² plots to represent AA, unless specified as totals across AA (from all 5 100m²). Snag and tree metrics were not placed on a per hectare basis because the AA and sampled plots do not necessarily represent homogenous patches and many wetlands are not forested but may have occasional trees. Basal area was not calculated because diameters were estimated in classes.		
SECTION 9	**DEAD/SNAG COUNT METRICS - Based on data from FORM V-4 (Snag/standing dead tree section)**		
TOTN_XXTHIN_ SNAG	Total Number Dead tree or snags 5 to 10 cm DBH (diameter breast height)	∑ number of XXTHIN_SNAGS across of all 100-m² plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
TOTN_XTHIN_ SNAG	Total number of dead trees or snags 11 to 25cm DBH	∑ number of **XTHIN_SNAGS** across of all 100-m^2 plots	C
TOTN_THIN_ SNAG	Total number of dead trees or snags 26 to 50cm DBH	∑ number of **THIN_SNAG**S across of all 100-m^2 plots	C
TOTN_JR_ SNAG	Total number of dead trees or snags 51 to 75cm DBH	∑ number of **JR_SNAGS** across of all 100-m^2 plots	C
TOTN_THICK_ SNAG	Total number of dead trees or snags 76 to 100cm DBH	∑ number of **THICK_SNAGS acro**ss of all 100-m^2 plots	C
TOTN_XTHICK_ SNAG	Total number of dead trees or snags 101 to 200 cm DBH	∑ number of **XTHICK_SNAGS** across of all 100-m^2 plots	C
TOTN_SNAGS	Total number of dead trees and snags	∑ number of all dead trees and snags across all DBH classes	C
XN_XXTHIN_ SNAG	Mean Number Dead tree or snags 5 to 10 cm DBH (diameter breast height)	∑ number of **XXTHIN_SNAG/**5 plots	C
XN_XTHIN_SNAG	Mean number of dead trees or snags 11 to 25cm DBH	∑ number of **XTHIN_SNAG/**5 plots	C
XN_THIN_SNAG	Mean number of dead trees or snags 26 to 50cm DBH	∑ number of **THIN_SNAG/**5 plots	C
XN_JR_SNAG	Mean number of dead trees or snags 51 to 75cm DBH	∑ number of **JR_SNAG/**5 plots	C
XN_THICK_SNAG	Mean number of dead trees or snags 76 to 100cm DBH	∑ number of **THICK_SNAG/**5 plots	C
XN_XTHICK_ SNAG	Mean number of dead trees or snags 101 to 200 cm DBH	∑ number of **XTHICK_SNAG/**5 plots	C
XN_SNAGS	Mean number of dead trees and snags	∑ number of dead trees and snags across all DBH classes/5 plots	C
			C
SECTION 10	**TREES - COUNTS AND COVER**		
SECTION 10.1	***TREE COVER METRICS***		
N_TREESPP	Richness tree species	Count unique tree species (taxa) across all 5 plots	C
N_VSMALL_TREE	Richness tree species, trees < 0.5m tall	Count unique tree species (taxa) in **VSMALL_TREE** height class across all 5 plots	C
N_SMALL_TREE	Richness tree species, trees 0.5m to 2m tall	Count unique tree species (taxa) in **SMALL_TREE** height class across all 5 plots	C
N_LMED_TREE	Richness tree species, trees > 2 to 5m tall	Count unique tree species (taxa) in **LMED_TREE** height class across all 5 plots	C
N_HMED_TREE	Richness tree species, trees > 5m to 15m tall	Count unique tree species (taxa) in **HMED_TREE** height class across all 5 plots	C
N_TALL_TREE	Richness tree species, trees > 15m to 30m tall	Count unique tree species (taxa) in **TALL_TREE** height class across all 5 plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
N_VTALL_TREE	Richness tree species, trees > 30m tall	Count unique tree species (taxa) in **VT_TREE** height class across all 5 plots	C
N_TREE_ GROUND	Richness tree species in ground layer (e.g., seedlings, saplings), trees < 2m	Count unique tree species (taxa) in GROUND LAYER (**VSMALL_TREE and SMALL_TREE** height classes) across all 5 plots	C
N_TREE_MID	Richness tree species in subcanopy layer, trees 2m to 15m tall	Count unique tree species (taxa) in MID LAYER (**LMED_TREE and HMED_TREE heig**ht classes) across all 5 plots	C
N_TREE_UPPER	Richness tree species in subcanopy layer, trees > 15m	Count unique tree species (taxa) in UPPER LAYER (**TALL_TREE and VTALL_TREE** height classes) across all 5 plots	C
PCTN_TREE_ GROUND	Percent richness of tree species found in ground layer (e.g., seedlings, saplings), trees < 2m	(N_TREE_GROUND/N_TREESPP) x 100	C
PCTN_TREE_MID	Percent richness of tree species found in subcanopy layer, trees 2m to 15m tall	(N_TREE_MID/N_TREESPP) x 100	C
PCTN_TREE_ UPPER	Percent richness of tree species found in subcanopy layer, trees > 15m	(N_TREE_UPPER/N_TREESPP) x 100	C
FREQ_VSMALL_ TREE	Frequency (proportion of plots) of VSMALL trees, trees < 0.5m tall	(Number of 100-m^2 plots in which any species of **VSMALL tree**s occurs/5 plots) x 100	C
FREQ_SMALL_ TREE	Frequency (proportion of plots) of SMALL trees, trees 0.5m to 2m tall	(Number of 100-m^2 plots in which any species of **SMALL tree**s occurs/5 plots) x 100	C
FREQ_LMED_ TREE	Frequency (proportion of plots) of LMED trees, trees > 2 to 5m tall	(Number of 100-m^2 plots in which any species of **LMED tree**s occurs/5 plots) x 100	C
FREQ_HMED_ TREE	Frequency (proportion of plots) of HMED, trees > 5m to 15m tall	(Number of 100-m^2 plots in which any species of **HMED tree**s occurs/5 plots) x 100	C
FREQ_TALL_TREE	Frequency (proportion of plots) of TALL trees, trees > 15m to 30m tall	(Number of 100-m^2 plots in which any species of **TALL tree**s occurs/5 plots) x 100	C
FREQ_VTALL_ TREE	Frequency (proportion of plots) of Frequency of individual, trees > 30m tall	(Number of 100-m^2 plots in which any species of **VTALL tree**s occurs/5 plots) x 100	C
FREQ_TREE_ GROUND	Frequency (proportion of plots) of ground layer trees < 2m	(Number of 100-m^2 plots in which any species of GROUND LAYER (**VSMALL or SMALL) tree**s occurs/5 plots) x 100	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
FREQ_TREE_MID	Frequency (proportion of plots) of subcanopy, trees 2m to 15m tall	(Number of 100-m^2 plots in which any species of MID LAYER (**LMED or HMED) trees** occurs/5 plots) x 100	C
FREQ_TREE_ UPPER	Frequency (proportion of plots) of CANOPY trees, trees >15m	(Number of 100-m^2 plots in which any species of UPPER LAYER (**LMED or HMED) trees** occurs/5 plots) x 100	C
XCOV_VSMALL_ TREE	Mean absolute cover VSMALL trees, trees < 0.5m tall	∑ of cover for all tree species in **VSMALL** height class across all plots/5 plots	C
XCOV_SMALL_ TREE	Mean absolute cover SMALL trees, trees 0.5m to 2m tall	∑ of cover for all tree species in **SMALL** height class across all plots/5 plots	C
XCOV_LMED_ TREE	Mean absolute cover LMED trees, trees > 2 to 5m tall	∑ of cover for all tree species in **LMED** height class across all plots/5 plots	C
XCOV_HMED_ TREE_	Mean absolute cover HMED trees, trees > 5m to 15m tall	∑ of cover for all tree species in **HMED** height class across all plots/5 plots	C
XCOV_TALL_TREE	Mean absolute cover TALL trees, trees > 15m to 30m tall	∑ of cover for all tree species in **TALL** height class across all plots/5 plots	C
XCOV_VTALL_ TREE_	Mean absolute cover VTALL trees, trees > 30m tall	∑ of cover for all tree species in **VTALL** height class across all plots/5 plots	C
XCOV_TREE_ GROUND	Mean absolute cover trees in ground layer (e.g., seedlings, saplings), trees < 2m	∑ of cover for all tree species in GROUND LAYER (**VSMALL_TREE and SMALL_TREE** height classes) across all plots/5 plots	C
XCOV_TREE_MID	Mean absolute cover trees in MID layer, trees 2m to 15m tall	∑ of cover for all tree species in MID LAYER (**LMED_TREE and HMED_TREE** height classes) across all plots/5 plots	C
XCOV_TREE_ UPPER	Mean absolute cover trees in UPPER layer, trees >15m	∑ of cover for all tree species in UPPER LAYER (**TALL_TREE and VTALL_TREE** height classes) across all plots/5 plots	C
IMP_VSMALL_ TREE	Importance of VSMALL trees, trees < 0.5m tall	(FREQ_VSMALL_TREE + XCOV_VSMALL_TREE)/2	C
IMP_SMALL_TREE	Importance of SMALL trees, trees 0.5m to 2m tall	(FREQ_SMALL_TREE + XCOV_SMALL_TREE)/2	C
IMP_LMED_TREE	Importance of LMED trees ,trees > 2 to 5m tall	(FREQ_LMED_TREE + XCOV_LMED_TREE)/2	C
IMP_HMED_TREE	Importance of HMED trees, trees > 5m to 15m tall	(FREQ_HMED_TREE + XCOV_HMED_TREE)/2	C
IMP_TALL_TREE	Importance of TALL trees, trees > 15m to 30m tall	(FREQ_TALL_TREE + XCOV_TALL_TREE)/2	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
IMP_VTALL_TREE	Importance of VTALL trees, trees > 30m tall	(FREQ_VTALL_TREE + XCOV_VTALL_TREE)/2	C
IMP_TREE_GROUN D	Importance of trees in GROUND layer (e.g., seedlings, saplings), trees < 2m	(FREQ_TREE_GOUND + XCOV_TREE_GROUND)/2	C
IMP_TREE_MID	Importance of trees in MID layer, trees 2m-15m tall	(FREQ_TREE_MID + XCOV_TREE_MID)/2	C
IMP_TREE_UPPER	Importance of trees in UPPER layer, trees > 15m	(FREQ_TREE_UPPER + XCOV_TREE_UPPER)/2	C
SECTION 10.2	***TREE COUNT METRICS***		
TOTN_XXTHIN_ TREE	Total number of tree stems in XXTHIN class, trees 5 to 10cm DBH (diameter breast height)	∑ number of tree stems in **XXTHIN_TREE clas**s across all species and across all 100-m^2 plots	C
TOTN_XTHIN_ TREE	Total number of tree stems in XTHIN class, trees 11 to 25cm DBH	∑ number of tree stems in **XTHIN_TREE clas**s across all species and across 100-m^2 plots	C
TOTN_THIN_ TREE	Total number of tree stems in THIN class, trees 26 to 50cm DBH	∑ number of tree stems in **THIN_TREE clas**s across all species and across all 100-m^2 plots	C
TOTN_JR_TREE	Total number of tree stems in JR class, of trees 51 to 75cm DBH	∑ number of tree stems in **JR_TREE clas**s across all species and across all 100-m^2 plots	C
TOTN_THICK_ TREE	Total number of tree stems in THICK class, trees 76 to 100cm DBH	∑ number of tree stems in **THICK_TREE clas**s across all species and across all 100-m^2 plots	C
TOTN_XTHICK_ TREE	Total number of tree stems in XTHICK class, trees 101 to 200cm DBH	∑ number of tree stems in **XTHICK_TREE clas**s across all species and across all 100-m^2 plots	C
TOTN_XXTHICK_ TREE	Total number of tree stems in XXTHICK class, of trees > 200cm DBH	∑ number of tree stems in **XXTHICK_TREE clas**s across all species and across all 100-m^2 plots	C
TOTN_TREES	Total number of tree stems across all classes DBH	∑ number of tree stems across all size classes, across all species, and across all 100-m^2 plots	C
TOTN_LARGE	Total number of tree stems ≥ 76cm DBH	TOTN_THICK_TREE + TOTN_XTHICK_TREE + TOTN_XXTHICK_TREE	C
TOTN_MID	Total number of tree stems 26 to 75cm DBH	TOTN_THIN_TREE + TOTN_JR_TREE	C
TOTN_SMALL	Total number of tree stems 5 to 25cm DBH	TOTN_XX_THIN_TREE + TOTN_XTHIN_TREE	C
XN_XXTHIN_ TREE	Mean number of tree stems in XXTHIN class, trees 5 to 10 cm DBH (diameter breast height)	TOTN_XXTHIN_TREES/5 plots	C
XN_XTHIN_TREE	Mean number of tree stems in XTHIN class, trees 11 to 25cm DBH	TOTN_XTHIN_TREES/5 plots	C

METRIC NAME	METRIC DESCRIPTION	**CALCULATION** (listed in Metric Row), **SPECIES TRAIT TYPE** (indicated in Banner if applicable)	**METRIC TYPE** (C = condition, S = stress)
XN_THIN_TREE	Mean number of tree stems in THIN class, trees 26 to 50cm DBH	TOTN_THIN_TREES/5 plots	C
XN_JR_TREE	Mean number of tree stems in JR class, of trees 51 to 75cm DBH	TOTN_JR_TREES/5 plots	C
XN_THICK_TREE	Mean number of tree stems in THICK class, trees 76 to 100cm DBH	TOTN_THICK_TREES/5 plots	C
XN_XTHICK_TREE	Mean number of tree stems in XTHICK class, trees 101 to 200 cm DBH	TOTN_XTHICK_TREES/5 plots	C
XN_XXTHICK_TREE	Mean number of tree stems in XXTHICK class, of trees > 200 cm DBH	TOTN_XXTHICK_TREES/5 plots	C
XN_TREES	Mean number of tree stems across all classes DBH	TOTN_TREES/5 plots	C
XN_LARGE	Mean number of tree stems ≥ 76cm DBH	XN_THICK_TREE + XN_XTHICK_TREE + XN_XXTHICK_TREE	C
XN_MID	Mean number of tree stems 26 to 75cm DBH	XN_THIN_TREE + XN_JR_TREE	C
XN_SMALL	Mean number of tree stems 5 to 25cm DBH	XN_XX_THIN_TREE + XN_XTHIN_TREE	C

Chapter 9: Vegetation Multimetric Indices and Wetland Condition

9.1 Overview – Vegetation Multimetric Index (VMMI)

Multimetric indices (MMIs) of ecological condition based on biological assemblages (e.g., wetland vegetation, fish, birds, periphyton, macroinvertebrates) are cornerstones of the USEPA National Aquatic Resource Surveys (NARS). For MMIs, good and poor condition are defined relative to characteristics of the biota in least-disturbed sites. This chapter describes the process of ***Vegetation Multimetric Index (VMMI)*** development and the development of thresholds (also known as benchmarks) for good, fair, and poor condition based on VMMI values observed at least-disturbed sites. **Figure 1-1** in the Analysis Overview illustrates how the VMMI fits into the NWCA Analysis Pathway: 1) steps supporting VMMI development (see **Chapter 6:**,**Chapter 7**:, and **Chapter 8:** for details), 2) VMMI development and the determination of condition thresholds based on VMMI values (this chapter), and 3) the use of VMMI values, condition thresholds, and site weights in estimating wetland area in good, fair, or poor ecological condition (see **Chapter 15:**).

Previously, a national-scale VMMI, based on four broadly applicable metrics, was developed for the 2011 NWCA (USEPA 2016a, USEPA 2016b, Magee et al. 2019a). However, the availability of the added data from the 2016 survey made it possible to develop more specific, finer-scale VMMIs. Using vegetation data from the 1,985 unique NWCA sites sampled in 2011 or 2016 and methods detailed in Magee et al. (2019), numerous candidate VMMIs were generated for the following site groups:

- National scale - all sampled wetlands (**Table 8-1**)
- Five subpopulations based on RPT_UNIT_6 groups (**Figure 8-2**, **Table 8-3**): tidally-influenced Estuarine Wetlands in coastal areas (TDL) and Inland Wetlands in Five NWCA Aggregated Ecoregions (ICP, EMU, PLNS-ARW, and WVM)
- Four broad Wetland Group subpopulations (WETCLS_GRP (**Table 8-4**))

Characteristics of these groups are discussed in **Section 8.3**. Candidate vegetation metrics that passed several screening tests (**Section 8.5**) for each site group were used in VMMI development. The methods for VMMI development (**Section 9.3**) detailed in this chapter were applied to all the above VMMI site groups or subpopulations. Metrics that passed screening for the national-scale, for the five subpopulations based on RPT_UNIT_6, or for the four of WETCLS_GRP subpopulations, were scored (standardized) (**Section 9.3.1**) and used in developing numerous candidate VMMIs by subpopulation (**Section 9.3.2**). Evaluation of performance criteria (**Section 9.3.2**) for the candidate VMMIs for each of these groups, indicated the WETCLS_GRP subpopulations had the strongest performance. Based on these results, four final VMMIs were ultimately selected, one for each Wetland Group: Estuarine Herbaceous (VMMI-EH), Estuarine Woody (VMMI-EW), Inland Herbaceous (VMMI-PRLH), and Inland Woody (VMM-PRLW). Thresholds for good, fair, and poor condition (**Section 9.3.3**) were established for each Wetland Group VMMI. The Wetland Group VMMIs and their condition thresholds were used to calculate population estimates of condition (**Section 15.1**) for the 2016 survey and for change analysis between 2011 and 2016 (see **Chapter 15:** and USEPA 2022). Consequently, in the results sections of this chapter (**Sections 9.4** and **9.4.3**), we discuss only these final four VMMIs.

The R-code for VMMI development and threshold assignment was developed using Statistical Software, ver. 3.6.1 (R Core Team 2019).

9.2 Calibration and Validation Data

During the NWCA VMMI development process, numerous candidate vegetation metrics (n = 426, **Section 8.8, Appendix E**) were examined for potential utility in indicating condition and hundreds of thousands potential VMMIs were generated and evaluated (**Section 9.3**). To aid in developing the strongest final VMMIs and avoid over-fitting them to specific data collected in 2011 and 2016, vegetation data were divided into calibration (80% of sampled sites, n = 1,587) and validation (20% of sampled sites, n = 398) data sets. Numbers of calibration and validation sites in various subpopulations are listed in **Table 8-1** through **Table 8-4**. Metric scoring and VMMI development were conducted using the calibration data and the validation data were used to confirm the performance of the most promising candidate VMMIs.

The 20% of sampled sites included in the validation data were randomly selected from the total number of sampled sites and reserved to evaluate the consistency of candidate VMMIs. To encompass the range of disturbance and wetland types in the NWCA, sites for the validation data set were designated by stratified-random selection based on disturbance class (least-, intermediate-, and most-disturbed) and four Wetland Groups (WETCLS_GRP).

The 80% of sampled sites comprising the calibration data were used to score candidate metrics on a 0 to 10 continuous scale (**Sections 9.3.1, 9.4**). Candidate metrics that passed screening tests (**Section 8.5**) were scored within the NWCA subpopulations used for metric screening and development of potential VMMIs. The resulting metric scoring was applied to the corresponding validation data. A robust potential VMMI based on calibration data metric scoring is expected to similarly distinguish least-disturbed from most-disturbed sites for both calibration and validation data (VanSickle 2010, Magee et al. 2019a), and we evaluated this ability using box-and-whisker plots (see **Section 9.4**)

9.3 Developing Vegetation Multimetric Indices (VMMIs) – Methods

Using procedures that were developed for the 2011 NWCA (USEPA 2016b, Magee et al 2019), numerous candidate VMMIs were generated and evaluated for the national scale, for subpopulations of RPT_UNIT_6 (**Table 8-3**, **Figure 8-2**) , and for subpopulations of WETCLS_GRP (**Table 8-4**). These groups were selected in an effort to minimize within group variability and maintain a sufficient number of least-disturbed sites within each group to allow VMMI development (see **Section 8.3**). Methods for candidate VMMI generation and evaluation are summarized in this section and any differences from Magee et al. 2019 are incorporated in this summary.

9.3.1 *Step 1 – Metric Scoring*

Candidate metrics must be standardized to the same scale before they can be used as components of a VMMI. Metrics that passed screening tests for a given subpopulation were standardized on a 0 to 10 continuous scale using the calibration data. The metrics were scored based on interpolation of metric values between the 5^{th} (floor) and 95^{th} (ceiling) percentiles across all calibration sites (Blocksom 2003). The direction of each metric was determined by the direction of the difference between the mean of the least-disturbed sites and the mean of the most-disturbed sites. If the difference was positive, better condition is associated with higher metric values, and if negative, the reverse is true. For metrics decreasing with increasing disturbance, the ceiling was scored as 10 and the floor as zero. Conversely, for metrics that increased with increasing disturbance, the floor was scored as 10 and the ceiling as zero. Scores were truncated to 0 or 10 if observed values fell outside the floor to ceiling range. The resulting metric scoring was applied to the corresponding validation (see **Section 9.2**) data. A robust potential VMMI developed using this metric scoring should similarly distinguish least-disturbed from most-disturbed sites for both the calibration and validation data.

9.3.2 *Step 2 – Generating and Screening Candidate VMMIs*

Determining the optimal set of metrics for inclusion in a Vegetation Multimetric Index (VMMI) is a complex process. In analyses based on the 2011 NWCA vegetation data, USEPA (2016b) found that a random approach for selecting sets of metrics to include in candidate VMMIs (adapted from VanSickle 2010) ultimately produced more robust VMMIs than did expert selection of sets of individual metrics that were maximally responsive. Accordingly, Magee et al. (2019) refined this approach to build a national-scale wetland VMMI using the 2011 NWCA vegetation data. The methods of Magee et al. (2019) were applied to the vegetation data from 1,985 unique NWCA sites sampled in 2011 or 2016 to develop a set of finer-scale VMMIs, based on NWCA subpopulations, for describing wetland condition across the conterminous US. To this end, the calibration data set (n = 1,587 sites) was used to generate and evaluate numerous candidate VMMIs.

Candidate VMMIs were developed based on all sites in the calibration data set for several NWCA subpopulations using the final set of scored metrics applicable to that subpopulation. All candidate metrics, passing metric screens for a particular subpopulation, were used in generating the random metric combinations for the candidate VMMIs. Each potential VMMI was calculated and placed on a 100-point scale using the formula:

$$\text{VMMI} = \Sigma \text{ metric scores} \times 10/\text{number of metrics}$$

Magee et al. (2019) found that when developing VMMIs across numerous wetland types and large scales, candidate VMMIs with between 4 and 6 metrics better distinguished least- and most-disturbed sites than those with 7 to 10 metrics. Consequently, here, we considered candidate VMMIs based on 4, 5, or 6 randomly selected metrics for the national scale, the five RPT_UNIT_6 subpopulations and the four WETCLS_GRP subpopulations. In addition, for the Inland Herbaceous (PRLH) and Inland Woody (PRLW) Wetland Groups, candidate VMMIs based on 7 randomly selected metrics were also considered because a somewhat larger number of metrics passed screening tests for these two groups. 100,000 candidate VMMIs were generated for each metric number applicable to the national scale and each of the six RPT_UNIT_6 subpopulations, and the four WETCLS_GRP subpopulations.

The resulting candidate VMMIs were evaluated using a series of performance criteria to determine which VMMIs were most effective. Performance statistics for evaluating the candidate VMMIs included measures of redundancy, sensitivity, repeatability, and precision (Magee et al. 2019). To avoid metric redundancy, only candidate VMMIs with maximum and mean Pearson correlations among component metrics of < 0.75 and < 0.5, respectively, were retained for further review. Sensitivity of each VMMI was evaluated using an interval test, (Kilgour et al. 1998), alpha = 0.05, to determine the percentage of most-disturbed sites with VMMI values that were significantly less than the fifth percentile of the distribution of VMMI values for least-disturbed sites (Van Sickle 2010). Repeatability for each candidate VMMI was assessed using a Signal:Noise (S:N) ratio (Kaufmann et al. 1999, Section 8.5.2) calculated based on data from the primary sampling visits for calibration sites and repeat sampling visits (i.e., revisits) for a subset of these primary visit sites (see Table 8-1 through Table 8-4 for site numbers by subpopulations). The standard deviation (SD) of VMMI values among the least-disturbed sites was used to describe precision of the VMMI.

To identify the most effective candidate VMMIs for each subpopulation, we first arranged all relevant VMMIs that passed the correlation filter in order of increasing correlation and decreasing sensitivity. Typically, the VMMIs with the lowest correlations were also the most sensitive. Next, for the most sensitive VMMIs in each subpopulation set (up to several hundred), those with the lowest mean and maximum correlation among component metrics were identified. Among these, the VMMIs with the highest S:N and smallest SD were identified. The resulting reduced set of candidate VMMIs was further evaluated by collectively considering redundancy, sensitivity, S:N, SD, and the ecological content of component metrics to identify 9 to 12 highest performing VMMIs in each VMMI subpopulation. Finally, for each subpopulation, box-and-whisker plots were created for the set of 9 to 12 most promising VMMIs to evaluate their robustness and responsiveness by comparing how well each VMMI distinguished 1) the least- and most-disturbed sites for calibration data vs. validation data and 2) least- and most-disturbed sites from data for all sampled sites in the pertinent subpopulation.

Consideration of the performance criteria and the box plots for the best candidate VMMIs informed the selection of the four final VMMIs for use in condition assessment for NWCA 2016. The four VMMIs were based on the Wetland Group subpopulations (Section 9.4): Estuarine Herbaceous (VMMI-EH), Estuarine Woody (VMMI-EW), Inland Herbaceous (VMMI-PRLH), and Inland Woody (VMMI-PRW). Thresholds for good, fair, and poor ecological condition for each of these VMMIs were set using the distribution of VMMI values for subpopulation relevant least-disturbed sites. Lastly, for the four selected VMMIs, a final evaluation of VMMI responsiveness was conducted using two sample t-tests (Welsh t-test to account for unequal variances and sample size, Welsh 1947) to compare mean VMMI values between all sampled least- and most-disturbed sites occurring within each Wetland Group.

9.3.3 *Step 3 – Determining Ecological Condition Thresholds Based on VMMI Values*

Thresholds for good, fair, and poor ecological condition were determined only for the final four Wetland Group VMMIs: Estuarine Herbaceous (VMMI-EH), Estuarine Woody (VMMI-EW), Inland Herbaceous (VMMI-PRLH), and Inland Woody (VMMI-PRLW). Prior to setting condition thresholds for each of these VMMIs, the relevant set of least-disturbed sites were evaluated for outlier VMMI values, and values below the 25th percentile – 1.5*IQR (interquartile range) for a VMMI group were excluded in setting thresholds. Ecological condition categories (good, fair, and poor) were defined based on the distribution of VMMI values observed in least-disturbed sites in a particular Wetland Group, following the percentile approach described in Paulsen et al. (2008). Good condition was defined by VMMI values greater than or equal to the 25th percentile, fair condition ranged from the 5th up to the 25th percentile, and poor condition was delimited as less than the 5th percentile of the least-disturbed sites (**Figure 9-1**).

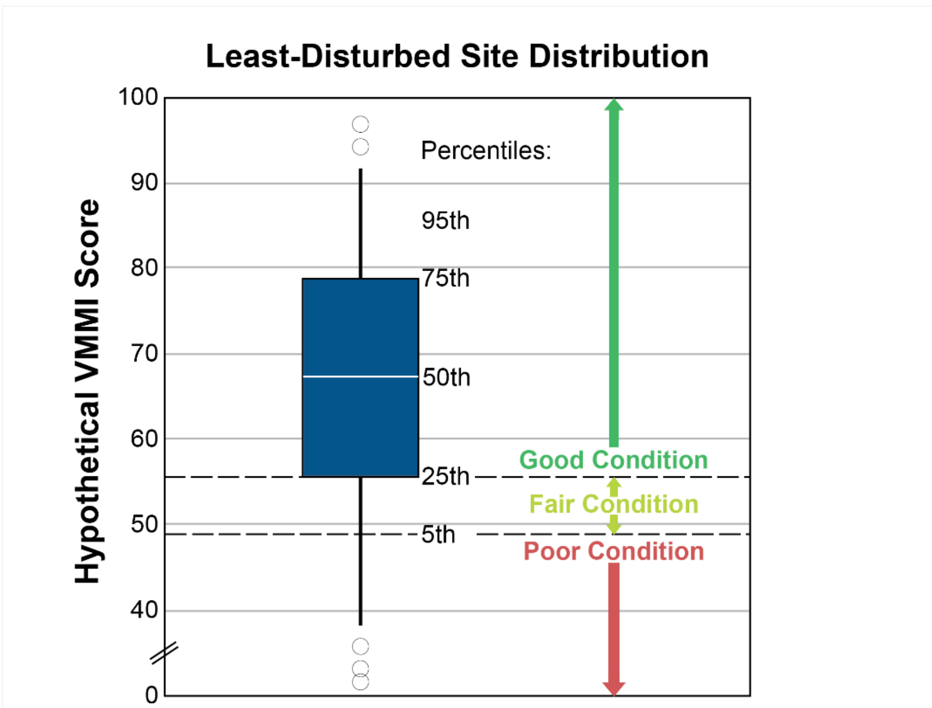


Figure 9-1. Criteria for setting VMMI thresholds for good, fair, and poor condition categories based on VMMI values observed for least-disturbed sites (REF_NWCA = L). Box plot whiskers: lower = the 25th percentile - 1.5 X IQR (interquartile range), upper = the 75th percentile + 1.5 X IQR.

Once the condition thresholds were established, each sampled site was assigned a condition category (good, fair, or poor) based on the Wetland Group threshold applicable to the site and the site's observed VMMI value.

9.4 Final VMMIs – Results

Using the VMMI development process outlined in **Section 9.3**, four of the candidate VMMIs were selected for use in estimating wetland area in good, fair, and poor condition based on the 2016 NWCA and for estimating areal changes in wetland condition between NWCA 2011 and 2016. The four final VMMIs represented subpopulations of WETCLS_GRP: Estuarine Herbaceous (EH), Estuarine Woody (EW), Inland

Herbaceous (PRLH), and Inland Woody (PRLW). These four VMMIs had stronger performance than the highest-performing national-scale VMMI or the best VMMIs for subpopulations of RPT_UNIT_6.

Results describing the four final VMMIs for the NWCA 2016 analysis are organized under three headings:

- VMMI Description, Metric Scoring, and VMMI Calculation (**Section 9.4.1**)
- VMMI Performance (**Section 9.4.2**)
- VMMI Condition Thresholds (**Section 9.4.3**)

9.4.1 *VMMI Description, Metric scoring, and VMMI Calculation*

An overview of the Wetland Group VMMIs (VMMI-EH (Estuarine Herbaceous, VMMI-EW (Estuarine Woody), VMMI-PRLH (Inland Herbaceous), and VMMI-PRLW (Inland Woody)) is provided in **Table 9-1**, which lists the name and a brief description of all individual metrics included in each VMMI. Methods for calculating the metrics comprising each VMMI can be found in **Section 8.8:, Appendix E**; metrics included in the four NWCA 2016 *Wetland Group VMMIs* is indicated in the **METRIC TYPE** column of Appendix in bold, color-coded font:

- **VMMI-EH in light blue**,
- **VMMI-EW in dark blue**,
- **VMMI-PRLH in purple**, and
- **VMMI-PRLW in forest green**.

Note that the Appendix E descriptions/formulas for how to calculate individual metrics may contain names of other metrics listed in Appendix E or parameter names (**Section 7.12:, Appendix C**) that refer to specific field collected data. For metrics that include information using species traits (e.g., growth habit, duration, plant categories, wetland indicator status, native status, and coefficients of conservatism), it may be useful to refer to the relevant section in **Chapter 7:** (**Sections 7.6** through **7.9**).

The NWCA metric scoring process (see **Section 9.3**), standardizes all individual metrics on a continuous scale from 0 to 10, with higher values reflecting less disturbed conditions. Scoring of the metrics comprising each VMMI was based on the metric values from the calibration data sites for that particular VMMI site group (**Table 8-4**) and was applied to all sampled sites[7] evaluated for that group. For scoring the individual metrics that make up each VMMI (VMMI-EH, **Table 9-2**; VMMI-EW, **Table 9-3**; VMMI-PRLH, **Table 9-4**; VMMI-PRLW, **Table 9-5**), the following information is provided 1) the direction of each metric's response to disturbance based on observed metric values, 2) the metric floor (5th percentile) and ceiling (95th percentile) values, and 3) the formula for metric scoring. VMMI-EH, VMMI-EW, and VMMI-PRLH include one or metrics where observed values increase in response to disturbance. For metrics that increase in response to disturbance, scoring is reversed so that the standardized metric scores will always reflect less disturbance with higher values. The metric scoring reflected in **Table 9-2** through **Table 9-5** was used in to calculate VMMI values (scaled from 0 to 100) for each site based on the relevant VMMI for the site (*nwca_2016_veg_mmi.csv*). The equations for VMMI-EH, VMMI-EW, VMMI-PRLH, and VMMI-PRLW are presented immediately below the relevant scoring table.

[7] All sampled sites include all Index Visits (probability and handpicked) and all site visits for sites sampled more than once (i.e., revisit and resample events).

Table 9-1. Metrics included in each of the four NWCA 2016 Vegetation Multimetric Indices (VMMIs). **See Section 8.8:, Appendix E** for formulas for calculation of these metrics.

VMMI	Metric Name	Description
EH (Estuarine Herbaceous)	XRCOV_HTOL	Relative cover highly tolerant species (C-value <= 2)
	XRCOV_MONOCOTS_NAT	Relative cover native monocots
	XRCOV_SEN	Relative cover sensitive species (C-value >= 7)
	XRCOV_FORB	Relative cover forbs
	N_ANNUAL	Annual species richness
	PCTN_NATSPP	Percent richness native species
EW (Estuarine Woody)	PCTN_MONOCOT	Monocot percent richness
	XRCOV_GRAMINOID	Relative cover graminoids
	RIMP_NATSPP	Relative importance native species
	XCOV_WD_FINE	Mean Cover of fine woody debris (< 5cm diameter)
	PCTN_NATSPP	Percent richness native species
	PCTN_ISEN	Percent richness intermediately sensitive species (C-value = 5 or 6)
PRLH (Inland Herbaceous)	PCTN_OBL_FACW	Percent richness Obligate + Facultative Wetland species
	FQAI_ALL	Floristic quality index based on all species
	XRCOV_NATSPP	Relative cover native species
	N_TOL	Richness tolerant species (C-value < = 4)
PRLW (Inland Woody)	XRCOV_MONOCOTS_NAT	Relative cover native monocots
	XC_ALL	Mean coefficient of conservatism based on all species
	XRCOV_NATSPP	Relative cover native species
	RFREQ_NATSPP	Relative frequency native species

Table 9-2. VMMI-EH metrics: floor and ceiling values, disturbance response, and interpolation formula for scoring individual metrics. Final scores for each metric decrease with disturbance.

VMMI-EH Metrics	Unscored response to Disturbance	Floor	Ceiling	Scoring formula (Observed = metric value at a given site)
XRCOV_HTOL	Increases[a]	0	84.57	(84.57 - Observed)/(84.57 - 0)*10
XRCOV_MONOCOTS_NAT	Decreases	0.29	100	(Observed – 0.29)/(100 – 0.29)*10
XRCOV_SEN	Decreases	0	100	(Observed - 0)/(100 – 0)*10
XRCOV_FORB	Increases[a]	0	69.37	(69.37 - Observed)/(69.37 – 0)*10
N_ANNUAL	Increases[a]	0	2	(2 – Observed)/(2 – 0)*10
PCTN_NATSPP	Decreases	62.96	100	(Observed – 62.96)/(100 – 62.96)*10

Note: Scoring based on EH calibration data (n= 298 sites) and applied to all EH data (n = 374 sites).
[a]Scoring is reversed for metrics that increase with disturbance. Scores truncated to 0 or 10 if observed values fell outside the floor to ceiling range. Metrics are defined in **Table 9-1**.

The Estuarine Herbaceous VMMI (VMMI-EH) was calculated for each site on a continuous 0 to 100 scale:

$$\boldsymbol{VMMI\ EH} = (\text{XRCOV\_HTOL\_SC} + \text{XRCOV\_MONOCOTS\_NAT\_SC} + \text{XRCOV\_SEN\_SC} + \text{XRCOV\_FORB\_SC} + \text{N\_ANNUAL\_SC} + \text{PCTN\_NATSPP\_SC}) * \frac{10}{6}$$

where, the '_SC' suffix is the scored value for a metric.

Table 9-3. VMMI-EW metrics: floor and ceiling values, disturbance response, and interpolation formula for scoring individual metrics. Final scores for each metric decrease with disturbance.

VMMI-EW Metrics	Unscored response to Disturbance	Floor	Ceiling	**Scoring formula** (Observed = metric value at a given site)
PCTN_MONOCOT	Decreases	0	55.68	(Observed – 0)/(55.68 - 0)*10
XRCOV_GRAMINOID	Decreases	0	90.36	(Observed -0)/(90.36 – 0)*10
RIMP_NATSPP	Decreases	68.56	100	(Observed – 68.56)/(100 – 68.56)*10
XCOV_WD_FINE	Increases[a]	0	13.85	(13.85 - Observed)/(13.85 – 0)*10
PCTN_NATSPP	Decreases	66.98	100	(Observed – 66.98)/(100 - 66.98)*10
PCTN_ISEN	Decreases	7.57	45.45	(Observed – 7.57)/(45.45 – 7.57)*10

Note: Scoring based on EW calibration data (n = 70 sites) and applied to all EW data (n = 87 sites).
[a]Scoring is reversed for metrics that increase with disturbance. Scores truncated to 0 or 10 if observed values fell outside the floor to ceiling range. Metrics are defined in **Table 9-1**.

The Estuarine Woody VMMI (VMMI-EW) was calculated for each site on a continuous 0 to 100 scale:

$$\boldsymbol{VMMI\ EW} = (\text{PCTN\_MONOCOT\_SC} + \text{XRCOV\_GRAMINOID\_SC} + \text{RIMP\_NATSPP\_SC} + \text{XCOV\_WD\_FINE\_SC} + \text{PCTN\_NATSPP\_SC} + \text{PCTN\_ISEN\_SC}) * \frac{10}{6}$$

where, the '_SC' suffix is the scored value for a metric.

Table 9-4. VMMI-PRLH metrics: floor and ceiling values, disturbance response, and interpolation formula for scoring individual metrics. Final scores for each metric decrease with disturbance.

VMMI-PRLH Metrics	Unscored response to Disturbance	Floor	Ceiling	**Scoring formula** (Observed = metric value at a given site)
PCTN_OBL_FACW	Decreases	17.21	100	(Observed – 17.21)/(100 – 17.21)*10
FQAI_ALL	Decreases	4.90	35.77	(Observed – 4.90)/(35.77 – 4.90)*10
XRCOV_NATSPP	Decreases	12.42	100	(Observed – 12.42)/(100 – 12.42)*10
N_TOL	Increases[a]	3	41	(41 - Observed)/(41 - 3)*10

Note: Scoring based on PRLH calibration data (n = 522 sites) and applied to all PRLH data (n = 654 sites).
[a]Scoring is reversed for metrics that increase with disturbance. Scores truncated to 0 or 10 if observed values fell outside the floor to ceiling range. Metrics are defined in **Table 9-1**.

The Inland Herbaceous VMMI (VMMI-PRLH) was calculated for each site on a continuous 0 to 100 scale:

$$\boldsymbol{VMMI\ PRLH} = (\text{PCTN\_OBL\_FACW\_SC} + \text{FQAI\_ALL\_SC} + \text{XRCOV\_NATSPP\_SC} + \text{N\_TOL\_SC}) * \frac{10}{4}$$

where, the '_SC' suffix is the scored value for a metric.

Table 9-5. VMMI-PRLW metrics: floor and ceiling values, disturbance response, and interpolation formula for scoring individual metrics. Final scores for each metric decrease with disturbance.

VMMI-PRLW Metrics	Unscored response to Disturbance	Floor	Ceiling	Scoring formula (Observed = metric value at a given site)
XRCOV_MONOCOTS_NAT	Decreases	0.17	48.41	(Observed – 0.17)/(48.41 – 0.17)*10
XC_ALL	Decreases	2.52	6.19	(Observed – 2.52)/(6.19 – 2.52)*10
XRCOV_NATSPP	Decreases	53.04	100	(Observed – 53.04)/(100 – 53.04)*10
RFREQ_NATSPP	Decreases	62.83	100	(Observed – 62.83)/(100 – 62.83)*10

Note: Scoring based on PRLW calibration data (n = 697 sites) and applied to all PRLW data (n = 872 sites). [a]Scoring is reversed for metrics that increase with disturbance. Scores truncated to 0 or 10 if observed values fell outside the floor to ceiling range. Metrics are defined in **Table 9-1**.

The Inland woody VMMI (VMMI-PRLW) was calculated for each site on a continuous 0 to 100 scale:

$$\boldsymbol{VMMI\ PRLW} = (\text{XRCOV\_MONOCOTS\_NAT\_SC} + \text{XC\_ALL\_SC} + \text{XRCOV\_NATSPP\_SC} + \text{RFREQ\_NATSPP\_SC}) * \frac{10}{4}$$

where, the '_SC' suffix is the scored value for a metric.

9.4.2 *VMMI Performance*

Descriptive statistics – Descriptive statistics for the Wetland Group VMMIs (EH, EW, PRLH, PRLW) are summarized in Table 9-6. The high S:N values for the EH, PRLH, and PRLW VMMIs reflect consistency in the VMMI across repeat samplings. However, the S:N value for the EW VMMI is not very meaningful because only two revisit sites (i.e., a second sampling visit to a site during the same year as the first sampling visit) were available. Low mean correlations among metrics in VMMI indicate low redundancy among metrics. Sensitivity, or the percentage of most-disturbed sites distinguished from least-disturbed sites, based on the conservative Kilgour test (VanSickle 2010), varies by wetland type group. The observed sensitivity values were comparatively high for MMIs (see Magee et al. 2019). VMMI-PRLW had the lowest separation of least- and most-disturbed sites, a pattern that may be influenced by the diversity of specific wetland community types and structural types within the PRLW group.

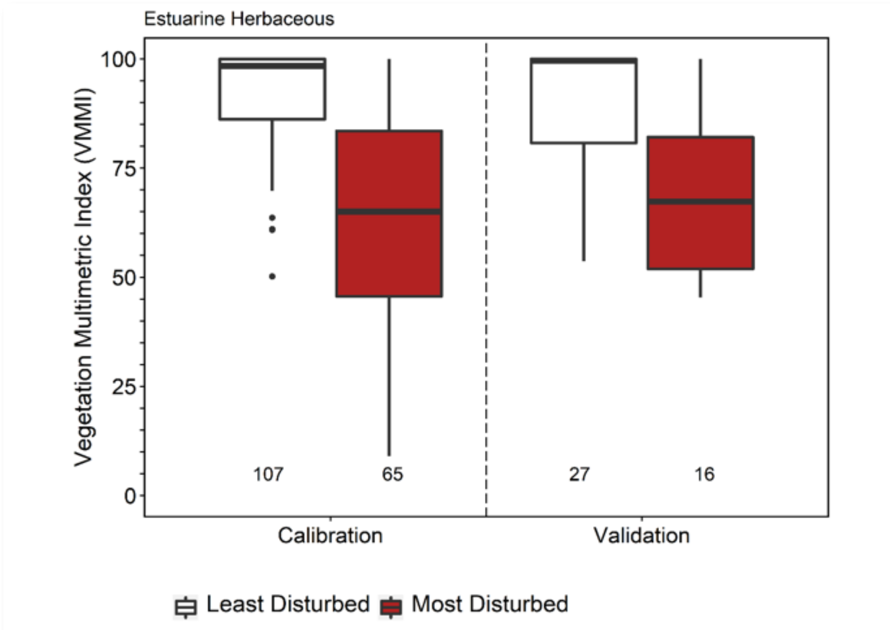
Box plot comparisons of calibration and validation data by VMMI – For all four VMMIs, comparison of VMMI values between calibration and validation data showed similar distributions and satisfactory discrimination between least- and most-disturbed sites (top graph in **Figure 9-2** (VMMI-EH), **Figure 9-3** (VMMI-EW), **Figure 9-4** (VMMI-PRLH), and **Figure 9-5** (VMMI-PRLW)). Similar results between calibration and validation data sets indicate consistent behavior for the VMMIs across different data sets, suggesting robustness of VMMI performance for wetland data collected in future years. Sample sizes in the validation data were very small for the Estuarine Woody VMMI (EW), so in this case differences in VMMI values for least-disturbed sites between calibration and validation data may not be meaningful.

Box plot comparisons of least- and most-disturbed sites by VMMI – For each of the Wetland Group VMMIs (bottom graphic in **Figure 9-2** (VMMI-EH), **Figure 9-3** (VMMI-EW), **Figure 9-4** (VMMI-PRLH), and **Figure 9-5** (VMMI-PRLW)), box plots comparing the VMMI value distributions showed clear separation for the set of least- and most-disturbed unique sites sampled in 2011 and 2016. These figures illustrate no overlap in VMMI values between the 25th percentile of the least-disturbed sites and the 75th percentile of most-disturbed sites for VMMI-EH, VMMI-EW and VMMI-PRLH. The separation between least- vs. most-disturbed sites is somewhat less distinct for the Inland Woody VMMI (PRLW), with slight overlap of the 25th percentile of the least-disturbed sites and the 75th percentile of most-disturbed sites. However, this response was improved by separating the PRLW sites into two groups, arid vs. mesic, for setting condition thresholds (see **Section 9.4.3** and **Figure 9-6**).

Table 9-6. Summary statistics for the final four VMMIs: EH – Estuarine Herbaceous, EW –Estuarine Woody, PRLH – Inland Herbaceous, PRLW – Inland Woody. Statistics calculated based on VMMI values for sampled sites and revisit sites from the calibration data set for the relevant VMMI group.

VMMI n = calibration data sites[3]	**n-sites by disturbance class**	**Mean VMMI (L sites)**	**SD[1] VMMI (L sites)**	**S:N[2]** n = revisit sites[4]	**Max r among metrics**	**Mean r among metrics**	**Sensitivity (%)**
EH n=298	L=107, I=126, M=65, ? = 0	92.37	10.37	35.53 n = 16	0.63	0.39	61.53
EW n=70	L=12, I=34, M=22, ? =2	75.52	7.46	32.12 n = 2	0.73	0.14	72.73
PRLH n=522	L=77, I=293, M=150, ?=2	78.27	11.46	16.82 n = 29	0.39	0.17	50.67
PRLW n=697	L=155, I=395, M=143, ?=4	68.95	12.48	17.30 n = 36	0.73	0.37	32.17

VMMIs defined in **Section 9.4.1**. L = least disturbed sites, I = intermediately disturbed sites, M=most disturbed sites, ?=undetermined disturbance, [1]SD =standard deviation, [2]S:N = signal/noise (For each VMMI, S:N is based on the [3]sampled sites and the [4]revisit sites from calibration data set), r = Pearson correlation. Sensitivity = Percent M sites with VMMI values significantly less than the fifth percentile of the distribution of VMMI values for L sites based on an interval test, alpha = 0.05 (Kilgour et al. 1998, Van Sickle 2010).



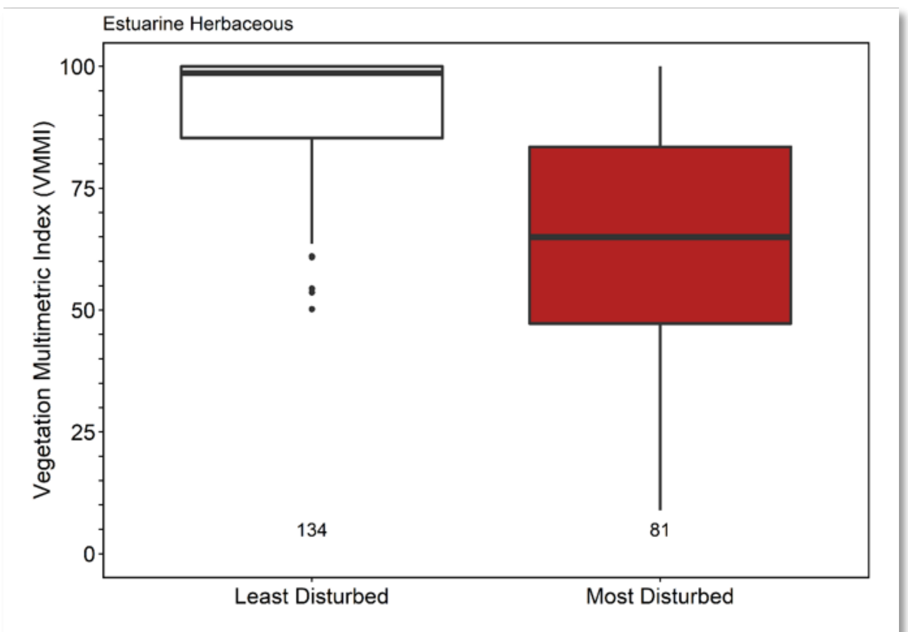
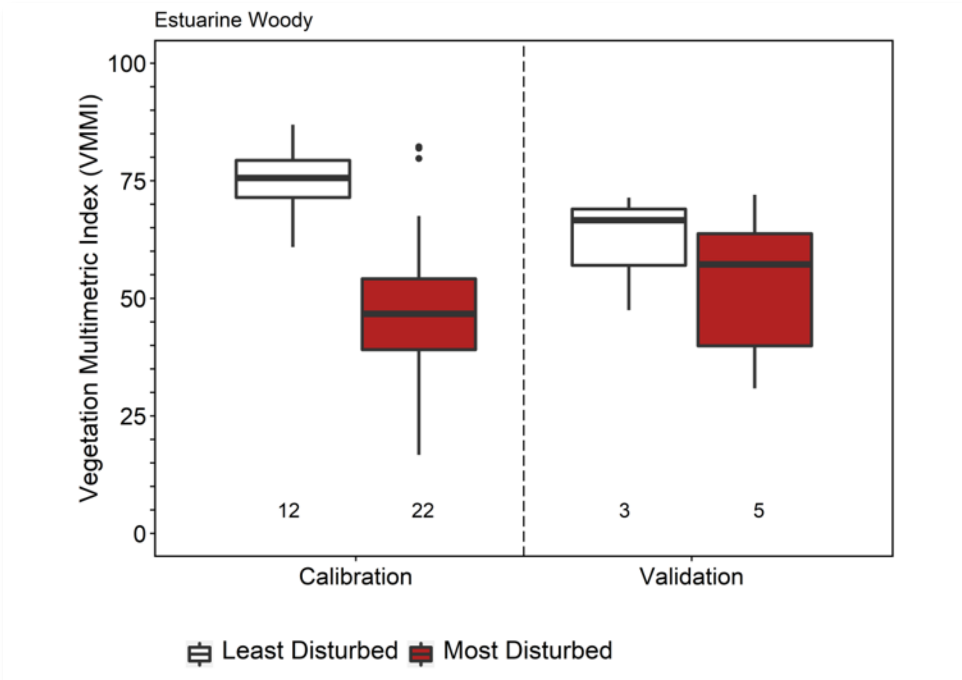


Figure 9-2. Comparison of VMMI Estuarine Herbaceous wetlands (VMMI-EH) for least-disturbed and most-disturbed sites. Top graph: Compares VMMI values for least- and most-disturbed EH sites in the calibration and validation data sets. Bottom graph: VMMI values for all least- and most-disturbed sampled EH sites. Box plots: box is interquartile (IQR) range, line in box is the median, and whiskers represent most extreme point a distance of no more than 1.5 × IQR from the box. Values beyond this distance are outliers. Numbers below each box plot represent number of the least-disturbed or most-disturbed sites sampled.



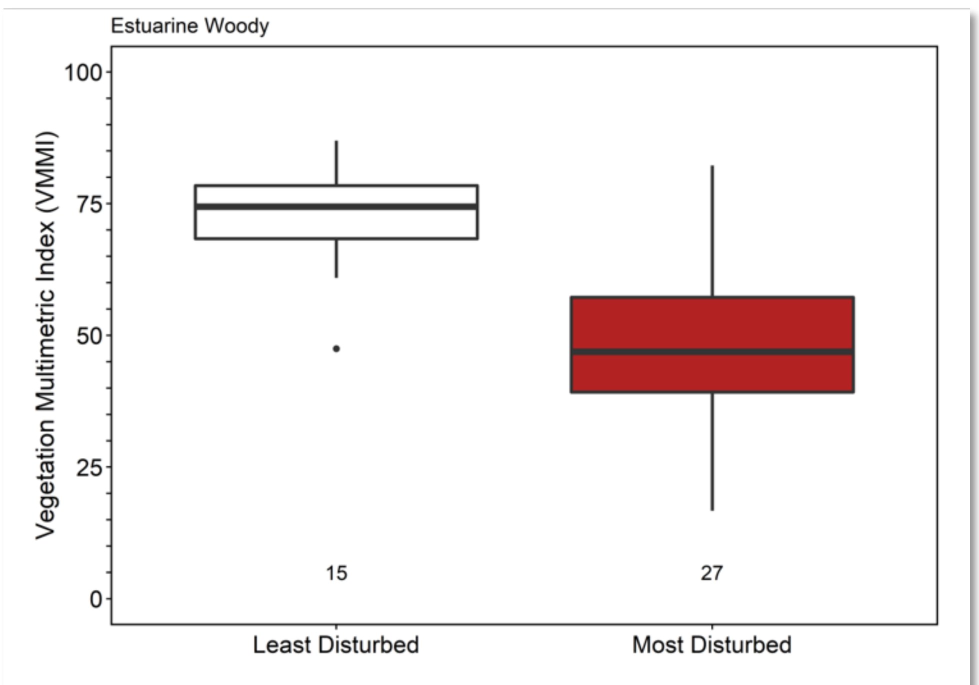


Figure 9-3. Comparison of VMMI Estuarine Woody wetlands (VMMI-EW) for least-disturbed and most-disturbed sites. Top graph: Compares VMMI values for least- and most-disturbed EW sites in the calibration and validation data sets. Bottom graph: VMMI values for all least- and most-disturbed sampled EW sites. Box plots: box is interquartile (IQR) range, line in box is the median, and whiskers represent most extreme point a distance of no more than 1.5 × IQR from the box. Values beyond this distance are outliers. Numbers below each box plot represent number of the least-disturbed or most-disturbed sites sampled.

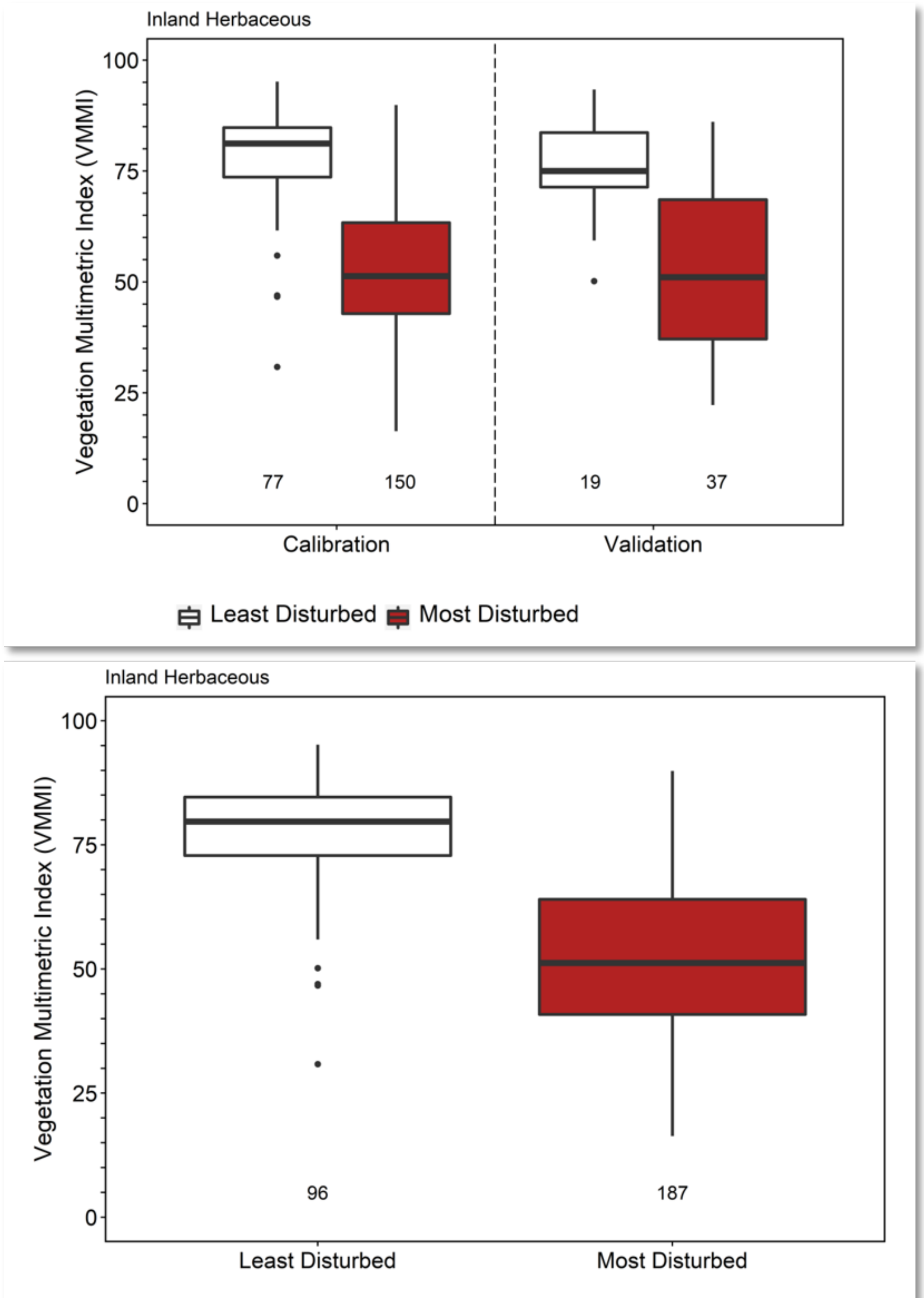
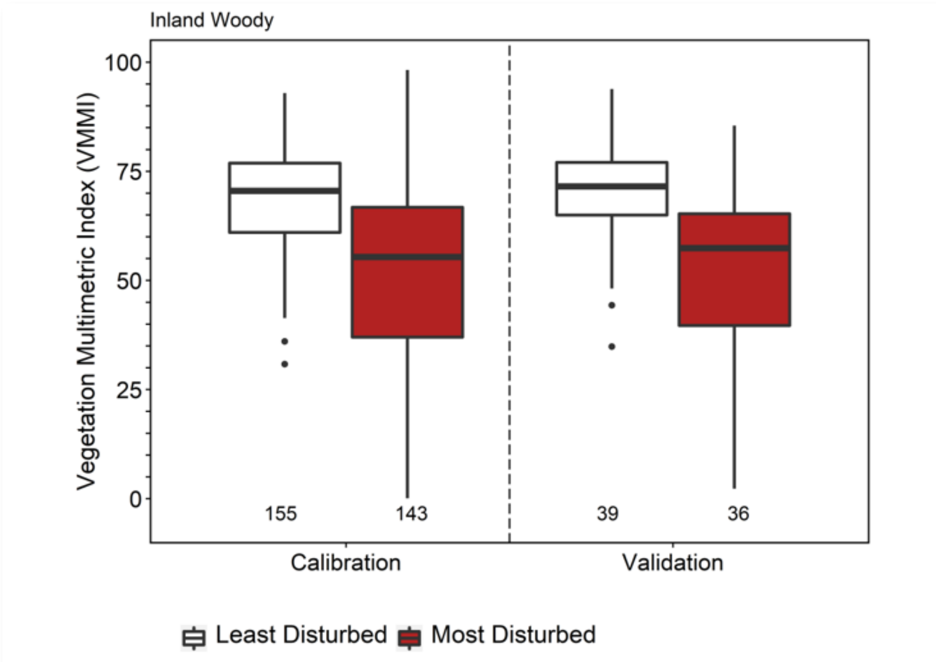


Figure 9-4. Comparison of VMMI Inland herbaceous wetlands (VMMI-PRLH) for least-disturbed and most-disturbed sites. Top graph: Compares VMMI values for least- and most-disturbed PRLH sites in the calibration and validation data sets. Bottom graph: VMMI values for all least- and most-disturbed sampled PRLH sites. Box plots: box is interquartile (IQR) range, line in box is the median, and whiskers represent most extreme point a distance of no more than 1.5 × IQR from the box. Values beyond this distance are outliers. Numbers below each box plot represent number of the least-disturbed or most-disturbed sites sampled.



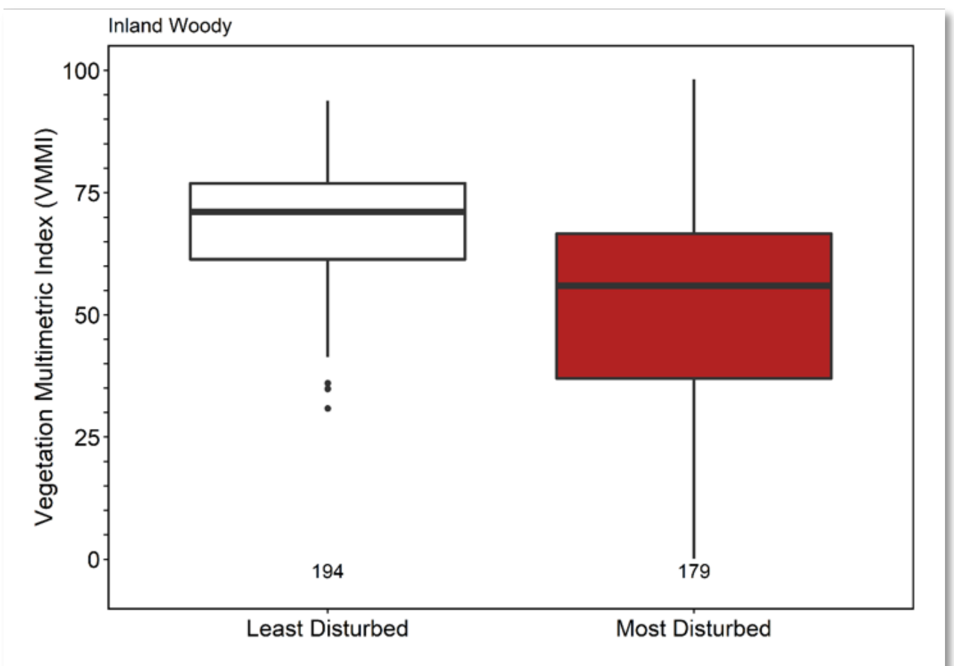


Figure 9-5. Comparison of VMMI Inland woody wetlands (VMMI-PRLW) for least-disturbed and most-disturbed sites. Top graph: Compares VMMI values for least- and most-disturbed PRLW sites in the calibration and validation data sets. Bottom graph: VMMI values for all least- and most-disturbed sampled PRLW sites. Box plots: box is interquartile (IQR) range, line in box is the median, and whiskers represent most extreme point a distance of no more than 1.5 × IQR from the box. Values beyond this distance are outliers. Numbers below each box plot represent number of the least-disturbed or most-disturbed sites sampled.

9.4.3 *Condition Thresholds for the Wetland Group VMMIs*

Wetland condition thresholds for each the four final VMMIs (**Table 9-7**) were based on the distribution of VMMI scores in least-disturbed sites (see **Section 9.3.3**):

- Good = VMMI scores ≥ 25^{th} percentile of least-disturbed sites
- Fair = VMMI scores from the 5^{th} up to the 25^{th} percentile of least-disturbed sites
- Poor = VMMI scores < 5^{th} percentile of least-disturbed sites
- Least-disturbed sites in a Wetland Group with VMMI values below the 25^{th} percentile – 1.5*IQR (interquartile range) were considered outliers and not used in setting condition thresholds

Note that the VMMI-PRLW values in least-disturbed PRLW sites varied widely by ecoregion (**Figure 9-6**, top graph). As a result, two sets of thresholds were developed for the VMMI-PRLW, one set for sites in more mesic regions ($PRLW_{OTHER}$) and one set for sites in more arid regions ($PRLW_{PLNARW}$) (**Table 9-7**, **Figure 9-6**, bottom graph). A final evaluation of responsiveness (two sample unequal variance t-tests) for each of the four NWCA VMMIs and the two VMMI-PRLW threshold groups showed significantly different mean VMMI values between all sampled least- and most-disturbed sites (**Table 9-8**).

Each sampled site was assigned a condition category (good, fair, or poor) based on the site's observed VMMI value and the Wetland Group VMMI and condition thresholds applicable to the site (*nwca_2016_veg_mmi.csv*).

Table 9-7. VMMI value thresholds indicating good, fair, and poor ecological condition based on least-disturbed sites in each Wetland Group (WETCLS_GRP). Sites with VMMI values from the 5^{th} up to the 25^{th} percentile for least-disturbed (REF_NWCA) sites are considered in fair condition.

NWCA VMMIs (n = least-disturbed sites)	**Description (Wetland Type and Site Groups)**	**Poor Condition** (VMMI < 5^{th} Percentile Least-Disturbed Sites)	**Good Condition** (VMMI > 25^{th} Percentile Least-Disturbed Sites)
VMMI-EH (n =134)	Tidal - Estuarine Herbaceous [ALL]	73.6	86.4
VMM-EW (n = 15)	Tidal - Estuarine Woody [ALL]	64.6	69.8
VMM-PRLH	Inland (Palustrine, Riverine, or Lacustrine) Herbaceous [ALL]	63.8	74.2
VMMI-PRLW	Inland (Palustrine, Riverine, or Lacustrine) Woody		
$PRLW_{OTHER}$ (n = 157)	Inland (Palustrine, Riverine, or Lacustrine) Woody [EMU, ICP, WVM]	53.7	65.5
$PRLW_{PLNARW}$ (n = 37)	Inland (Palustrine, Riverine, or Lacustrine) Woody [PLN, ARW]	43.7	49.9

Table 9-8. Two-sample unequal variances t-tests comparing VMMI value means for all sampled least- and most-disturbed sites for each Wetland Group VMMI.

VMMI	*t* statistic	*p* value	Degrees of freedom (df)
VMMI-EH	9.89	≤ ≤ 0.001	105.4
VMMI-EW	5.64	≤ ≤ 0.001	39.4
VMMI-PRLH	15.38	≤ ≤ 0.001	256.7
VMMI-PRLW	9.52	≤ ≤ 0.001	276.0
$PRLW_{OTHER}$	8.06	≤ ≤ 0.001	215.0
$PRLW_{PLNARW}$	6.90	≤ ≤ 0.001	58.0

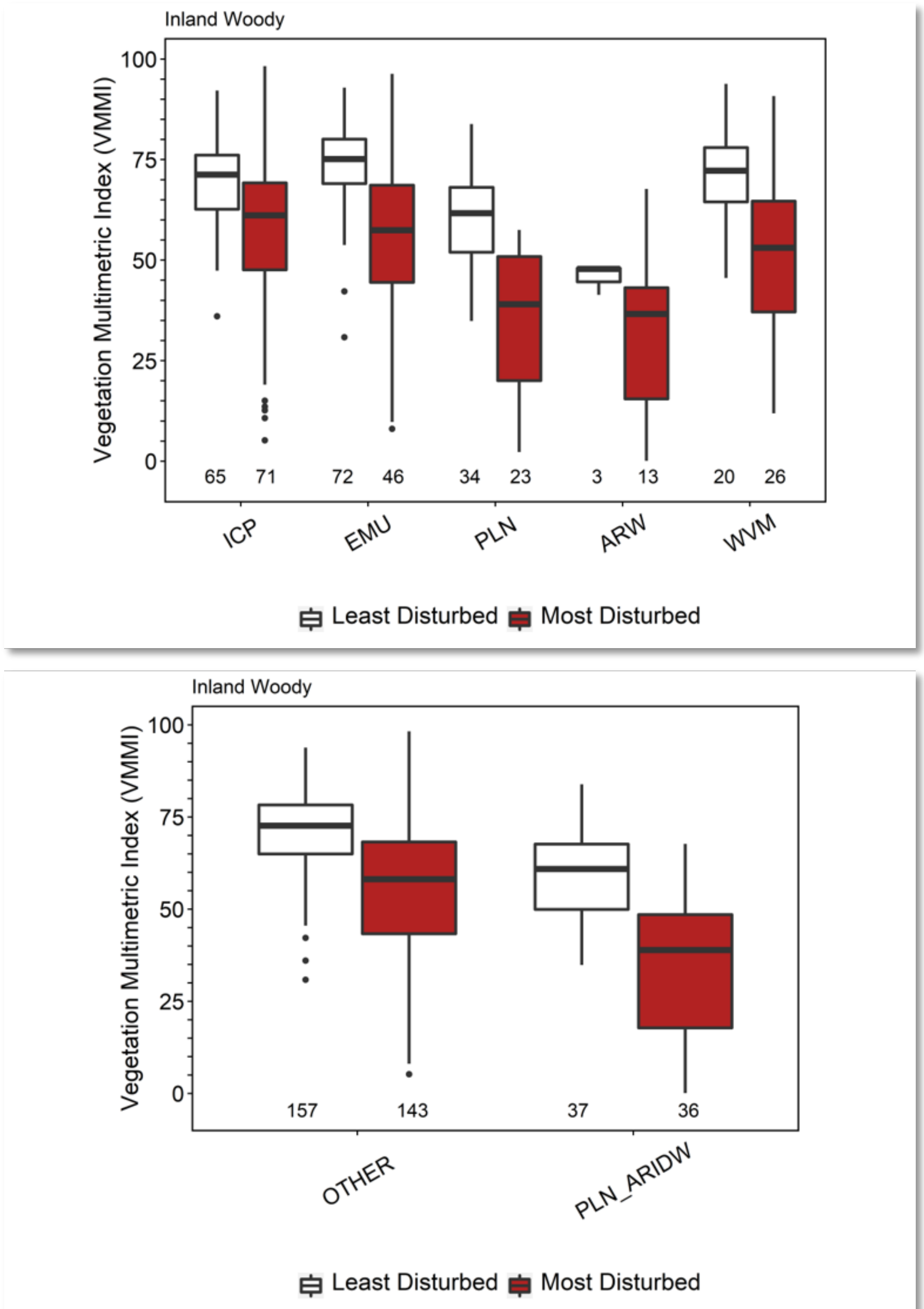


Figure 9-6. Comparison of VMMI values for Inland Woody wetlands (VMMI-PRLW) for least-disturbed and most-disturbed sites by ecoregions. **Top graph**: VMMI-PRLW values by Five NWCA Aggregated Ecoregions (ICP, EMU, PLN, ARW, WVM, (NWCA_ECO5) see map in **Figure 6-2** for definitions) **Bottom graph:** VMMI-PRLW values for more mesic (OTHER) vs. more arid (PLN_ARIDW) regional groups (OTHER = ICP, EMU, WVM; PLN_ARIDW = ARW & WVM). **Box plots:** box is interquartile (IQR) range, line in box is the median, and whiskers represent most extreme point a distance of no more than 1.5 × IQR from the box. Values beyond this distance are outliers. Numbers below each box plot represent number of the least-disturbed or most-disturbed sites sampled.

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Chapter 10: Nonnative Plant Indicator (NNPI)

10.1 Background

Nonnative plant species are widely recognized as important biological indicators of ecological stress on wetland condition (Mack and Kentula 2010, Magee et al. 2010). They can 1) reflect ecological condition of the 'natural' vegetation, 2) be indicators of anthropogenic disturbance, or 3) behave as direct stressors to vegetation and ecosystem properties (e.g., Kuebbing et al. 2015, Magee et al. 2008, 2010, 2019, Pyšek et al. 2020, Riccardi et al. 2020, Ruaro et al 2020, Simberloff 2011). Presence and abundance of nonnative plants are often positively related to human mediated disturbance (Lozon and MacIsaac 1997, Mack et al. 2000, Magee 1999, Magee et al. 2008, Ringold et al. 2008). In addition, nonnative plants can act as direct stressors to ecological condition by competing with or displacing native plant species or communities, altering vegetation structure, or by altering ecosystem structure and processes (Vitousek et al. 1997, Dukes and Mooney 2004). Numerous direct and indirect effects of nonindigenous plants on native vegetation and other ecosystem components demonstrate their role as potential stressors and indicators of lowered ecological condition.

For example, nonnative plant species have been linked to:

- increased risk of local extinction or population declines for many rare, native plant species (Randall 1996, Lesica 1997, Seabloom et al. 2006),
- changes in species composition within and among plant community types, and to local and regional floristic homogenization (McKinney 2004, Rooney et al. 2004, Magee et al. 2008),
- alteration of fire regimes (Dwire and Kauffman 2003, Brooks et al. 2004),
- alteration of geomorphic and hydrologic processes (Rowantree 1991, Sala et al. 1996), and
- alteration of carbon storage patterns (Farnsworth and Meyerson 2003, Bradley et al. 2006), nutrient cycling, and composition of soil biota (Belnap and Phillips 2001, Ehrenfeld 2003).

Major ecological changes like these negatively influence the intactness or integrity of natural ecosystems (Angermeier and Karr 1994, Dale and Beyeler 2001) and can lead to losses of ecosystem services (Dukes and Mooney 1999, Dale et al. 2000, Hooper et al. 2005, Meyerson and Mooney 2007).

Recall from **Section 7.8** (Species Traits – Native Status) and from Magee et al. 2019 that NWCA defines *nonnative plants to include both alien and cryptogenic taxa*. Concepts describing native status categories used by the NWCA, including alien and cryptogenic, are described in brief here and in **Table 7-5**. First, *Native* plant taxa are defined as indigenous to specific states in the conterminous US. *Introduced* taxa are indigenous outside of, and not native, in any of conterminous US. *Adventive* taxa are native to some parts of the conterminous US but introduced to the location of occurrence. We use the term ***Alien*** to include both introduced and adventive taxa. ***Cryptogenic*** species include taxa that have both introduced (often aggressive) and native (generally less prevalent) genotypes, varieties, or subspecies. Because many cryptogenic species are invasive or act as ecosystem engineers (Magee et al. 2019), we grouped them with alien species and considered them nonnative for the purpose of indicating ecological stress.

The ***Nonnative Plant Indicator (NNPI)***[8] was developed as a categorical descriptor of stress to ecological condition for the 2011 NWCA (Magee et al 2019, USEPA 2016a) and was also used in the NWCA 2016

[8] In the NWCA 2011 Technical Report (USEPA 2016a), the NNPI was referred to as the "Nonnative Plant Stressor Indicator" (NPSI) – a name that is no longer used.

analysis. Magee et al. (2019) detailed the development of the Nonnative Plant Indicator (NNPI) and, based on the 2011 NWCA, reported on relationships of the NNPI to disturbance and environmental conditions and on the 2011 extent of wetland area in different NNPI condition categories.

In the following subsections, data collection, data preparation, description of the NNPI, and condition category threshold definitions are described.

10.2 Data Collection

Nonnative plant data were collected as part of the standard Vegetation Protocol (USEPA 2016a). An overview of vegetation field and laboratory methods is provided in **Chapter 7, Section 7.3**.

10.3 Data Preparation

Preparation and validation of raw data for nonnative plant species are described in **Chapter 7, Sections 7.4 and 7.5**. Definition of the native status categories used in the NWCA and the procedures for determining state-level native status for the individual species observed in the 2011 and 2016 NWCAs are provided in **Chapter 7, Section 7.8**. Numerous metrics summarizing different attributes of nonnative species (e.g., all alien and cryptogenic species, or subgroups of these species based on life history traits) were calculated and are described in **Chapter 8, Sections 8.4 and 8.8 (Appendix E).**

10.4 Nonnative Plant Indicator Overview

The categorical NNPI was based on three straightforward continuous metrics (**Table 10-1**) that reflect different potential impacts of nonnative plants, and which can be readily calculated from field observations.

Table 10-1. Definition of metrics used in the NNPI.

Metric Name	Calculation[a]	Range
XRCOV_AC – Relative Cover of Nonnative Species	(∑ Absolute cover nonnative species$_i$/∑ Absolute cover all species$_i$) × 100; where for each unique species *i*: Absolute Cover = 0–100%	0 to 100%
TOTN_AC – Richness of Nonnative Species	Number of unique nonnative species observed at a site	*Number of unique nonnative species*
RFREQ_AC – Relative Frequency of Nonnative Species	∑ Frequency nonnative species$_i$/∑ Frequency all species$_i$) × 100; where for each unique species *i*: Frequency = 0–100%, calculated as the percent of Veg Plots in which it occurred.	0 to 100%

[a]Calculation of metrics based on data collected in the five 100-m^2 vegetation plots sampled at each site.

Additional information about these metrics can be found in **Chapter 8, Section 8.8 (Appendix E)** by referencing the metric names indicated in red font in the list above and highlighted in **red and bolded** in the appendix. The "_AC" suffix in the metric names refers to combined alien and cryptogenic species that together are considered nonnative by the NWCA.

Each of the three metrics consider all nonnative species at a location but, taken together, integrate different avenues of impact to ecological condition. ***Relative Nonnative Cover*** (0 to 100%) reflects preemption of space and resources and is often associated with changes in plant community composition (species identity, richness, and abundance) and vegetation structure (horizontal or vertical), or with alteration of ecosystem processes (e.g., hydrology, nutrient cycling, fire regime). 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. Increasing ***Relative Nonnative Frequency*** (0 to 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. Of the three metrics, relative nonnative cover is likely to represent the greatest potential negative effect on ecological condition. The other two metrics provide additional pathways of impact that may have synergistic relationships with relative nonnative cover, potentially increasing the amount overall stress related to nonnative plants.

The three metrics of the NNPI are used together in a decision matrix to assign a condition category reflecting potential stress from nonnative species to each site. Four condition categories (good, fair, poor, or very poor) were defined[9]. Assignment of the condition category for each site is based ***exceedance values*** for each of the three metrics; see the following section (Section 8.5) for details.

10.5 NNPI Condition Threshold Definition

NNPI condition thresholds were developed to:

- reflect wetland condition as an additional indicator to the VMMI (Chapter 9:) and
- indicate stressor condition related to nonnative plants.

The same thresholds were used for both of these purposes. Details of how the NNPI is used in final reporting for wetland condition and stressor condition are discussed in Chapter 15:.

The three NNPI metrics (nonnative relative cover, nonnative richness, and nonnative relative frequency), were used together in a decision matrix to assign each sampled site to a condition category (good, fair, poor, or very poor) based on exceedance values for each of the metrics (see Table 10-2, below, and Magee et al. 2019). The overall NNPI status for each site was determined by the lowest condition category observed across the three NNPI metrics.

Exceedance values for the four condition categories 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 with varying levels of nonnative cover, frequency, or richness. Exceedance values for the four condition categories (Table 10-2) reflect the strong influence of

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[9] In previous work (USEPA 2016a, Magee et al. 2019), the NNPI categories were described in relation to potential stress (i.e., low, moderate, high, or very high). However, to better align with other USEPA National Aquatic Resource Surveys, the NNPI categories were renamed to reflect condition (good, fair, poor, or very poor). Now, *good condition* is equivalent to the previously defined *low stressor-level*, and *very poor condition* is equivalent to the formerly described *very high stressor-level*.

nonnative relative cover, with the values for nonnative richness and nonnative relative frequency set to consider these two metrics as additional sources of ecological stress.

Table 10-2. Condition Threshold Exceedance Values for each of the metrics informing the Nonnative Plant Indicator (NNPI): Relative Cover of Nonnative Species (XRCOV_AC), Nonnative Richness (TOTN_AC), and Relative Frequency of Nonnative Species (RFREQ_AC).

Condition Category*	XRCOV_AC	TOTN_AC	RFREQ_AC
Good	≤1	≤5	≤10
Fair	>1-15	>5-10	>10-30
Poor	>15-40	>10-15	>30-60
Very Poor	>40	>15	>60

*Exceedance of a threshold value for a particular condition category for any one of the three metrics moves the metric condition to next lower (better to worse) category. The NNPI condition for a site is based on the lowest observed condition category among the metrics.

The approach for designating the NNPI condition category for each site integrates information from three different pathways from which nonnative species may influence ecological condition. To see how the exceedance thresholds work, consider the two hypothetical examples of nonnative species results that are outlined below.

Hypothetical Site 1 (NNPI Condition Category = Poor) has:

- XRCOV_AC = 7% ➔ Fair Condition
- TOTN_AC = 14 nonnative species ➔ Poor Condition
- RFREQ_AC = 52% ➔ Poor Condition

Hypothetical site 1 has nonnative relative cover of 7%, placing the site in the fair condition category. However, this site also has nonnative richness of 14 species and relative frequency of 52%, which reflect poor condition for both metrics. Thus, the site would be assigned to the NNPI poor condition category. Even though relative nonnative cover is not extensive at this hypothetical site, the number of individual nonnative species and their frequency of occurrence might indicate shifting community composition and strong risk for expansion of nonnative cover.

Hypothetical Site 2 (NNPI Condition Category = Very Poor) has:

- XRCOV_AC = 80% ➔ Very Poor Condition
- TOTN_AC = 1 nonnative species ➔ Good Condition
- RFREQ_AC = 59% ➔ Poor Condition

Next, consider hypothetical site 2 with 80% nonnative relative cover indicating very poor condition, nonnative richness of 1 indicating good condition, and nonnative relative frequency of 59% indicating poor condition. Here, the overall NNPI condition category would be very poor. Even though there is only one nonnative species present at the site, it occupies 80% of the total vegetation cover and nearly 60% of all species occurrences across the sampled area of the vegetation plots are nonnative.

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Chapter 11: Human-Mediated Physical Alterations

Physical indicators of disturbance to a wetland site are one of the key categories of data (in addition to chemical and biological indicators) used in wetland assessment for the NWCA. Six Human-Mediated Physical Alteration (hereon, "Physical Alteration") indices were developed in addition to two indicators that integrate scores from all six Physical Alteration indices. Thresholds associated with the six indices and the two metrics were used for:

- assigning disturbance class and
- indicating stressor condition.

Physical Alteration thresholds used to assign disturbance class are discussed broadly in **Chapter 6:** (and specifically in **Section 6.3**), while thresholds used to indicate stressor condition are provided in **Section 11.5** at the end of this chapter. Note that the disturbance class thresholds differ from the stressor condition thresholds. The methods used to develop the six Physical Alteration indices are discussed in the following subsections of this chapter.

11.1 Data Collection

In both the 2011 and 2016 NWCAs, two separate protocols (and, thus, two forms) were used in the field to collect data pertaining to physical disturbances (**Figure 11-1**, USEPA 2011a, 2016a):

- The Hydrology field protocol and corresponding H-1 Form instructed crews to identify and record the presence of a set of stressors (hereon referred to as "items") within the Assessment Area (AA).

- The Buffer field protocol and corresponding B-1 Form instructed crews to identify and record the presence of a set of items within six categories in 13 plots: one plot at the center of AA and twelve 100-m^2 plots located along transects outside of the AA (four plots at each of the cardinal directions at 40m, 85m, and 130m from the AA center).

On both the H-1 and B-1 Forms, field crews were instructed to use the "other" bubbles to identify and describe observations of disturbances that were not adequately captured in the provided lists.

Although the H-1 and B-1 Forms changed slightly between 2011 and 2016, the protocols and the majority of items on the forms remained the same.

Logic checks of the data from the field forms identified potential issues that were resolved by the NWCA Technical Analysis Team. For example, unless the PLOT_NOT_SAMPLED bubble was filled for the plot on the B-1 Form to indicate that it was not evaluated, buffer plots that had no filled bubbles were assumed to have no observed disturbances. In addition, the NWCA Technical Analysis Team evaluated all "other" write-ins on both the H-1 and B-1 Forms and determined whether the observation was valid (i.e., a disturbance). Any write-in that was unclear (i.e., not well-described, for example, "woody debris") or considered a natural disturbance was excluded from the analysis. For example, “earthworms”, “gopher activity”, and “beaver run” were considered to be natural and not reflective of anthropogenic disturbance to the site, and, therefore, were not used in the analysis.

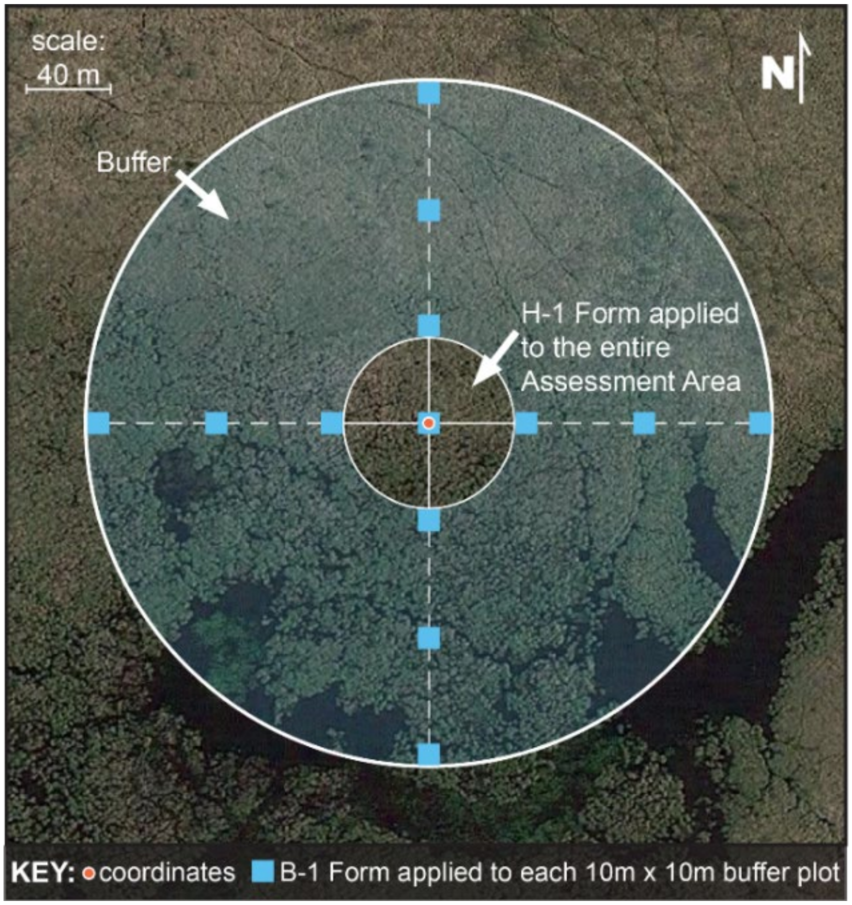


Figure 11-1. The entire AA was evaluated using the H-1 Form and 13 buffer plots were evaluated using the B-1 Form.

11.2 Development of Physical Alteration Indices

Six physical indices of disturbance were developed from the data collected from the H-1 and B-1 Forms (USEPA 2011a, 2016a) and include Vegetation Removal (VEGRMV), Vegetation Replacement (VEGRPL), Water Addition/Subtraction (WADSUB), Flow Obstruction (WOBSTR), Soil Hardening (SOHARD), and Surface Modification (SOMODF) (**Table 11-1**). These indices are collectively referred to as “Human-Mediated Physical Alterations” and indicate human impacts to the three components that define wetlands: vegetation (Vegetation Removal, Vegetation Replacement), hydrology (Water Addition/Subtraction, Flow Obstruction), and soils (Soil Hardening, Surface Modification). Each of the six indices is composed of eight Physical Alteration metrics. To build the metrics, we started with the H-1 and B-1 Forms and combined, simplified, and reorganized all the listed items and the relevant “other” items into 48 Physical Alteration metrics[10]. Items that were repeated on the H-1 and B-1 Forms were only counted once in the AA (if observed on both forms) to eliminate double-counting.

[10] These metric categories are used to bridge analyses between 2011/2016 and 2021, where the Physical Alteration Form and field protocol is used for the first time.

Table 11-1. Six indices of human-mediated physical alterations and the 48 metrics crosswalked from items on the 2011 and 2016 H-1 Hydrology or B-1 Buffer Forms. Note that the write-in "others" are numerous and not all are included in this table.

Physical Alteration Index	Physical Alteration Metrics	H-1 Hydrology Form Items Included	B-1 Buffer Form Items Included
Vegetation Removal (VEGRMV)	Forest Clear Cut	N/A	• *Forest Clear Cut*
	Forest Selective Cut	N/A	• *Forest Selective Cut*
	Vegetation Damage from Insects	N/A	• *Tree Canopy Herbivory (insect)*
	Herbicide/Pesticide Use	N/A	• *Herbicide/Pesticide Use*
	Shrub/Tree Browsing	N/A	• *Shrub Layer Browsed (wild or domestic)*
	Grass/Forb Grazing	N/A	• *Highly Grazed Grasses (overall <3" high)*
	Mowing/Pruning/Clearing	• *Other: "Right of Way"*	• *Mowing/Shrub Cutting*
	Human-Altered Fire Regime	N/A	• *Recently Burned Forest (canopy)* • *Recently Burned Grassland (blackened)*
Vegetation Replacement (VEGRPL)	Abandoned Crop Field/Historical Cultivation	N/A	• *Fallow Field (old – grass, shrubs, trees)* • *Other: "Historic Cultivation"*
	Recent Fallow/Resting Crop Field	N/A	• *Fallow Field (recent – resting row crop field)*
	Lawn/Park/Cemetery /Golf Course	N/A	• *Golf Course* • *Lawn/Park* • *Other: "Garden", "Landscape"*
	Silviculture/Tree Plantation/Orchard/Nursery	N/A	• *Orchard/Nursery* • *Silviculture/Tree Plantation*
	Active Row or Field Crop	N/A	• *Row Crops – Tilling*
	Range (passively managed)	N/A	• *Range*
	Pasture (actively managed)	N/A	• *Pasture/Hay*
	Nonnative Pest Plants	N/A	N/A

Table 11-1 (continued)

Physical Alteration Index	Physical Alteration Metrics	H-1 Hydrology Form Items Included	B-1 Buffer Form Items Included
Water Addition/Subtraction (WADSUB)	Ditch/Channelized Stream (human-made)	• *Culverts & Ditching: Ditches* • *Culverts & Ditching: Channelized Streams*	• *Ditches, Channelization* • *Inlets, Outlets*
	Culvert (corrugated pipe, arch, box)	• *Culverts & Ditching: Corrugated Pipe* • *Culverts & Ditching: Box*	N/A
	Point Source/Pipe (effluent, sewer, stormwater)	• *Pipes: Sewer Outfall* • *Pipes: Standpipe Outflow*	• *Point Source/Pipe (effluent or stormwater)*
	Tile Drainage/Drain Tiles	• *Field Drainage Tiling*	• *Drain Tiling*
	Irrigation	• *Pumps: Irrigation*	• *Irrigation*
	Water Withdrawal Pump	• *Pumps: Other* • *Pumps: Water Supply*	N/A
	Impervious Surface Input (sheetflow)	N/A	• *Impervious Surface Input (sheetflow)*
	Human-mediated Shallow Channels (ruts)	• *Shallow Channels: Vehicle Ruts* • *Shallow Channels: Abandoned Road* • *Shallow Channels: Eroded Foot Paths* • *Shallow Channels: Trails* • *Shallow Channels: Animal Trampling*	N/A
Flow Obstruction (WOBSTR)	Dike/Berm/Levee	• *Damming Features: Dikes* • *Damming Features: Berms*	N/A
	Dam (human-made or beaver-modified structure)	• *Damming Features: Dams*	• *Dike/Dam/Road/RR Bed (impede flow)*
	Wall/Riprap	N/A	• *Wall/Riprap*
	Trash/Soil/Gravel/Spoil/Organic Debris Heap (human-made)	N/A	• *Fill/Spoil Banks*
	Road/Railroad/Walkway (raised bed)	• *Damming Features: Roads (all types)* • *Damming Features: Railroad Bed*	N/A
	Water Level Control Structure	N/A	• *Water Level Control Structure* • *Other: "tide gates"*
	Pond/Retention Basin/Quarry (human-made)	N/A	• *Other: "Wastewater Lagoon", "Stocked Pond", "Created Pond"*
	Silvicultural/Agricultural Mounding of Soil	• *Other: "Pine Plantation Bedding"*	N/A

Table 11-1 (continued)

Physical Alteration Index	Physical Alteration Metrics	H-1 Hydrology Form Items Included	B-1 Buffer Form Items Included
Soil Hardening (SOHARD)	Oil/Gas/Utility Wells/Drilling/Pipeline	N/A	• *Oil/Gas Wells/Drilling* • *Other: "Gas Pipeline"*
	Soil Compaction/Pugging/Wallows	N/A	• *Confined Animal Feeding* • *Dairy (on 2011 B-1 Form only)* • *Livestock or Domesticated Animals (on 2016 B-1 Form Only)* • *Soil Compaction (animal or human)*
	Non-Paved Trail	• *Impervious Surfaces: Compacted non-paved (on 2016 H-1 Form only)*	• *Trails*
	Vehicle Rut/Off-Road Vehicle Damage	N/A	• *Offroad Vehicle Damage* • *Other: "Vehicle Ruts"*
	Unpaved Road (gravel, aggregate, dirt, sand)	N/A	• *Road (paved or unpaved) (on 2016 B-1 Form only)* • *Road – Gravel (on 2011 B-1 Form only)*
	Paved Road (asphalt, concrete, chip & seal)	• *Impervious Surfaces: Roads (on 2011 H-1 Form only)*	• *Road – Two Lane (on 2011 B-1 Form only)* • *Road – Four Lane (on 2011 B-1 Form only)*
	Other Impervious Surface (building, parking lot, drive)	• *Impervious Surfaces: Asphalt* • *Impervious Surfaces: Concrete*	• *Parking Lot/Pavement* • *Rural Residential* • *Suburban Residential* • *Urban/Multifamily* • *Other: "General Structure"*
	Piling/Utility Pole/RR Track (fence, dock, boardwalk)	N/A	• *Power Line* • *Other: "Boardwalk", "Fence pilings"*
Surface Modification (SOMODF)	Conspicuous Trash/Dumping	N/A	• *Dumping* • *Trash*
	Soil/Gravel/Spoil/Organic Debris Heap (human-made)	N/A	• *Other: "Slash", "Trees", "Wood Pilings"*
	Landfill (active or historic)	N/A	• *Landfill*
	Excavation/Dredging	• *Excavation/Dredging*	• *Excavation, Dredging* • *Gravel Pit*
	Mine (surface/underground)	N/A	• *Mine (surface/underground)*
	Soil Deposition/Sedimentation	• *Recent Sedimentation*	• *Freshly Deposited Sediment (unvegetated)*
	Soil Erosion/Oxidation/ Subsidence (human-mediated)	N/A	• *Soil Erosion/Deposition (from wind, water, or overuse)* • *Soil Loss/Root Exposure*
	Soil Tilling/Plowing/ Disking/Harrowing	N/A	• *Other: "Soil Tilling"*

11.3 Scoring Each of the Six Physical Alteration Indices

For each site, each of the six Physical Alteration indices (i.e., VEGRMV, VEGRPL, WADSUB, WOBSTR, SOHARD, and SOMODF) was scored using a proximity-weighted scheme (illustrated in **Figure 11-2**), with observations in the AA receiving the highest scores and observations in the furthest buffer plots from the AA receiving the lowest scores. The following steps describe the methods for calculating the site score for any one of the six Physical Alteration indices:

1. First, each of the six Physical Alteration indices for the AA was scored using data from the H-1 Form and only the center buffer plot of the B-1 Form. Each metric with observed items[11] in the AA scored 25 points. For each of the six indices, the total points of the metrics in the AA were summed as $PALT_{AA}$ so that the highest score any one index could receive in the AA was 200 points (i.e., 8 metrics x 25 points).

2. Next, the 12 buffer plots outside the AA were scored using proximity-weighting (Kaufmann et al. 2014), with each metric with observed items in the inner-ring plots scoring 4 points, middle-ring plots scoring 2 points, and outer-ring plots scoring 1 point. For each of the six indices, the total points of the metrics with observed items were summed for the sampled plots ($PALT_{buffer}$). Maximum scores were: 32 points in an inner-ring buffer plot (i.e., 8 metrics x 4 points), 16 points in a middle-ring buffer plot (i.e., 8 metrics x 2 points), and 8 points in an outer-ring buffer plot (i.e., 8 metrics x 1 point).

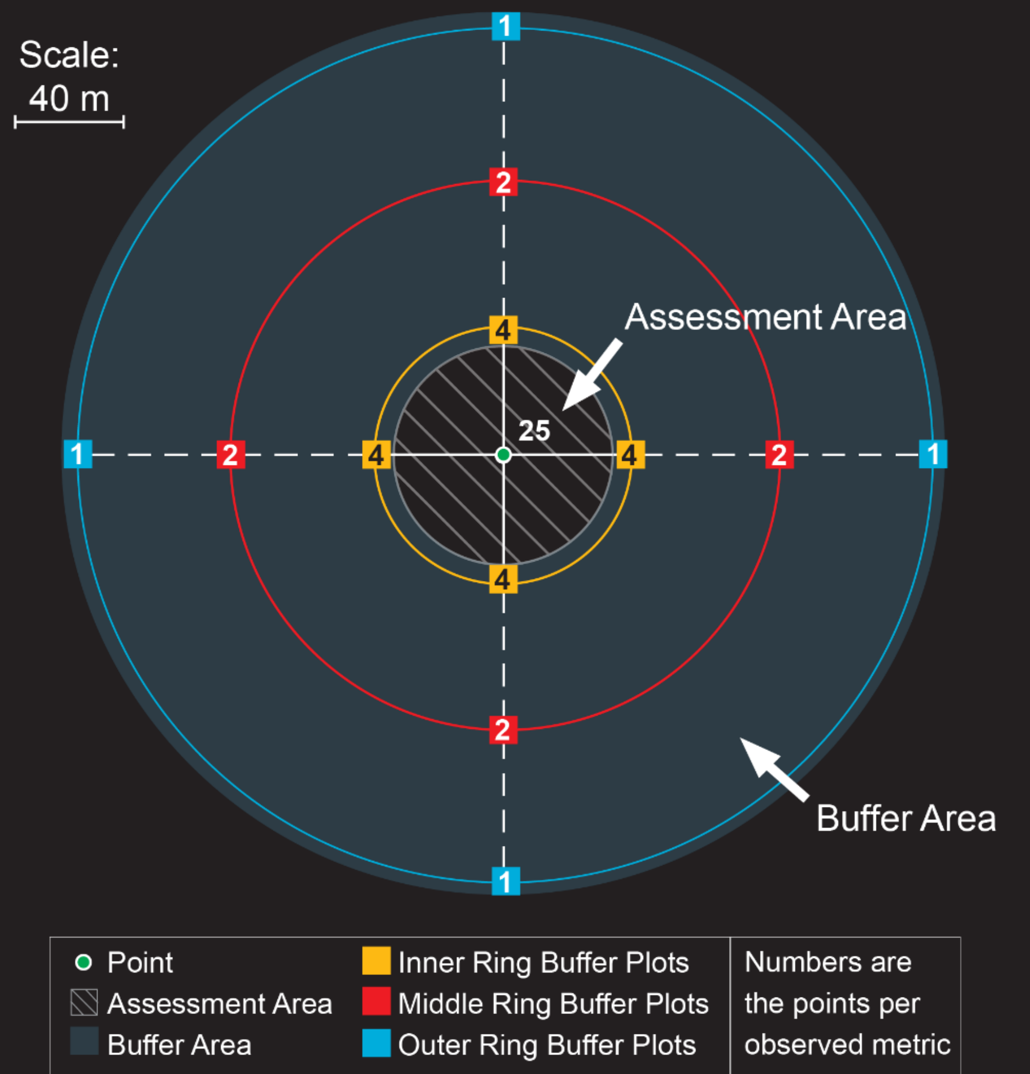
   If any of the buffer plots were not sampled in the field, the points were redistributed among the number of sampled plots within the same ring; for example, if only two of four plots were sampled in the inner ring, each metric with observed items would be scored as 8 points (i.e., instead of the 4 points used when all four plots were sampled).

3. Finally, the total for each of the six physical indices (VEGRMV, VEGRPL, WADSUB, WOBSTR, SOHARD, and SOMODF) was calculated. The calculation for determining an overall site ($PALT_{site}$) score for any one of the six physical alteration indices is the sum of the PALT scores for the AA and buffer, i.e. $PALT_{AA} + PALT_{buffer} = PALT_{site}$.

Note that Field crews may have observed multiple items on the H-1 or B-1 Forms pertaining to a single metric. Even if multiple items associated with a metric were observed, the metric was scored only once. For example, if a field crew marked observations for items "Gravel Pit" *and* "Excavation, Dredging" on the B-1 Form for the same inner-ring buffer plot, the metric "Excavation/Dredging" only received one score of 4 points. This example, in which "Gravel Pit" and "Excavation, Dredging" are essentially the same disturbance, also illustrates how the metrics reduce double-counting (as opposed to scoring each observed item).

[11] Recall from **Table 11-1** that multiple items from the H-1 and B-1 Forms may be included under any given metric, yet the metric receives only one score even if multiple items associated with that metric are observed.

2016 NWCA Physical Alteration Metric Scoring



Six Physical Alteration indices representing Vegetation Removal, Vegetation Replacement, Water Addition/Substraction, Water Obstruction, Soil Hardening, Surface Modification, each with 8 metrics (i.e., checkboxes from 2016 NWCA B-1 and H-1 forms), are evaluated in the Assessment Area and in 12 Buffer Plots. Metric scoring is based on proximity to the Point, with a maximum score of 424 per index for the site. Scoring is as follows:

Location	Points per Observed Metric	Number of Plots	Distance from the Point	Plot Area	Maximum Index Score *per Plot*	Maximum Index Score *per Location*
Assessment Area	25	1	0-40 m	5000 m^2 (0.5 ha)	200	200
Inner Ring Buffer	4	4	40-50 m	100 m^2	32	128
Middle Ring Buffer	2	4	85-95 m	100 m^2	16	64
Outer Ring Buffer	1	4	130-140 m	100 m^2	8	32

Figure 11-2. 2016 NWCA Physical Alteration Metric Scoring, with the points assigned to each observation located in the respective area (either the AA or buffer plot). Note that observations in the center buffer plot (within the AA) also received 25 points.

11.4 Physical Alteration Screen Scoring (PALT_ANY and PALT_SUM)

Two Physical Alteration screens that integrate scores from all six Physical Alteration indices are calculated for each site: PALT_ANY and PALT_SUM. Both of these screens are used to set thresholds assigning disturbance class (**Section 6.3**), and PALT_SUM (in addition to scores for each index as described in the previous section) are used to set thresholds for indicating stressor condition.

11.4.1 *PALT_ANY*

PALT_ANY indicates the maximum degree of Human-Mediated Physical Alterations for any index and is calculated as the maximum Physical Alteration index score among all six Physical Alteration index scores for a site.

For any one index at a sampled site, there are only 8 metrics that can be scored within 13 locations (the AA and 12 buffer plots); therefore, the maximum PALT_ANY score for the site is 424 points:

  25 points * 1 AA *8 metrics
+ 4 points * 4 inner ring buffer plots * 8 metrics
+ 2 points * 4 middle ring buffer plots * 8 metrics
+ 1 point* 4 outer ring plots * 8 metrics
  424 maximum points total per index

However, it is implausible that every single metric within an index would occur at the same time in the AA and in all buffer plots. The observed maximum PALT_ANY score was 149 considering all unique sites (i.e., Index Visit, probability and handpicked sites) from 2011 and 2016.

11.4.2 *PALT_SUM*

PALT_SUM is a secondary screen that indicates the cumulative amount of Human-Mediated Physical Alterations among all indices. It is calculated as the sum of all six Physical Alteration index scores for a site. This screen was developed to detect instances, e.g., where several metric items were observed, but the observations are dispersed across several Physical Alteration indices (i.e., no one index has a particularly high score). Thus, a site may pass the threshold for the PALT_ANY screen and fail the threshold for the PALT_SUM screen (but not *vice versa*).

With 424 total points per index, and six indices, the highest possible PALT_SUM score for a site is 2,544. However, it is implausible that every single metric within an index would occur at the same time in the AA and in all buffer plots, much less across all indices. The observed maximum PALT_SUM score was 396 considering all unique sites from 2011 and 2016.

11.5 Physical Alteration Stressor Condition Thresholds

Like other National Aquatic Resource Survey (NARS) assessments, the NWCA data was used to identify connections between the presence of indicators of stress and ecological condition. Anthropogenic stressors act to degrade ecological condition, and consequently, evaluation of indicators of stress is an important component of an assessment method (Fennessy et al. 2007). Using physical, chemical, and human-health indicators of stress, the NWCA analysis examined a variety of stressor data to detect factors likely affecting wetland condition. The use of stressor data is consistent with current approaches to assess wetlands and recognizes the connection between the presence of stressors and wetland condition. For example, rapid assessment methods have been developed which use only stressors as indicators of condition (e.g., the Delaware Rapid Assessment Method (Jacobs 2007)) and models comprising an HGM assessment (a Level 3, intensive assessment) use stressors as variables (e.g., Whigham et al. 2007, Wardrop et al. 2007). The data sources for the indicators of stressor condition used in the NWCA analysis were primarily from field observations and soil and water chemistry samples collected from the Assessment Area (AA) and its buffer at each sampled site.

Seven physical indicators of stressor condition are reported for the 2016 NWCA:

- Vegetation Removal (VEGRMV),
- Vegetation Replacement (VEGRPL),
- Water Addition/Subtraction (WADSUB),
- Flow Obstruction (WOBSTR),
- Soil Hardening (SOHARD),
- Surface Modification (SOMODF), and
- Physical Alterations (PALT_SUM).

In contrast to the Disturbance Gradient, six individual Physical Alteration indices are used instead of the PALT_ANY screen to indicate stressor condition. The reasoning for this decision to use the six individual indices was to provide condition extent and relative and attributable risk associated with each of these specific indicators.

For each of the seven Physical Alteration indicators, each site was assigned to “good”, “fair”, or “poor” stressor condition based on thresholds for each indicator. The same national thresholds were used for all seven indicators, with sites scoring:

- 0 points assigned to good stressor condition,
- ≥ 50 points assigned to poor stressor condition, and
- > 0 and < 50 points (i.e., everything between good and poor) assigned to fair stressor condition.

These thresholds were chosen based on common sense for the good condition threshold (i.e., the expectation for a good condition site is to have no observed physical alterations) and best professional judgement for the poor condition threshold. For any one of the seven indicators of stressor condition, a site assigned to poor stressor condition for that indicator, for example, may have:

- two or more observed physical alteration metrics in the AA (scored 25 points each);
- one observed physical alteration metric in the AA (scored 25 points) and two observed metrics in each of half of the buffer plots (i.e., two metrics in two inner-ring buffer plots for 4 points each, two metrics in two middle-ring buffer plots for 2 points each, and two metrics in two outer-ring buffer plots for 1 point each); or
- two observed physical alteration metrics in each of the 12 buffer plots.

An explanation of how stressor condition extent estimates, and relative and attributable risk are calculated for each indicator of stressor condition is discussed explicitly in.

11.6 Literature Cited

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Chapter 12: Soil Heavy Metals

Chemical indicators of disturbance to a wetland site are one of the key categories of data (in addition to physical and biological indicators). Soil heavy metals were established as the main chemical indicator of disturbance for the 2011 NWCA (USEPA 2016a) and have been clearly associated with anthropogenic disturbance (Alloway 2013, Nahlik et al. 2019). For the 2011 NWCA, natural background concentrations were established using published values (in Alloway 2013) for terrestrial soils in, or as close to the US as possible. For the 2016 NWCA, in part because of the larger number of sites and associated data available after two surveys, the NWCA Analysis Team made the decision to update the heavy metal natural background concentrations so they reflect the wetland soils in the NWCA sample population. Using these updated natural background concentrations, a Heavy Metal Index (HMI) and an Enrichment Factor (EF) metric based on soil heavy metal concentrations were developed. Thresholds associated with the HMI and EF were used for:

- assigning disturbance class and
- indicating stressor condition.

Soil heavy metal thresholds used to assign disturbance class are discussed broadly in **Chapter 6:** (and specifically in **Section 6.4**), while thresholds used to indicate stressor condition are provided in **Section 12.4** at the end of this chapter. Note that the disturbance class thresholds differ from the stressor condition thresholds. The methods used to develop the HMI and the EF are discussed in the following subsections.

12.1 Data Collection

The Heavy Metal Index (HMI) and Enrichment Factors (EFs) are based on observational data and physical samples collected from soil pits excavated each site according to the Soils Protocol in the *NWCA Field Operations Manual* (USEPA 2011a, USEPA 2016b). Briefly, field crews excavated a soil pit with a maximum depth of 125 cm in 2011 and of 100 cm in 2016. For each soil horizon, field crews described the soil colors, characteristics, and soil type of each horizon. Additionally, field crews collected a bulk soil sample (approximately 1.5 L) from boundary to boundary of the horizon and between one (in 2011) and three (2016) bulk density samples from the top of each horizon. In 2016, field crews also collected a Standardized Depth Soil Core (SDSC) from 0 cm (i.e., surface) to 10 cm deep. Each of these samples were shipped to the US Department of Agriculture Natural Resources Conservation Service (NRCS) Kellogg Soil Survey Laboratory in Lincoln, Nebraska for analysis following the procedures in the *NWCA Laboratory Operations Manual* (USEPA 2011b).

Soil chemistry data returned from NRCS were merged with soil profile data (i.e., observational data) collected by Field Crews. The resulting soil chemistry database was thoroughly inspected for quality assurance. Using both manual screening and customized R code, potential data errors were identified. Whenever large quantities of data are collected, it is not surprising for some errors related to data or sample collection, recording, sample analysis, or data entry to occasionally occur. Therefore, the NWCA established a number of cross-checks in the data collection and processing procedures within the protocols and field forms, to allow identification and resolution of potential errors. Once the data were entered, quality assurance review was critical to identifying and resolving any errors potentially impacting data quality.

Errors that could be resolved by inspecting the original field data forms were corrected in an annotated soil chemistry database, with detailed notes of how the error was corrected. If the error could not be resolved, the associated data were removed from the database (resulting in an "NA" in place of the value) or flagged if the datum was suspect but could not be identified as being absolutely incorrect.

NRCS performed internal quality assurance on soil chemistry data. Some soil chemistry data returned by NRCS was flagged, e.g., if it was below the practical quantitation limit (PQL) or minimum detection limit (MDL) of the equipment using to analyze the samples. **Table 12-1**) provides information about the meaning of the flags in the data.

In 2016, all values below the MDL were flagged by the NRCS lab as ND. These, in turn, were all changed from 0 value to "NA" in the data files. All values above MDL but below PQL, flagged "L", were retained as the same value the lab provided. For some analytes, the lab reported "0" values due to how values were rounded, and these were retained in the data files. Note that there are some "0" values in the data files that do not have an "L" or "ND" flag associated with them. These are values above the PQL but that still round to zero because of rounding format used by NRCS. Values remaining in the database (particularly from 2011) below the MDL were changed to half the specified MDL in the soil chemistry database.

Table 12-1. Table of NARS chemistry flag codes and their definitions.

NARS Flag Code	Definition
L	Result is below the practical quantitation limit (PQL)
ND	Result is below the method detection limit (MDL)
NA1	Not applicable when % carbon > 20
NA2	Not applicable from pretest
N	Insufficient sample for analysis
NF	No 2-20 mm fragments in sample
NAL	2-20 mm fragments present but not analyzed

In 2011, the Heavy Metal Index was developed using the uppermost horizon within the top 10 cm that had soil chemistry data[12]. Most sites, approximately 97% of those sampled, had soil chemistry data that began within the top 10 cm, although, the thickness of the horizon varied among sites. To address these consistency issues, field crews collected a Standardized Depth Soil Core (SDSC) from the surface to 10-cm deep at the soil pit of each site in 2016. A comparison of soil heavy metal concentrations from the resampled sites (i.e., sites sampled both in 2011 and 2016) showed that 2011 data from the uppermost horizon were, in most cases, highly correlated with 2016 data from the 10-cm deep SDSC (**Figure 12-1**). Therefore, we used the uppermost horizon within the top 10 cm that had soil chemistry data for 2011 data *and* the SDSC for 2016 to develop heavy metal background concentrations and to calculate the Enrichment Factors and the Heavy Metal Index. If data associated with the SDSC for 2016 were missing, data associated with the uppermost horizon within the top 10 cm that had soil chemistry were substituted.

[12] In 2011, soil chemistry data were only generated for each soil layer greater than 8 cm in thickness, and nearly one-quarter of the described soil layers (948 of 4444) were less than 8 cm thick and not sampled for soil chemistry. Furthermore, the first layer, containing the most biologically active soil and most indicative of recent human impacts, was not sampled at nearly one-third of the sites for soil chemistry because Layer 1 was less than 8 cm thick (347 of 1082 sites).

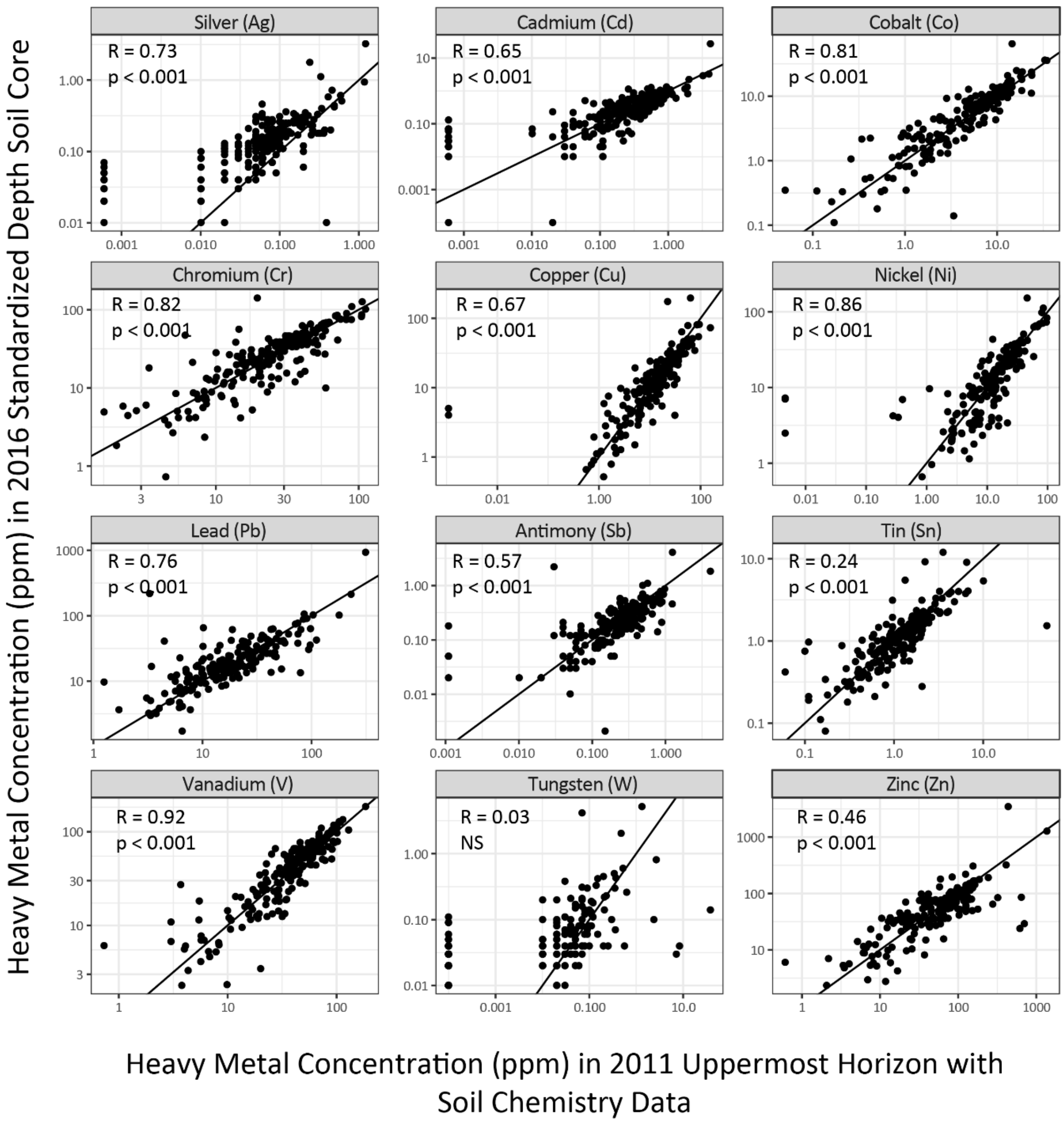

Figure 12-1. Comparison of heavy metal concentrations (ppm) for 12 heavy metals measured in resampled sites, with the 2011 uppermost horizon within the top 10 cm that had soil chemistry data on the x-axis and the 2016 Standardized Depth Soil Core that was collected from the surface to a depth of 10 cm on the y-axis. The correlation statistics and the significance are reported as R and p-value (α = 0.05) in the upper left corner of each plot. NS = Not Significant

12.2 Development of Heavy Metal Background Concentrations

For the first NWCA conducted in 2011, natural background concentrations of 12 heavy metals (silver (Ag), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), antimony (Sb), tin (Sn), vanadium (V), tungsten (W), and zinc (Zn) that have known associations with anthropogenic activities were established using published values (in Alloway 2013) for terrestrial soils in, or as close to the US as possible (USEPA 2016a, Nahlik et al. 2019). In part because of the larger number of sites and associated data available after two surveys, the NWCA Analysis Team made the decision to update the heavy metal natural background concentrations of each of these 12 heavy metals so that they reflected the wetland soils in the NWCA sample population. To do this, only Visit 1, Index Visit sites from 2011 and 2016 that passed the both the PALT_ANY (see Section 11.4.1) and PALT_SUM (see Section 11.4.2) Physical Alteration screens (i.e., candidate least-disturbed sites, see Chapter 6: Section 6.3) were used. Next, for each heavy metal, the distributions of heavy metal concentrations were evaluated by region (RPT_UNIT_5). Heavy metal background concentrations were set using the 75th percentiles of soil the concentrations found in candidate least-disturbed sites (**Figure 12-2**). This method of using the 75th percentile for setting thresholds is a common method used in the USEPA National Aquatic Resource Surveys (NARS) as described in Herlihy et al. (2008, 2013) and USEPA (2016a). The heavy metal background concentrations (ppm) are presented in **Table 12-2**.

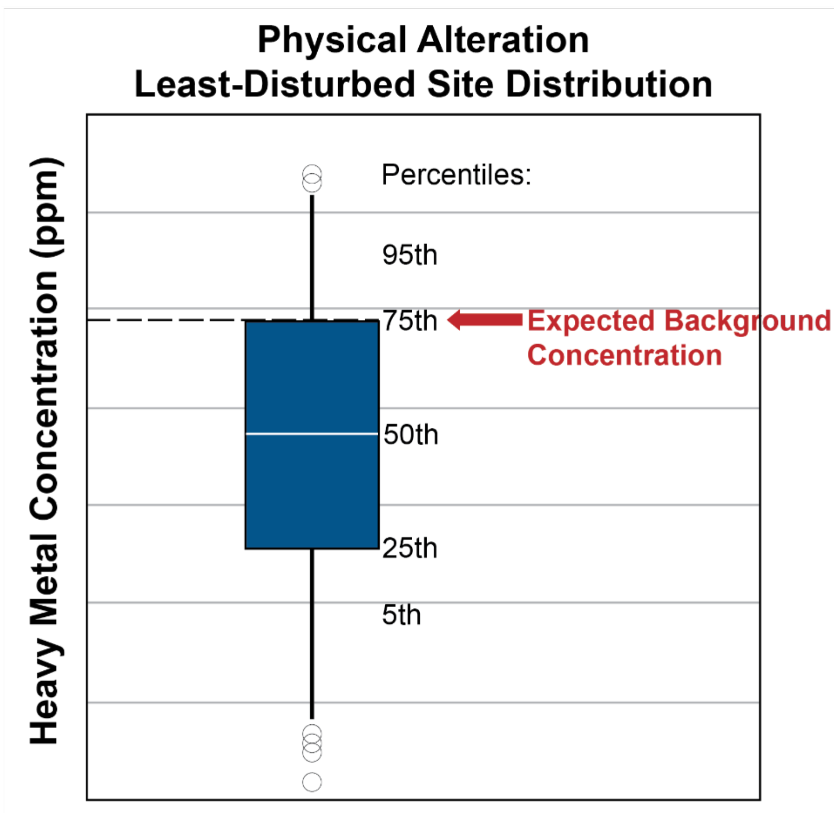

Figure 12-2. Illustration of the 75th percentiles of soil heavy metal concentrations of sites that passed the Physical Alteration screens (i.e., deemed to be candidate least-disturbed sites), used to set expected background concentrations for soil heavy metals. Note that this method is conducted for each of the 12 heavy metals evaluated and by each of five regions in RPT_UNIT_5.

Table 12-2. Heavy metal background concentrations (ppm) for wetlands in five regions (RPT_UNIT_5) of the United States.

	Tidal Saline (TDL)	Inland Coastal Plains (ICP)	Eastern Mts & Upper Midwest (EMU)	Plains (PLN)	West (WST)
Silver (Ag)	0.15	0.09	0.15	0.17	0.19
Cadmium (Cd)	0.15	0.26	0.82	0.55	0.46
Cobalt (Co)	7.30	8.06	5.17	9.17	8.99
Chromium (Cr)	53.8	39.4	22.9	38.8	39.7
Copper (Cu)	17.2	14.2	15.2	19.5	28.5
Nickel (Ni)	21.4	18.3	13.8	23.3	22.6
Lead (Pb)	25.1	24.6	37.4	26.4	24.3
Antimony (Sb)	0.29	0.31	0.40	0.34	0.47
Tin (Sn)	1.69	1.47	1.41	1.45	1.46
Vanadium (V)	75.8	52.9	33.9	65.6	65.4
Tungsten (W)	0.06	0.05	0.18	0.04	0.19
Zinc (Zn)	73.0	64.6	61.7	97.2	81.7

12.3 Calculation of Enrichment Factor (EF) Values and the Heavy Metal Index (HMI)

Enrichment factor (EF) values and the Heavy Metal Index (HMI) are calculated for each site based on the heavy metal background concentrations. Both the HMI and the maximum EF value across all 12 heavy metals (EF_MAX) are used to set thresholds assigning disturbance class (Section 6.4Chemical Screens and Thresholds) and for indicating stressor condition (discussed in the following Section 12.4).

12.3.1 *Enrichment Factor (EF)*

The Heavy Metal Index calculation used for the 2011 NWCA (USEPA 2016a, Nahlik et al. 2019) was improved and updated for the 2016 NWCA by incorporating Enrichment Factors (EFs). EFs capture the degree to which soils are enriched with heavy metals and, for each metal, are calculated as:

$$\textbf{Enrichment Factor = EF =} \left(\frac{\textbf{Observed heavy metal concentration at a site}}{\textbf{Regional 75th percentile heavy metal background}}\right)$$

This calculation is similar to that reported by Chen et al. (2007); however, unlike the methods reported in Chen et al. 2007, heavy metal concentrations were not normalized to the textural characteristics of the soils. Due to the wide range of wetland types and soil types sampled in the NWCA, the background concentrations estimated for wetlands (Table 12-2) were used as the denominators in the EF calculations. To interpret the results, the same enrichment factor scale reported by Chen et al. (2007) was used and are reported in the following table (Table 12-3):

Table 12-3. Interpretation of Enrichment Factor (EF) results

Enrichment Factor (EF)	Interpretation
EF <1	No enrichment
EF <3	Minor enrichment
EF = 3-5	Moderate enrichment
EF = 5-10	Moderately severe enrichment
EF = 10-25	Severe enrichment
EF = 25-50	Very severe enrichment
EF > 50	Extremely severe enrichment

12.3.2 *Heavy Metal Index (HMI)*

Next, the revised Heavy Metal Index (HMI) was calculated based on the number of soil heavy metals with EFs greater or equal to three, indicating moderate enrichment or greater, depending on the EF values. The HMI is calculated as:

$$\sum \text{number of heavy metals with EF} \geq 3 = \text{Heavy Metal Index} = \text{HMI}$$

where the maximum the HMI can be for any site is 12 (i.e., if all 12 heavy metal EFs are equal to or greater than 3).

EF_MAX indicates the highest degree to which a site was contaminated by any of the heavy metals and is calculated for each site as:

Maximum Enrichment Factor = EF_MAX = maximum value of the 12 heavy metal EFs

The EF_MAX detects sites that have at least one heavy metal in high concentrations above the expected background. This indicator is important, as some sites have only one principal contaminant, so the HMI can be low even though one or more heavy metals are severely enriched, which indicate stress to the wetland.

12.4 Soil Heavy Metal Stressor Condition Thresholds

Like other National Aquatic Resource Survey (NARS) assessments, the NWCA data was used to identify connections between the presence of indicators of stress and ecological condition. Anthropogenic stressors act to degrade ecological condition, and consequently, evaluation of indicators of stress is an important component of an assessment method (Fennessy et al. 2007). Using physical, chemical, and human-health indicators of stress, the NWCA analysis examined a variety of stressor data to detect factors likely affecting wetland condition. The use of stressor data is consistent with current approaches to assess wetlands and recognizes the connection between the presence of stressors and wetland condition. For example, rapid assessment methods have been developed which use only stressors as indicators of condition (e.g., the Delaware Rapid Assessment Method (Jacobs 2007)) and models comprising an HGM assessment (a Level 3, intensive assessment) use stressors as variables (e.g., Whigham et al. 2007, Wardrop et al. 2007).The data sources for the indicators of stressor condition used in the NWCA analysis were primarily from field observations and soil and water chemistry samples collected from the Assessment Area (AA) and its buffer at each sampled site.

One soil heavy metal indicator of stressor condition is reported for the 2016 NWCA. This chemical indicator considers both the HMI score and the EF_MAX score at a site to assign a site to a "good", "fair", or "poor" stressor condition. National thresholds were used for the soil heavy metal indicator, with sites with:

- HMI ≤ 1 *and* EF_MAX ≤ 5 assigned to good stressor condition,
- HMI > 3 *or* EF_MAX > 10 assigned to poor stressor condition, and
- HMI = 2-3 *or* EF_MAX = 6-10 (i.e., everything between good and poor) assigned to fair stressor condition.

These thresholds were chosen based on best professional judgement. A site assigned to good heavy metal stressor condition can have no more than one heavy metal (of the 12 included in the HMI) that is more than moderately enriched. A site assigned to poor soil heavy metal stressor condition, for example, may have:

- more than three heavy metals that are more than moderately enriched, or
- at least one heavy metal that is severely (or very severely, or extremely severely) enriched.

An explanation of how stressor condition extent estimates, and relative and attributable risk are calculated for the soil heavy metal indicator of stressor condition is discussed explicitly in **Chapter 15**.

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Chapter 13: Water Chemistry

Chemical indicators of disturbance to a wetland site are one of the key categories of data (in addition to physical and biological indicators). In the 2011 NWCA, water chemistry was introduced as a research indicator – in part due to the fact that only a subset of the NWCA sites were able to be sampled for water chemistry. Here, we present two water chemistry parameters, total nitrogen (TN) and total phosphorus (TP) concentrations, as core indicators of stressor condition. In order to use TN and TP as indicators of stressor condition, several distinct procedures needed to be completed to provide the basis for setting TN and TP stressor condition thresholds and include:

- Describing the population of wetlands sampled for water chemistry (**Section 13.3**);
- Developing Physical-Alterations-Possibly-Affecting-Chemicals (CALT) indices for use in screening sites to establish the disturbance gradient for sites sampled for water chemistry;
- Using two CALT indices and four landscape metrics and their associated disturbance thresholds to screen sites and assign disturbance classes (i.e., "least disturbed", "intermediate disturbed", and "most disturbed"); and, finally,
- Calculating "good", "fair", and "poor" thresholds for stressor condition using the 75th and 95th percentiles of TN and TP concentrations among least-disturbed sites sampled for water chemistry.

These steps are discussed in this chapter so that, ultimately, the extent of TN and TP stressor conditions may be reported for wetlands sampled for water chemistry in the final 2016 NWCA Report.

13.1 Data Collection

Water chemistry samples were collected at all wetlands having sufficient sampleable surface water within the 0.5 ha assessment area (AA) during the sampling visit. Because surface water was required to be within the AA, not all sites yielded a water sample – even when surface water was present elsewhere in the wetland. Furthermore, some wetlands lacked surface water entirely during the sampling visit. Sixty-four percent of probability and handpicked sites across both Visit 1 and Visit 2 yielded a water sample in 2016. The percentage of 2016 sites with water chemistry samples is approximately 10% higher than in the 2011 NWCA, largely attributed to the removal of the 2011 sampling location water-depth-minimum of 15 cm.

Laboratory analyses were conducted per methods detailed in 2016 *Field Operations Manual* (USEPA 2016a) and in **Table 13-1**. In summary, water chemistry sampling consisted of using a dipper to fill 1) a 1L bottle that was filtered on-site for later chlorophyll-a analysis, and 2) a 1L cubitainer for laboratory analysis of other water chemistry parameters. The chlorophyll filters and cubitainers were chilled immediately and express-shipped to the USEPA Pacific Ecological Systems Division (PESD) in Corvallis, Oregon for analyses.

In addition to the analytes measured in the lab (**Table 13-1**), conductivity and pH were measured in the field at some sites (at the field crew's discretion). While most analytes were measured in both the 2011 and 2016 surveys, four analytes were added to the 2016 analysis: turbidity, DOC, chloride, and sulfate. Chloride and sulfate, important indicators of anthropogenic disturbance (e.g., water softeners, fertilizers, and road salt for chloride (Herlihy et al. 1998) and mine influences for sulfate (Herlihy et al. 1990)), were only measured in freshwater samples. There is no expectation that chloride and sulfate concentrations in saltwater would be informative of anthropogenic impacts (i.e., concentrations would reflect the saltwater influence).

Table 13-1. Water chemistry analytes measured in the laboratory, with their associated units and a summary of methods.

Analyte	Units	Summary of Method
Conductivity	µS/cm at 25˚C	Electrolytic
pH (laboratory)	Standard (Std) Units	Automated with autotitrator and combination pH electrode *or* manual electrolytic analysis
Turbidity	Nephelometric Turbidity Units (NTU)	Automated nephelometric analysis *or* manual turbidmetric analysis (high turbidity samples)
Dissolved Organic Carbon (DOC)	mg-C/L	UV promoted persulfate oxidation to CO_2 with infrared detection
Ammonia (NH_3)	mg-N/L	FIA automated colorimetric (with use of salicylate, dichloroisocyanurate)
Nitrate-Nitrite (NO_3-NO_2)	mg-N/L	Ion chromatography (freshwater samples) *or* FIA automated colorimetric (cadmium reduction for brackish or freshwater samples)
Total Nitrogen (TN)	mg/L	Persulfate digestion followed by FIA automated colorimetric analysis
Total Phosphorus (TP)	mg-P/L	Persulfate digestion followed by FIA automated colorimetric analysis
Sulfate (SO_4)	mg-SO_4/L	Ion Chromatography (freshwater samples only)
Chloride (Cl)	mg-Cl/L	Ion Chromatography (freshwater samples only)
Chlorophyll-a	µg/L	90% acetone exraction followed by fluorometry analysis

13.2 Data Validation

Data validation refers to the process of checking for completeness and repeatability the data, which begins upon receiving the data from participating laboratories through the assembly of data into results files. Validation is especially important for water chemistry data because samples were processed by multiple state and regional laboratories across the US. Data validation was completed for all water chemistry parameters using completeness-checking, repeatability-checking, and evaluation of cross-visit repeatability. Details about how each of these methods were applied to the data are discussed in the following paragraphs.

Completeness-checking refers to checking and addressing any missing values or any data values that *should* be set to missing because of documented collection or analysis concerns. Water chemistry analytes whose values were flagged as being below the laboratory's minimum detection limit (MDL) were generally assigned a value of half that detection limit. Per Hornung and Reed (1990), the practice of using half the MDL more accurately preserves the data distribution properties than alternatives, such as setting below-detection values to zero. An exception to this general rule was made for certain chlorophyll-a and ammonia samples. These few samples had high detection limits due to either 1) the amount of water filtered in the field or 2) the amount of dilution that occurred in the laboratory before analysis to get the sample within instrument range. To avoid over-inferring concentration values these samples that were poorly characterized by such high detection limits, flagged samples with MDLs above 2.0 µg/L for chlorophyll-a and 0.03 mg-N/L for ammonia were set to "missing" (i.e., "NA" in the database).

Data for TN and TP were complete across the dataset (i.e., no missing values), as were data for ammonia, nitrate/nitrite, conductivity, pH, and turbidity. Chloride and sulfate data, which are associated exclusively with freshwater, were not analyzed (i.e., missing) from 55 saltwater sites identified by high conductivity levels. Several DOC values were missing because one laboratory erroneously analyzed total organic carbon (TOC). Chlorophyll-a values were laboratory-reported as "missing" from four sites due to problems with filter type or filter volume, and an additional 27 sites were set to "missing" due to flagged samples with MDLs above 2.0 µg/L. While the dataset started as complete, 26 ammonia values were set to "missing" due to flagged samples with MDLs above 0.03 mg-N/L, and five cases were missing because the ammonia concentration of the sample exceeded that of TN (indicating measurement error).

Repeatability-checking included the comparison of analyte values between Visit 1 and Visit 2 (for the approximately 10% of sites where a second visit was done), and comparison of any field measurements for conductivity and pH to the corresponding laboratory measurements. The field versus laboratory comparisons revealed several cases of conductivity being recorded in the wrong units in the field (e.g., milliSiemens rather than microSiemens per centimeter), likely because of limitations on the field meter display. Once these were corrected, the Pearson correlation between field-measured and lab-measured conductivity was extremely high (r = 0.99), confirming that conductivity is consistent between laboratory and field measurements. On the other hand, there are consistent differences in laboratory-measured pH and field-measured pH (r = 0.72) – likely driven by varying degrees of carbon dioxide (CO_2) saturation. Parallel to findings from the 2011 survey (USEPA 2016c), laboratory-measured pH values tended to be higher than those measured in the field for acidic waters (i.e., pH < 7.0), while laboratory-measured pH values tended to be lower than those measured in the field for alkaline waters (i.e., pH > 7.0).

Cross-visit repeatability can be assessed directly by analyzing the correlation of values between visits to the same site within the same year (i.e., Visit 1 compared to Visit 2). However, the interpretation of cross-visit repeatability is affected by the rate at which below-detection (i.e., MDL) values occur for any given analyte. Abundant data below the MDL (e.g., NH_4 and NO_3) results in the same low below detection limit values, leaving few data to correlate.

Comparing the variance associated with a sampling site (signal) to the variance associated with repeated visits to the same site (noise) results in the ***Signal-to-Noise Ratio (S:N)*** (Kaufmann et al. 1999, 2014), which is described in detail in Chapter 8:, Section 8.5.2. All sites are included in the signal, whereas only revisit sites contribute to the noise component. S:N is a useful for discerning environmentally-significant patterns for an analyte against the background of its typical variability. Analytes with high S:N are more likely to show consistent responses, and S:N values ≤ 1 indicate that sampling a site twice yields as much or more variability as sampling two different sites (Stoddard et al. 2008).

Considering all sites sampled in the 2016 NWCA, only nitrate-nitrite, chloride, and TN had S:N < 3 (**Table 13-2**), indicating that these analytes had high within-site variability. Chloride (and to a lesser extent sulfate), which were not measured in saltwater sites but may have been measured in brackish sites (discussed previously in **Section 13.1**), had low S:N for all 2016 sites as a result of high between-visit variability in estuarine sites. However, when S:N is calculated for inland (i.e., freshwater) sites, the ratio for both chloride and sulfate increased to > 10.

Table 13-2. Variability and repeatability of water chemistry analytes measured in the 2016 NWCA, including below-detection rates for all 2016 NWCA sites (Visit 1 and Visit 2, probability and handpicked), cross-visit correlations based on the 61 revisit sites, and Signal-to-Noise ratios (S:N) for all sites and inland (freshwater) sites.

Analyte	Below-Detection Rate	Cross-Visit Pearson Correlation (r)	S:N (All 2016 Sites)	S:N (2016 Inland Sites)
Conductivity	None	0.97	20.9	29.7
pH (laboratory)	NA	0.88	15.9	18.3
Turbidity	0.3%	0.58	40.1	37.6
Dissolved Organic Carbon (DOC)	0.2%	0.87	6.67	7.11
Ammonia (NH_3)	37.1%	0.10	3.94	4.30
Nitrate-Nitrite (NO_3-NO_2)	33.6%	0.28	1.97	3.11
Total Nitrogen (TN)	None	0.39	1.98	1.55
Total Phosphorus (TP)	0.3%	0.85	17.6	14.7
Sulfate (SO_4)	2.7%	0.94	3.09	12.9
Chloride (Cl)	0.3%	0.99	1.40	10.3
Chlorophyll-a	7.3%	0.62	11.9	13.1

13.3 Establishing a Disturbance Gradient for Sites Sampled for Water Chemistry

The wetland population represented by water chemistry is a subset of the larger NWCA wetland population; 56% and 65% of the wetlands in 2011 and 2016, respectively, sampled across both Visit 1 and Visit 2 had sufficient surface water to collect and analyze. Thus, water chemistry data were excluded from the generation of the disturbance gradient used to identify abiotic and final least- and most-disturbed sites (i.e., ABIOTIC_REF_NWCA and REF_NWCA), discussed in **Chapter 6:**.

However, in order to develop chemical indicators of stressor condition based on TN and TP measured in the water column (presented later in **Section 13.4**), it is necessary to create a specially-defined disturbance gradient for the subset of sites that were sampled for water chemistry. To establish a water chemistry disturbance gradient, all 1,198 unique probability and handpicked sites across both the 2011 NWCA *and* the 2016 NWCA that were sampled for water chemistry (**Table 13-3**) were used. The general process for setting least-disturbed and most-disturbed thresholds, and for assigning disturbance class is discussed in **Chapter 6:, Section 6.2.2** through **Section 6.2.4**. Here, the process used for assigning least-disturbed and most-disturbed water chemistry sites is described, beginning with the development of indices used to develop least- and most-disturbed thresholds.

Table 13-3. The number of Visit 1 (V1) probability and handpicked sites sampled for water chemistry in 2011 and 2016, with their totals. Additionally, the numbers of resampled sites with water chemistry data are reported in paratheses to indicate that these are subtracted from the subtotals above. The total number of unique probability and handpicked sites with water chemistry data are reported with the final number of Index Visit sites (in the red cell) used in the establishment of the water chemistry disturbance gradient. Note that this table does not include the 51 Visit 2 sites with water chemistry sampled in 2011 and 64 Visit 2 sites with water chemistry sampled in 2016, which are only used to calculate Signal-to-Noise ratios.

SURVEY YEAR	V1 PROBABILITY WITH WATER CHEMISTRY (n-sites)	HANDPICKED WITH WATER CHEMISTRY (n-sites)	TOTAL
2011 NWCA	531	86	**617**
2016 NWCA	611	64	**675**
SUBTOTAL	**1142**	**150**	**1292**
2011 Sites with Water Chemistry Resampled in 2016	(94)	(0)	**(94)**
TOTAL UNIQUE SITES WITH WATER CHEMISTRY	**1048**	**150**	**1198**

13.3.1 *Development of Physical-Alterations-Possibly-Affecting-Chemicals (CALT) Indices*

Three indices, collectively referred to as the Physical-Alterations-Possibly-Affecting-Chemicals (CALT) indices, were developed for use in screening sites to establish the disturbance gradient for sites sampled for water chemistry:

- the CALT_NUT index, alterations thought likely to affect nutrient levels,
- the CALT_SED index, alterations thought likely to affect suspended sediment levels, and
- the CALT_SAL index, alterations thought likely to affect salinity levels.

These three indices were based on observational data associated with the stressor check lists (hereon referred to as “Items”) on the H-1 and B-1 Forms (see **Table 11-1**). Best professional judgement (BPJ) was used to evaluate if and how each H-1 and B-1 Form Item might affect nutrients, suspended sediments, and salinity at a site. Write-in “others” were not considered and were therefore excluded from this analysis. Based on this evaluation, a subset of the H-1 and B-1 Form Items were assigned to one, two, or all three of the Chemical-Response-to-Physical-Alteration indices (Table 13-4). Note that not all metrics were assigned to one of the CALT indices (hence, “subset”).

Table 13-4. Subset of Physical Alteration metrics (defined in **Chapter 11:, Section 11.2**) assigned to the Physical-Alterations-Possibly-Affecting-Nutrient (CALT_NUT), Physical-Alterations-Possibly-Affecting-Suspended Sediments (CALT_SED), and Physical-Alterations-Possibly-Affecting-Salinity (CALT_SAL) indices. "X" indicates that the Physical Alteration metric was included the CALT index. Note that not all Physical Alteration metrics were assigned to a CALT index. Write-in "others" from the H-1 and B-1 Forms were not considered and are therefore excluded from the list of Form Items.

Form	Form Items	2016 Parameter Name	Nutrients (CALT_NUT)	Suspended Sediments (CALT_SED)	Salinity (CALT_SAL)
B-1	*Forest Clear Cut*	HAB_CLEAR-CUT	X	X	
B-1	*Forest Selective Cut*	HAB_SELECTIVE_CUT		X	
B-1	*Tree Canopy Herbivory (insect)*	HAB_HERBIVORY			
B-1	*Herbicide/Pesticide Use*	HAB_HERBICIDE_PESTICIDE			
B-1	*Shrub Layer Browsed (wild or domestic)*	HAB_SHRUB			
B-1	*Highly Grazed Grasses (overall <3" high)*	HAB_GRAZED	X	X	
B-1	*Mowing/Shrub Cutting*	HAB_MOWING			
B-1	*Recently Burned Forest (canopy)*	HAB_FOREST_BURNED		X	
B-1	*Recently Burned Grassland (blackened)*	HAB_GRASS_BURNED		X	
B-1	*Fallow Field (old – grass, shrubs, trees)*	AGR_FALLOW_OLD			
B-1	*Fallow Field (recent – resting row crop field)*	AGR_FALLOW_RECENT		X	
B-1	*Golf Course*	RES_GOLF	X	X	X
B-1	*Lawn/Park*	RES_LAWN	X		X
B-1	*Orchard/Nursery*	AGR_ORCHARD	X		
B-1	*Silviculture/Tree Plantation*	HAB_PLANTATION			
B-1	*Row Crops – Tilling*	AGR_ROW	X	X	X
B-1	*Range*	AGR_RANGE	X		
B-1	*Pasture/Hay*	AGR_PASTURE	X		
H-1	*Culverts & Ditching: Ditches*	DITCH_PRESENT			
H-1	*Culverts & Ditching: Channelized Streams*	CHANNELIZED_PRESENT			
H-1	*Culverts & Ditching: Corrugated Pipe*	CORR_PRESENT			
H-1	*Culverts & Ditching: Box*	BOX_PRESENT			
H-1	*Pipes: Sewer Outfall*	SEWER_PRESENT	X		X
H-1	*Pipes: Standpipe Outflow*	STANDPIPE_PRESENT			
H-1	*Field Drainage Tiling*	TILING_PRESENT			
H-1	*Pumps: Irrigation*	IRRIGATION_PRESENT	X		
H-1	*Pumps: Other*	PUMP_OTHER_PRESENT	X		
H-1	*Pumps: Water Supply*	WAT_SUPPLY_PRESENT			
H-1	*Shallow Channels: Vehicle Ruts*	RUTS_PRESENT		X	
H-1	*Shallow Channels: Abandoned Road*	ABANDONED_PRESENT		X	
H-1	*Shallow Channels: Eroded Foot Paths*	PATHS_PRESENT		X	
H-1	*Shallow Channels: Trails*	TRAILS_PRESENT		X	
H-1	*Shallow Channels: Animal Trampling*	ANTRAMP_PRESENT	X	X	
B-1	*Ditches, Channelization*	HYD_DITCH			
B-1	*Inlets, Outlets*	HYD_INLETS			
B-1	*Point Source/Pipe (effluent or stormwater)*	HYD_PIPE			
B-1	*Drain Tiling*	AGR_TILING		X	X
B-1	*Irrigation*	AGR_IRRIGATION	X		X
B-1	*Impervious Surface Input (sheetflow)*	HYD_IMPERVIOUS			X

Form	Form Items	2016 Parameter Name	Nutrients (CALT_NUT)	Suspended Sediments (CALT_SED)	Salinity (CALT_SAL)
H-1	*Damming Features: Dikes*	DIKES_PRESENT			
H-1	*Damming Features: Berms*	BERMS_PRESENT			
H-1	*Damming Features: Dams*	DAMS_PRESENT			
H-1	*Damming Features: Roads (all types)*	ROADS_PRESENT		X	X
H-1	*Damming Features: Railroad Bed*	RRBED_PRESENT			
B-1	*Dike/Dam/Road/RR Bed (impede flow)*	HYD_DDRR			
B-1	*Wall/Riprap*	HYD_WALL			
B-1	*Fill/Spoil Banks*	HYD_FILL		X	
B-1	*Water Level Control Structure*	HYD_WATER			
H-1	*Impervious Surfaces: Compacted non-paved (on 2016 H-1 Form only)* *Impervious Surfaces: Roads (on 2011 H-1 Form only)*	IMPER_ROADS_PRESENT			X
H-1	*Impervious Surfaces: Asphalt*	IMPER_ASPHALT_PRESENT			X
H-1	*Impervious Surfaces: Concrete*	IMPER_CONCRETE_PRESENT			X
B-1	*Oil/Gas Wells/Drilling*	IND_OIL_GAS		X	X
B-1	*Confined Animal Feeding*	AGR_ANIMAL	X	X	X
B-1	*Dairy (on 2011 B-1 Form only)* *Livestock or Domesticated Animals (on 2016 B-1 Form Only)*	AGR_DAIRY	X	X	X
B-1	*Soil Compaction (animal or human)*	HAB_SOIL		X	
B-1	*Trails*	HAB_TRAILS		X	
B-1	*Offroad Vehicle Damage*	HAB_ORV		X	
B-1	*Road (paved or unpaved) (on 2016 B-1 Form only)* *Road – Gravel (on 2011 B-1 Form only)* *Road – Two Lane (on 2011 B-1 Form only)* *Road – Four Lane (on 2011 B-1 Form only)*	RES_ROAD		X	
B-1	*Parking Lot/Pavement*	RES_LOT		X	X
B-1	*Rural Residential*	AGR_RURAL			X
B-1	*Suburban Residential*	RES_RES		X	X
B-1	*Urban/Multifamily*	RES_URBAN			X
B-1	*Power Line*	RES_POWER			
H-1	*Excavation/Dredging*	EXCAVATION_PRESENT		X	
H-1	*Recent Sedimentation*	SEDIMENT_PRESENT		X	
B-1	*Dumping*	RES_DUMPING			
B-1	*Trash*	RES_TRASH			
B-1	*Landfill*	RES_LANDFILL	X	X	X
B-1	*Excavation, Dredging*	HYD_EXCAVATION		X	
B-1	*Gravel Pit*	AGR_GRAVEL		X	X
B-1	*Mine (surface/underground)*	IND_MINING		X	X
B-1	*Freshly Deposited Sediment (unvegetated)*	HYD_SEDIMENT		X	
B-1	*Soil Erosion/Deposition (from wind, water, or overuse)*	HAB_EROSION		X	
B-1	*Soil Loss/Root Exposure*	HYD_SOIL		X	
B-1	*Military*	IND_MILITARY		X	X

For each site, each of the three Physical-Alterations-Possibly-Affecting-Chemicals indices (i.e., CALT_NUT, CALT_SED, and CALT_SAL) was scored by simply tallying the number of B-1 and H-1 Items observed and weighting each tally using the same proximity-weighted scheme used for the Physical Alteration indices. Observations in the AA received the highest scores (25 points for each tally) and observations in the buffer plots received increasingly lower weighted scores with distance from the AA (inner-ring buffer plots = 4 points per tally, middle-ring buffer plots = 2 points per tally, and outer-ring buffer plots = 1 point per tally). Detailed scoring protocol and a scoring illustration can be found in **Chapter 11:, Section 11.3** and **Figure 11-2**.

Site CALT_NUT, CALT_SED, and CALT_SAL scores range from 0 points (no items from H-1 or B-1 Forms observed) to almost 300 points, although few sites scored over 100 points.

TP, and to a lesser extent TN were correlated to CALT_NUT and CALT_SAL and these indices were used to help define the disturbance gradient screen. The third CALT index, the Physical-Alterations-Possibly-Affecting-Suspended Sediments (CALT_SED) index, was not included as a disturbance gradient screen (i.e., it was excluded from further use) because analysis revealed that it was not sufficiently related to nutrients or turbidity. Turbidity, a measure of the degree to which a beam of light passed through a water sample is attenuated by particulates in that water, is the one NWCA 2016 water chemistry measurement that might be expected to respond to sediment loading, but the ability to see such a response can be weakened by 1) the fact that turbidity also reflects the concentration of plankton algae in the water column, and 2) unless they are derived from very fine-grained sediments (e.g., clays), sediments loaded to wetlands settle out of the water column rather quickly.

13.3.2 *Screens and Thresholds for Sites Sampled for Water Chemistry*

Six physical and landscape screens were used to identify least-disturbed, intermediate-disturbed, and most-disturbed sites sampled for water chemistry. These screens include two Physical-Alterations-Possibly-Affecting-Chemicals (CALT) indices and four landscape metrics:

- the Physical-Alterations-Possibly-Affecting-Nutrients (CALT_NUT) index,
- the Physical-Alterations-Possibly-Affecting-Salinity (CALT_SAL) index,
- the Percent Agriculture in the 1000-m buffer surrounding the AA,
- the Percent Developed in the 1000-m buffer surrounding the AA,
- the Percent Agriculture in the HUC-12 in which the AA was located, and
- the Percent Developed in the HUC-12 in which the AA was located.

Land cover derived from 30-m resolution 2011 and 2016 rasters (depending on the NWCA collection year of the data being screened) of the 2016 National Land Cover Database (NLCD, Dewitz 2019) were used to calculate the extent of agriculture and developed land cover for the 1000-m buffer surrounding the AA and the US Geological Survey (USGS) 12-digit Hydrologic Unit Code (HUC-12) in which the AA was located. The extent (percent) of agriculture encompasses Planted/Cultivated Classes and includes NLCD Values 81 and 82.[13] The extent (percent) of developed encompasses the Developed Class and includes NLCD Values

[13] **Value 81 = Pasture/Hay** – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation. **Value 82 = Cultivated Crops** – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled. (https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description)

21, 22, 23, and 24.[14] Land cover at the 1000-m buffer scale and at the HUC-12 scale were highly correlated (r ≈ 0.7) but different enough to filter different sites, so both screens for both scales were used to help define the disturbance gradient for sites sampled for water chemistry.

National thresholds (i.e., the same thresholds regardless of region) for "least disturbed" and "most disturbed" were used for all six screens and are reported in **Table 13-5**. Sites that passed all six screens were considered "least disturbed" while sites that exceeded any one of the six most-disturbed thresholds were considered "most disturbed". All other sites were assigned to the intermediate disturbance class.

Table 13-5. Six water chemistry screens and their least-disturbed and most-disturbed thresholds used to assign disturbance class to each site sampled for water chemistry.

Water Chemistry Screen	Least-Disturbed Thresholds	Most-Disturbed Thresholds
Physical-Alterations-Possibly-Affecting-Nutrients (CALT_NUT)	< 5 points	≥ 50 points
Physical-Alterations-Possibly-Affecting-Salinity (CALT_SAL)	< 5 points	≥ 50 points
% Agriculture in 1000-m buffer	< 5%	≥ 50%
% Developed in 1000-m buffer	< 5%	≥ 50%
% Agriculture in HUC-12	< 5%	≥ 50%
% Developed in HUC-12	< 5%	≥ 50%

A summary of the number of sites within each water chemistry disturbance class are reported by region (RPT_UNIT_5) in **Table 13-6**. There were 1,198 unique NWCA sites (see **Table 13-3**) that had measured water chemistry with roughly equal sample sizes among the five reporting units. However, there were only six least-disturbed sites in the Plains (PLN). Even though so few sites are not ideal for analysis, the least-disturbed threshold would have needed to be so severely relaxed to gain the optimal 30-50 least-disturbed sites for PLN, that least-disturbed and most-disturbed thresholds would have been almost equivalent. Three sites that lacked CALT scores were assigned as "unknown".

Table 13-6. n-sites sampled for water chemistry, presented by disturbance class assignments (unpublished) reported by region (RPT_UNIT_5) for Visit 1, Index Visit 2011 and 2016 sites.

Region	Least Disturbed (L)	Intermediate Disturbed (I)	Most Disturbed (M)	Unknown (?)	Regional Totals
Tidal Saline (TDL)	92	204	32	1	**329**
Inland Coastal Plains (ICP)	31	117	40	1	**189**
E. Mts & Upper Midwest (EMU)	59	138	32	1	**230**
Plains (PLN)	6	65	142	0	**213**
West (WST)	56	91	90	0	**237**

[14] **Value 21 = Developed, Open Space** – areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. **Value 22 = Developed, Low Intensity** – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units. **Value 23 = Developed, Medium Intensity** – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units. **Value 24 = Developed, High Intensity** – highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover. (https://www.mrlc.gov/data/legends/national-land-cover-database-class-legend-and-description)

National Totals	**244**	**615**	**336**	**3**	**1198**

13.3.3 *Evaluation of the Disturbance Gradient for Sites Sampled for Water Chemistry*

The disturbance gradient for sites sampled for water chemistry was developed to support the development of TN and TP as indicators of stressor condition. Least-disturbed sites will serve as the foundation for defining TN and TP stressor condition thresholds (presented in the next section, **Section 13.4**), thus, it is imperative that least-disturbed sites are distinguished from most-disturbed sites in both the TN and TP data.

Using Log10-transformed TP and TN, t-tests performed on national data (i.e., unique 2011 and 2016 Visit 1 sites) showed that distinction of least-disturbed from most-disturbed sites was highly significant ($t > 11$, $p < 0.001$). **Figure 13-1** illustrates this distinction among five regions (RPT_UNIT_5). However, statistical analyses showed that there were no differences between least- and most-disturbed sites in Tidal Saline (TDL) wetlands, and there were not enough least-disturbed sites in the Plains (PLN) to reach any statistical conclusions. Significant differences ($t = 4$ to 8, $p < 0.001$) were found for the Inland Coastal Plains (ICP), Eastern Mountains and Upper Midwest (EMU), and West (WST). TP differences were generally stronger than TN differences (**Figure 13-1**).

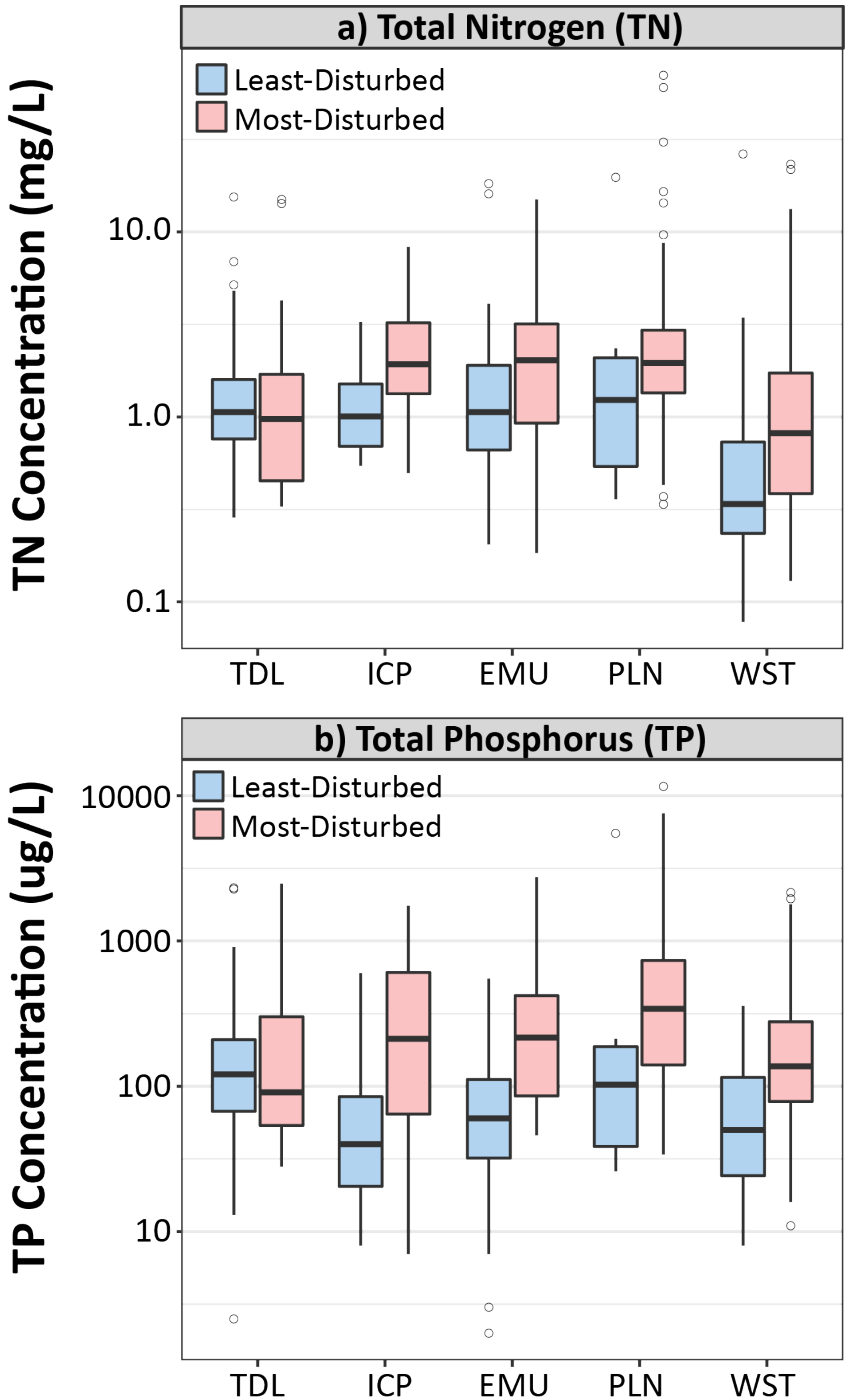

Figure 13-1. Box and whisker plots showing differences between least-disturbed (blue) and most-disturbed (red) (unique 2011 and 2016 Visit 1) sites among five regions (RPT_UNIT_5) for a) total nitrogen (TN) and b) total phosphorus (TP). TDL = Tidal Saline, ICP = Inland Coastal Plains, EMU = Eastern Mountains & Upper Midwest, PLN = Plains, and WST = West.

13.4 TN and TP Stressor Condition Thresholds

Like other National Aquatic Resource Survey (NARS) assessments, the NWCA data was used to identify connections between the presence of indicators of stress and ecological condition. Anthropogenic stressors act to degrade ecological condition, and consequently, evaluation of indicators of stress is an important component of an assessment method (Fennessy et al. 2007). Using physical, chemical, and human-health indicators of stress, the NWCA analysis examined a variety of stressor data to detect factors likely affecting wetland condition. The use of stressor data is consistent with current approaches to assess wetlands and recognizes the connection between the presence of stressors and wetland condition. For example, rapid assessment methods have been developed which use only stressors as indicators of condition (e.g., the Delaware Rapid Assessment Method (Jacobs 2007)) and models comprising an HGM assessment (a Level 3, intensive assessment) use stressors as variables (e.g., Whigham et al. 2007, Wardrop et al. 2007). The data sources for the indicators of stressor condition used in the NWCA analysis were primarily from field observations and soil and water chemistry samples collected from the Assessment Area (AA) and its buffer at each sampled site.

Two water chemistry indicators of stressor condition are reported for the 2016 NWCA: 1) total nitrogen (TN) and 2) total phosphrous (TP) concentrations measured in the water column of sampled sites with water. Because TN and TP are highly variable in wetlands depending on the wetland type, hydrology, and other defining characteristics of wetlands that influence nutrient cycling, there is no concurrence in the literature about expected "reference" concentrations of TN and TP. Thus, thresholds for water column TN and TP were developed using the same percentile approach that is used by NARS (e.g., Paulsen et al. 2008, USEPA 2016d).

First, subpopulations for which thresholds should be developed needed to be determined. This was completed by evaluating concentrations of TN and TP in least-disturbed sites sampled for water chemistry (defined in the previous **Section 13.3** and in **Table 13-6**) across regional subpopulations (specifically, Five Reporting Units (RPT_UNIT_5)). The results of these evaluations, illustrated in **Figure 13-1**, indicated that there were no significant differences in TN concentrations across the least-disturbed sites among the Five Reporting Units (i.e., TDL, ICP, EMU, PLN, and WST). However, TP concentrations across the least-disturbed sites were significantly higher in tidal (TDL) compared to the inland subpopulations (i.e., ICP, EMU, PLN, and WST), although TP did not differ significantly among the 4 inland reporting units. The significant differences among these subpopulations warranted separate TN and TP stressor condition thresholds for inland and tidal subpopulations (i.e., HYD_CLS, see **Table 5-1** in **Chapter 5:**).

Thus, TN and TP thresholds for good stressor condition and poor stressor condition were developed for inland and tidal subpopulations using the distribution of least-disturbed sites sampled for water chemistry. After deleting outliers using a 1.5*IQR test (with IQR referring to "interquartile range"), threshold values were calculated using the 75^{th} and 95^{th} percentiles of TN and TP concentrations among least-disturbed sites sampled for water chemistry (**Figure 13-2**). Specifically:

- Good stressor condition thresholds were calculated as the 75^{th} percentile of TN and TP concentrations among least-disturbed sites sampled for water chemistry.
- Poor stressor condition thresholds were calculated as the 95^{th} percentile of TN and TP concentrations among least-disturbed sites sampled for water chemistry.
- Sites with TN and TP concentrations higher than the threshold for "good" and lower than the threshold for "poor" are classified as fair stressor condition.

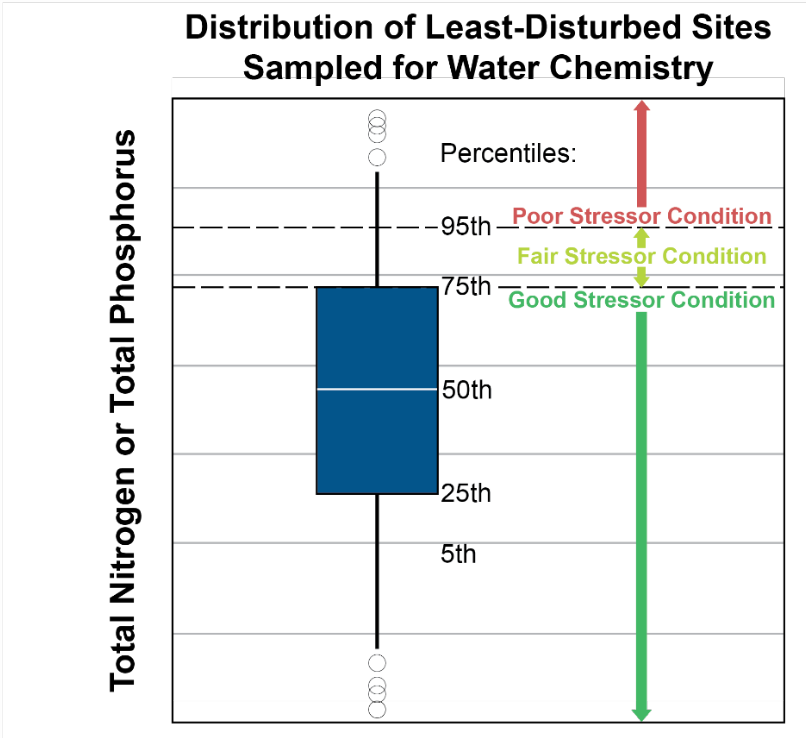

Figure 13-2. Good stressor condition and poor stressor condition threshold-setting using the 75th and 95th percentiles of total nitrogen (TN) or total phosphorus (TP) concentrations among least-disturbed sites sampled for water chemistry.

Threshold results for inland sites and tidal sites are shown in **Table 13-7**. Inland and tidal thresholds are very similar for TN (approximately 1.2 mg/L for both inland and tidal sites) but very different for TP (98 µg/L for inland sites and 174 µg/L for tidal sites). In general, wetlands tend to have higher "natural" background TN and TP concentrations compared to streams. For comparison, good stressor condition thresholds for NARS streams in mountainous ecoregions (SAP, NAP, and WMT from the AG_ECO9 subpopulation) are approximately 0.15-0.35 mg/L for TN and 15-20 µg/L for TP, and approximately 0.6-0.7 mg/L for TN and 50-90 µg/L for TP in the Plains ecoregions (NPL, SPL, and TPL from the AG_ECO9 subpopulation) (USEPA 2016d).

Table 13-7. Final total nitrogen (TN) and total phosphorus (TP) thresholds and relevant information for developing those thresholds, including the number of least-disturbed sites with water chemistry on which threshold percentiles are based (see **Section 13.3** for details), the high outlier cut-off, and the number of outlier sites.

	Total Nitrogen Inland Sites	Total Nitrogen Tidal Sites	Total Phosphorus Inland Sites	Total Phosphorus Tidal Sites
Number of Least-Disturbed Sites with Water Chemistry	152	92	152	92
High Outlier Cut-off	3.073 mg/L	2.858 mg/L	240.5 µg/L	424.0 µg/L
Number of Outlier Sites Removed from Analysis	14	10	9	7
Good (75th percentile) Stressor Condition Threshold	≤ 1.26 mg/L	≤ 1.24 mg/L	≤ 98 µg/L	≤ 174 µg/L
Poor (95th percentile) Stressor Condition Threshold	> 2.04 mg/L	> 2.18 mg/L	> 166 µg/L	> 358 µg/L

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Chapter 14: Microcystins

Microcystins are one group of naturally occurring toxins produced by various cyanobacteria (blue-green algae) that are common to surface waters (Chorus and Bartram 1999). Microcystins have been detected nationally in wetlands (USEPA 2016) and are considered to be the most commonly occurring class of cyanobacteria toxins (cyanotoxins) (Chorus and Bartram 1999). Microcystin exposure risk is typically elevated when an overabundance of cyanobacteria occurs in surface water causing a cyanobacteria harmful algal bloom (cyanoHABs). There is concern that changes in weather patterns, human population expansion, and associated behaviors are leading to perceived increases in occurrence and severity of cyanoHABs (Paerl and Scott 2010). Three main exposure scenarios are of potential concern regarding microcystins and wetlands: direct ecological impacts on plants and animals, human consumption of exposed organisms, and direct human exposure through recreational contact.

Adverse ecological impacts due to microcystin exposure on plants and animals have been summarized in several sources. Various adverse impacts of microcystins on cellular processes in a variety of aquatic and terrestrial plants resulting in diminished plant growth and accumulation of microcystins have been reported (Crush et al. 2008, Corbel et al. 2013, Romero-Oliva et al. 2014). Some macrophytes common to certain types of wetlands have shown sensitivity to microcystins also. Microcystins have been shown to inhibit the growth and oxygen production of some wetland macrophytes at concentrations of 1 µg/L or less (Rojo et al. 2013). Additionally, illness and mortality due to microcystin exposure has been reported in wildlife, livestock, companion animals and all trophic levels of freshwater, brackish and marine aquatic life. Animal illness and mortality has been reported in numerous cases including amphibians, cats, cattle, chickens, deer, dogs, frogs, horses, muskrat, sheep, turkey, and waterfowl, but the true number of cases remains unknown since many are not reported or observed (Chorus and Bartram 1999, Landsberg 2002, Briand et al. 2003, Handeland and Østensvik 2010, Vareli et al. 2013).

14.1 Data Collection and Analysis

Samples were collected for microcystin analysis from sites with sufficient surface water for sample collection and shipped to analytical labs following procedures outlined in the NWCA Field Operations Manual (USEPA 2016a). Samples were lysed by three sequential freeze/thaw cycles and filtered with 0.45 micron HVLP syringe filters (Loftin et al. 2008, Graham et al. 2010). Following the NWCA Laboratory Operations Manual (USEPA 2016b), samples were analyzed by one of two methods depending on whether practical salinity units (PSU) were ≤ 3.5 PPT (part per thousand, Method 1) or > 3.5 PPT (Method 2). Samples were stored frozen prior to further extraction (Method 2) and analysis for microcystins by enzyme-linked immunosorbent assay (Abraxis ADDA kit, Warminster, PA) at -20°C.

14.2 Application of EPA Recommended Criterion for Microcystins

Microcystins concentrations were evaluated against the EPA recommended recreational water quality criterion and swimming advisory level of 8 ppb (US EPA 2019). Microcystins results identify the percentage of wetland area at or below the criterion and above the criterion. The microcystins detection results were determined using the MDL of 0.1 ppb which was consistent in both surveys. The detection results presented in the public report and data dashboard represent the percentage of wetland area with measured values greater than 0.1 ppb.

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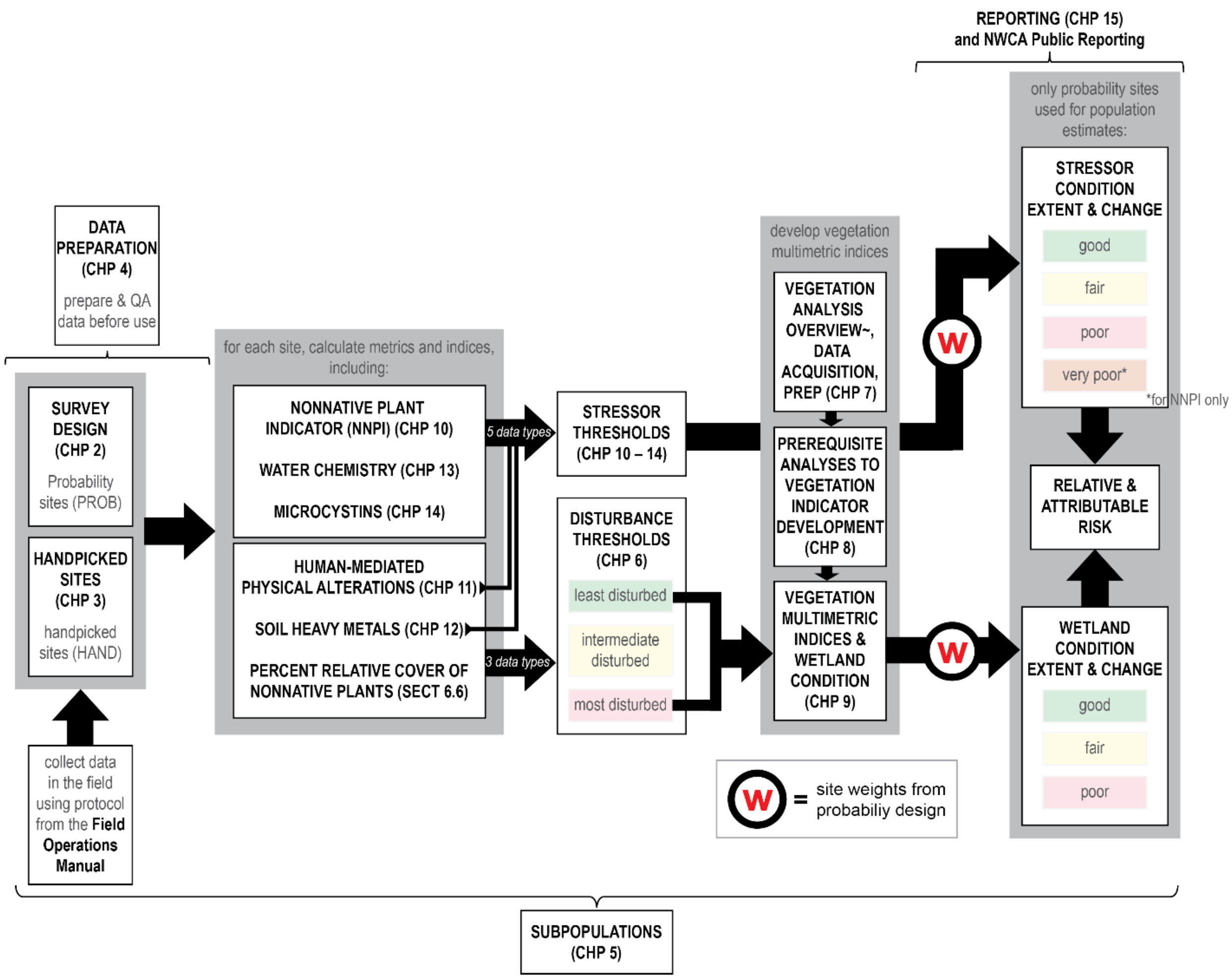
Chapter 15: Condition Extents, Change in Condition Extents, and Relative and Attributable Risk



Recap of Figure 1-1. Annotated analysis flow chart indicating the chapter number (abbreviated as “CHP”) in which details may be found.

The information provided in the previous chapters is intended to provide a solid understanding of how the 2016 NWCA was designed, conducted, and analyzed. Up to this point in this document, details have been provided regarding the:

- survey design (Chapter 2:),
- selection of handpicked sites (Chapter 3:),
- preparation of data (Chapter 4:),
- definition of subpopulations (Chapter 5:),
- establishment of the disturbance gradient (Chapter 6:),
- development of the Vegetation Multimetric Indices (VMMIs) (Chapter 7: through Chapter 9:),
- development of the Nonnative Plant Indicator (NNPI) (Chapter 10:), and

- development of physical and chemical indicators used for the disturbance gradient (**Chapter 6:**) and stressor condition (**Chapter 11: through Chapter 14:**).

This chapter will describe how all the above components are used to calculate population estimates, which include three different types of condition:

- wetland condition extent estimates based on the Vegetation Multimetric Indices (VMMIs) (**Section 15.1.1**),
- Nonnative Plant Indicator (NNPI) condition extent estimates (**Section 15.1.2**), and
- stressor condition extent estimates based on physical and chemical indicators (**Section 15.1.3**).

Wetland condition, NNPI condition, and stressor condition extent estimates are calculated using *spsurvey: Spatial Survey Design and Analysis* (Kincaid and Olsen 2019) and expressed as wetland area in acres or percent of the resource; therefore, site weights from the probability design must be used to generate population estimates along with the data from the probability sites sampled (n-sites = 967). The role of population estimates and site weights in these calculations is discussed in **Section 15.1**. Additionally, methods for calculating and reporting change in wetland condition and stressor condition extent estimates between the NWCA 2011 and NWCA 2016 (referred to as "change analyses") are discussed in **Section 15.2**. Ultimately, relative and attributable risk, discussed in detail in **Section 15.3**, are used to calculate the relationship between:

- wetland condition and stressors, and
- NNPI condition and stressors.

Final results, including:

- wetland condition extent estimates,
- NNPI condition extent estimates,
- stressor condition extent estimates,
- change analyses, and
- relative and attributable risk

are presented in *National Wetland Condition Assessment 2016: A Collaborative Survey of the Nation's Wetlands* (USEPA 2022a) and in the *USEPA National Wetland Condition Assessment 2016 Data Dashboard* (2022b), primarily as bar graphs. This document provides guidance on how to interpret these results.

15.1 Condition Extent Estimates

The survey design for the NWCA, discussed in **Chapter 2:** of this report, produces a spatially-balanced sample using a combination of two different geographic data layers: US Fish & Wildlife Service (USFWS) National Wetland Status and Trends (S&T) (Dahl and Bergeson 2009, Dahl 2011) and USFWS National Wetland Inventory (NWI) (USFWS 2014). Each point (n-probability sites = 967, see **Table 6-1**) has a known probability of being sampled (Stevens and Olsen 1999, Stevens and Olsen 2000, Stevens and Olsen 2004, Olsen et al. 2019), and a sample weight is assigned to each individual site as the inverse of the probability of that point being sampled. Sample weights are expressed in units of acres.

The probability of a site being sampled, as discussed in Chapter 2:**, Section 2.2.3**, was stratified by state with unequal probability of selection based on geographic regions and Wetland Groups (WETCLS_GRP) see **Table 5-1** in **Chapter 5:**) within each state. Site weights for the survey were adjusted to account for additional sites (i.e., oversample points) that were evaluated when the primary sites were not sampled (e.g., due to denial of access, being non-target). These site weights, designated by the red "W" enclosed in a circle (i.e., Ⓦ) in the Overview of Analysis figure (**Figure 1-1**), are explicitly used in the calculation of wetland condition extent estimates, NNPI condition extent estimates, and stressor condition extent estimates, so results can be expressed as estimates of wetland area (i.e., numbers of acres or percent of the entire resource) in a particular condition category (i.e., "good", "fair", "poor", and, for the NNPI only, "very poor") for the Nation and any of the subpopulations in **Table 5-1**. In the following sections, the methods by which estimates are calculated and reported are described for wetland condition extent (**Section 15.1.1**), NNPI condition extent (**Section**), and stressor condition extent (**Section 15.1.3**). It is important to note that the NWCA was not designed to report on individual sites or states, but to report at national and regional scales (see **Chapter 2:**).

15.1.1 *Wetland Condition Extent Estimates*

A Vegetation Multimetric Index (VMMI) summarizes several metrics describing different aspects of observed vegetation that together can reflect wetland condition in relation to least-disturbed wetland sites. For the NWCA 2016 analysis, four separate VMMIs were developed, one for each of four Wetland Groups: Estuarine Herbaceous, Estuarine Woody, Inland Herbaceous, and Inland Woody.

Wetland condition extent estimates are based on the four Vegetation Multimetric Indices (VMMIs). Each NWCA probability site is designated as in good, fair, or poor condition based on its VMMI value and associated thresholds appropriate to the site (**Chapter 7**). Next, the site weights from the probability design are summed across all sites in each condition category to estimate the wetland area in good, fair, and poor condition for the NWCA target wetland population (see **Chapter 2:, Section 2.2.5**) nationally and for the subpopulations reported in **Table 5-1**. The survey design allows calculation of confidence intervals around these condition estimates.

Note that only Visit 1 (i.e., the Index Visit) data and only probability sites are used in the calculation of extent. Handpicked sites have a weight of zero. Using this method, wetland area in a particular wetland condition category is estimated and reported in numbers of acres or by percent of the resource (**Figure 15-1**). The *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (2022a) provides national results, whereas the *USEPA National Wetland Condition Assessment 2016 Data Dashboard* (2022b) provides an interactive format for users to explore national results and results for different subpopulations.

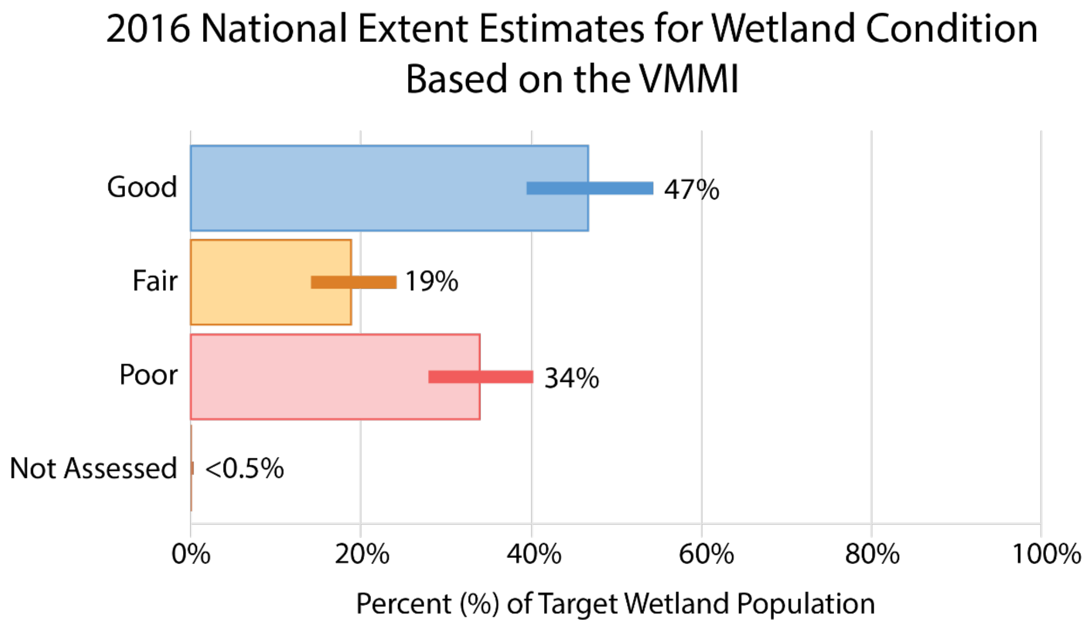


Figure 15-1. The 2016 NWCA national extent estimates for wetland condition based on the Vegetation Multimetric Indices (VMMIs). Wetland condition extent is presented for each condition category by percent of the resource (i.e., percent of target wetland area for the Nation). Error bars represent 95% confidence intervals as calculated by the R package spsurvey (Kincaid and Olsen 2019).

15.1.2 *Nonnative Plant Indicator (NNPI) Condition Extent Estimates*

Nonnative plant species are widely recognized as important biological indicators of lowered ecological condition. They have numerous direct and indirect effects on native vegetation and other ecosystem components, properties, and processes. The Nonnative Plant Indicator (NNPI) reflects wetland condition in relation to stress from nonnative plants (Magee et al. 2019) by incorporating attributes of richness, occurrence, and abundance for nonnative (alien and cryptogenic) plant species (see **Chapter 10:**).

NNPI condition extent estimates are based on the designation of each probability site as good, fair, poor, or very poor condition based on NNPI. Site weights from the probability design are summed across all sites in each condition category to estimate the wetland area in good, fair, poor, and very poor condition for the NWCA target wetland population (see **Chapter 2:, Section 2.2.5**) nationally and for the subpopulations reported in **Table 5-1**. The survey design allows calculation of confidence intervals around these condition estimates.

Note that only Visit 1 (i.e., the Index Visit) data and only probability sites are used in the calculation of extent. Handpicked sites have a weight of zero. Using this method, wetland area in a particular NNPI condition category is estimated and reported in numbers of acres or by percent of the resource (**Figure 15-2**). The *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (2022a) provides national results, whereas the *USEPA National Wetland Condition Assessment 2016 Data Dashboard* (2022b) provides an interactive format for users to explore national results and results for different subpopulations.

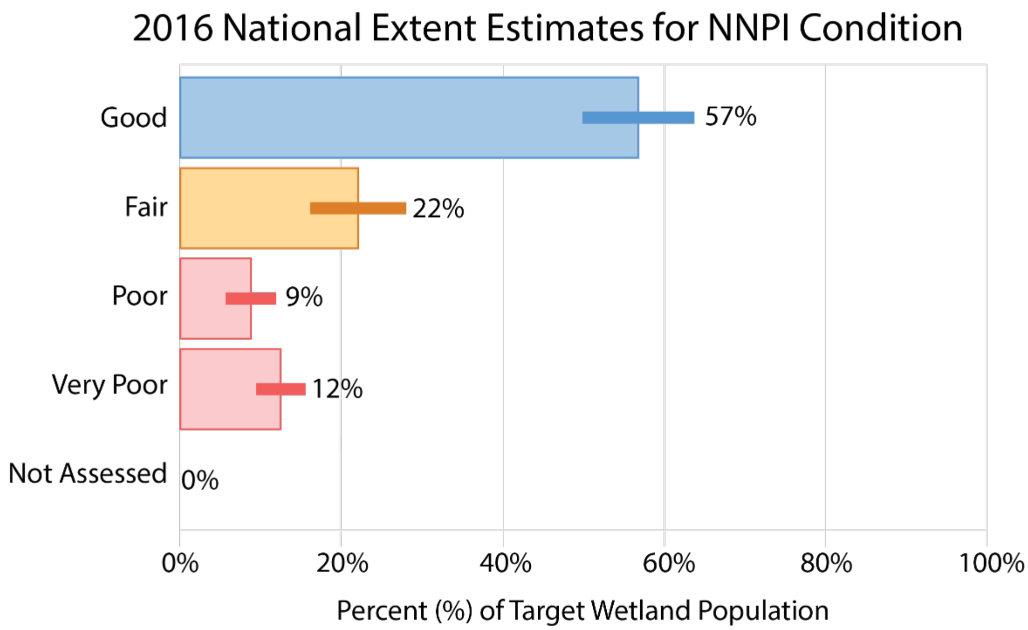


Figure 15-2. The 2016 NWCA national extent estimates for Nonnative Plant Indicator (NNPI) condition. NNPI condition extent is presented for each condition category by percent of the resource (i.e., percent of target wetland area for the Nation). Error bars represent 95% confidence intervals as calculated by the R package spsurvey (Kincaid and Olsen 2019).

15.1.3 *Stressor Condition Extent Estimates*

Indicators of stressor condition are used as descriptors of the potential impact of anthropogenic activities on wetland condition. Although indicators of stressor condition do not necessarily imply causation of ecological decline, they are often associated with impaired condition. For simplicity, they are sometimes referred to using the shorthand term “stressors”. Stressors are used to support analyses that provide four types of information (i.e., results):

- *Stressor Condition Extent* – an estimate (by percent of the resource or relative ranking of occurrence) of how spatially common a stressor is based on the population design;
- *Relative Extent* – an estimate of the areal percentage of the wetland population with poor stressor condition for a particular indicator;
- *Relative Risk* – the probability (i.e., risk or likelihood) of having poor condition when the stressor condition category is poor relative to when it is good; and,
- *Attributable Risk* – an estimate of the proportion of the population in poor condition that might be reduced if the effects of a particular stressor were eliminated (Van Sickle and Paulsen 2008).

Eleven indicators of stressor condition are reported for the 2016 NWCA (2022a,b):

- Vegetation Removal (VEGRMV),
- Vegetation Replacement (VEGRPL),
- Water Addition/Subtraction (WADSUB),
- Flow Obstruction (WOBSTR),

- Soil Hardening (SOHARD),
- Surface Modification (SOMODF), and
- Physical Alterations (PALT_SUM)
- Soil Heavy Metals (METALS),
- Total Nitrogen in the water column (TN),
- Total Phosphorus in the water column (TP), and
- Microcystins (MICX).

Stressor condition categories are defined at each wetland site as “good”, “fair”, or “poor”, except for microcystins, which is defined as “at or below benchmark” or “above benchmark”. These stressor condition categories were assigned for multiple physical, chemical, and human-health indicators based on specific thresholds, as described at the end of each of the individual chapters describing the indicators (i.e., **Chapter 10: through Chapter 14:**). To calculate stressor condition extent estimates, site weights were summed by stressor condition category and applied to the NWCA target wetland population (**Chapter 2:, Section 2.5**) nationally and the subpopulations reported in **Table 5-1** to estimate wetland area in the good, fair, and poor stressor condition categories. The *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (2022a) provides national results, whereas the *USEPA National Wetland Condition Assessment 2016 Data Dashboard* (2022b) provides an interactive format for users to explore national results and results for different subpopulations.

Note that only Visit 1 (i.e., the Index Visit) data and only probability sites are used in the calculation of extent. Handpicked sites have a weight of zero. Using this method, wetland area in a particular stressor condition category is estimated and reported in numbers of acres or by percent of the resource (**Figure 15-3**). Population results for condition based on the 11 stressors are detailed in the *National Wetland Condition Assessment 2016: A Collaborative Survey of the Nation’s Wetlands* (USEPA 2022a).

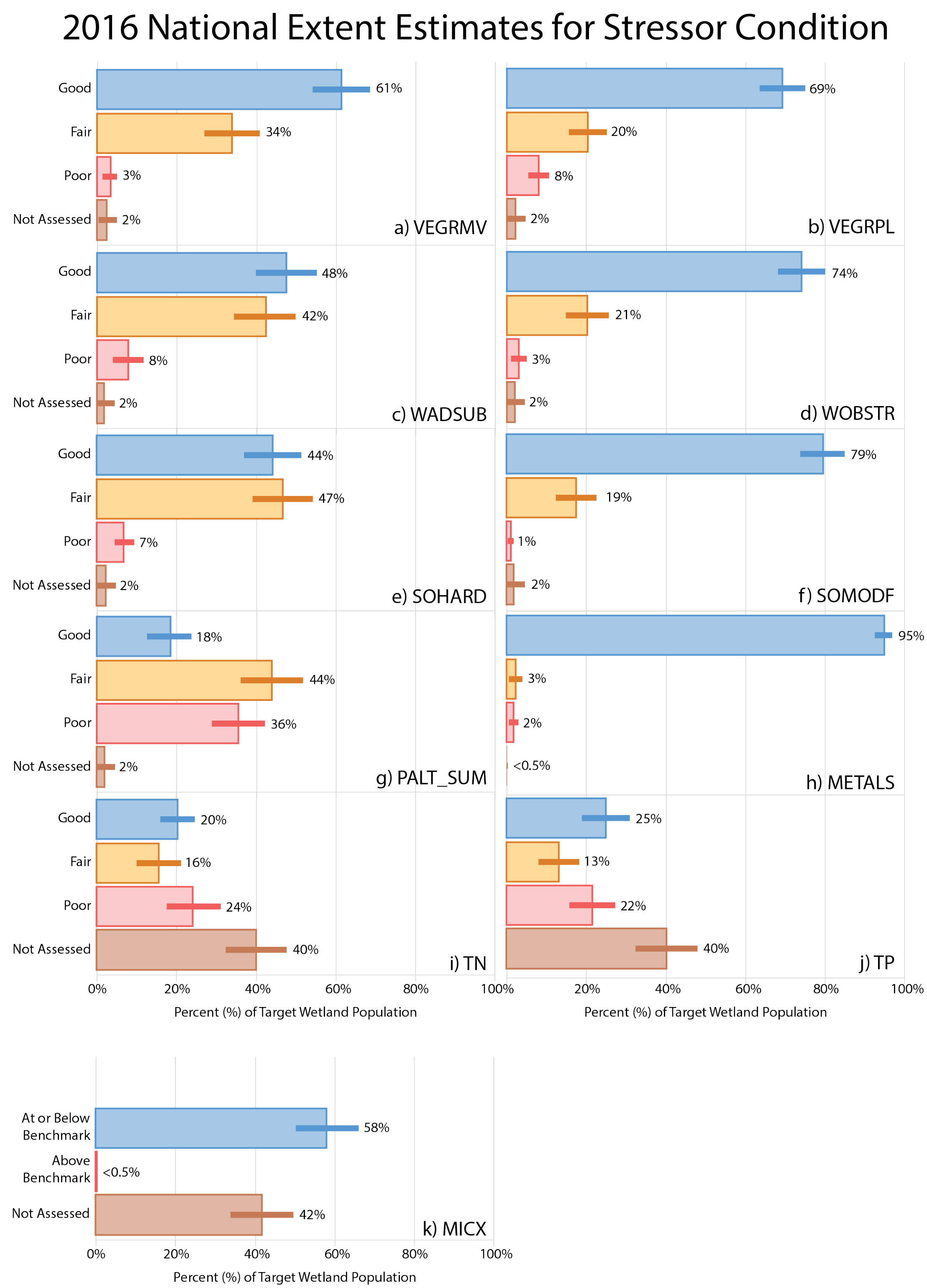


Figure 15-3. The 2016 NWCA national extent estimates for 11 indicators of stressor condition. Stressor condition extent is presented for each condition category by percent of the resource (i.e., percent of target wetland area for the Nation). Error bars represent 95% confidence intervals as calculated by the R package spsurvey (Kincaid and Olsen 2019). Stressor abbreviations are defined in **Section 15.1.3**.

15.2 Change in Condition Extent from 2011 to 2016

One of the objectives of the NWCA is to track changes in the condition of wetlands over time. For the first cycle of the NWCA, USEPA and partners reported on the condition of all wetlands in the NWCA 2011. For this second cycle of the NWCA, change analyses were performed to determine the difference in the condition of the wetland population between 2011 and 2016.

15.2.1 *Data Preparation*

2011 was the first NWCA survey and, as such, there were improvements that were made to the 2016 NWCA. Updates from 2011 to 2016 were made to the survey design, field protocols, the methods by which the indicators were calculated, and the thresholds used to assign disturbance classes and condition categories.

The NWCA Analysis Team made every effort possible to balance the evolution of the survey while keeping the 2011 and 2016 data comparable. Consequently:

- Comparability analyses were conducted using resampled site data when field protocols changed to ensure that results were not influenced by changes in sampling methods (e.g., **Figure 12-1**).

- All indicators were recalculated for 2011 using the new methods developed for the 2016 analysis to allow valid comparisons to 2016 results. All comparisons between the first NWCA and this one should be made using the new information presented in this document, in the *National Wetland Condition Assessment 2016: The Second Collaborative Survey of Wetlands in the United States* (2022a)), and in the interactive dashboard (2022b).

- Due to improvements in the sample frame for 2016, survey weights were updated for 2011 in order to make the population as comparable as possible to 2016.

However, a fundamental change in the survey design between 2011 and 2016 is the incorporation of NWI digital map data to enable better regional geographic coverage for sites in 2016 (see **Chapter 2:**). This affected the distribution and types of wetlands sampled across the nation and regionally, which may influence comparability in patterns – especially when evaluating change between 2011 and 2016. In other words, even though the regional allocation of sites improved in 2016, change analyses for those regions that were not well-covered in 2011 may be impacted.

15.2.2 *Change analysis*

Change analysis was conducted through the use of the spsurvey package in R (Kincaid and Olsen 2019). Within the GRTS (Generalized Random Tessellation Stratified) survey design, change analysis can be conducted on continuous or categorical variables. When using categorical variables, change is estimated by the difference in category estimates from the two surveys. Category estimates were defined as the estimated proportion of values in each category (i.e., good, fair, and poor (or very poor in the case of NNPI) categories). Change between the two years was statistically significant when the resulting error bars around the change estimate did not cross zero.

Change analysis is conducted between two points in time (n =2) and thus can only analyze differences between two survey time periods. In other words, changes between 2011 and 2016 do not necessarily indicate trend or pattern of change. Trends are likely to become clearer after multiple survey years (e.g., adding results from 2021 and 2026).

15.3 Relative Extent, and Relative and Attributable Risk

The relationship between condition based on the VMMI or the NNPI and the condition based on the 11 indicators of stress can be described by calculating relative extent, and relative and attributable risk.

15.3.1 *Relative Extent*

Relative extent shows the percent of the resource estimated to be in a given condition category for an indicator. Here, the relative extent of poor stressor condition for a given indicator is calculated for comparison to relative and attributable risk results (as shown in the left panels in **Figure 15-4**).

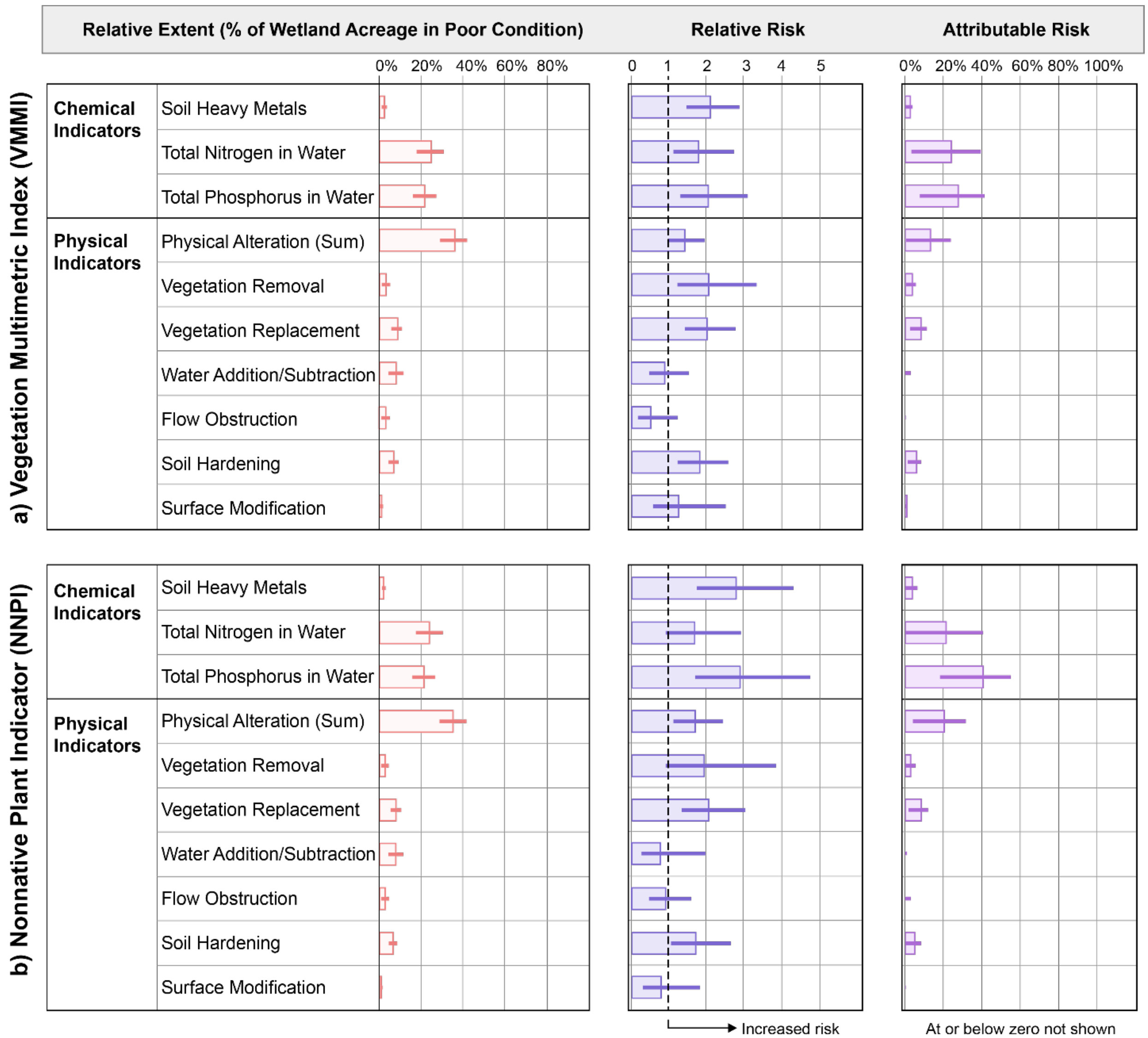


Figure 15-4. The 2016 NWCA relative extent of wetlands with stressors in poor condition, and the relative risk and attributable risk of poor a) VMMI condition or b) NNPI condition when stressor condition is poor as calculated by the R package spsurvey (Kincaid and Olsen 2019). Note that the microcystins results were excluded due to low values. For relative risk, values below the dashed line (i.e., a relative risk < 1) signifies that there is no association between the stressor and VMMI or NNPI condition.

15.3.2 *Relative Risk*

Relative risk is the probability (i.e., risk or likelihood) of having poor wetland condition based on the VMMI, or poor/very poor NNPI condition, when the stressor condition category is poor relative to when the stressor condition category is good. Relative risk analysis was derived from medical literature, where it is used commonly to describe, for example, the risk of having a heart attack based on cholesterol levels. The fact that relative risk is used so commonly to report human health risks is an advantage because, as a result, relative risk is an understandable concept to the general public. Applied to the NWCA, a relative risk analysis can be used to evaluate the relative effect of a stressor on wetland condition based on the VMMI or NNPI condition. Relative risk analyses are standard for reporting results in NARS assessments (e.g., USEPA 2006; USEPA 2009), and examples can be found for lake and stream NARS assessments in the literature (e.g., Van Sickle et al. 2006; Van Sickle et al. 2008; Van Sickle 2013).

15.3.2.1 *Example Calculation of Relative Risk*

Risk is calculated using ***contingency tables*** and expressed as a probability, which is unitless. Consider the example two-by-two contingency table[15] presented as **Table 15-1**, which relates stream condition indicated by Fish Index of Biotic Integrity (IBI) and stress indicated by total nitrogen (TN). The probabilities in the contingency table are calculated from weighted analysis of the data and reflect the proportion of the resource, stream length in the case of **Table 15-1**, which is in each of the four cells of the table. For wetland analysis, the resource is areal and the probabilities would reflect the proportion of wetland area in the population in each of the cells.

Table 15-1. Example contingency table for relative risk that reports the proportion of stream length associated with good and poor condition (as indicated by Fish Index of Biotic Integrity, IBI) and good and poor stressor condition (as indicated by stream water total nitrogen concentration, TN). Results are hypothetical.

CONDITION		STRESS LEVEL	
		TN: Good	**TN: Poor**
	Fish IBI: Good	0.598	0.275
	Fish IBI: Poor	0.070	0.056
	Total	*0.668*	*0.331*

Using the hypothetical example data provided in **Table 15-1**, the risk of a stream having ***poor*** fish condition when the TN stressor condition is ***poor*** is calculated as:

$$\frac{0.056}{0.331} = 0.169$$

The risk of a stream having ***poor*** condition when the TN stressor condition is ***good*** is calculated in the same manner:

$$\frac{0.070}{0.668} = 0.105$$

By comparing these two results, it is apparent that the risk of a stream having poor condition when the TN stressor condition is poor (0.169) is greater than when the TN stressor condition is good (0.105). The relative risk (RR) can then be simply calculated as the ratio of these two probabilities (Pr):

$$RR = \frac{\Pr(Poor\ condition\ given\ Poor\ stressor\ condition)}{\Pr\ (Poor\ condition\ given\ Good\ stressor\ condition)} = \frac{0.169}{0.105} = 1.61$$

Therefore, in this example, we can conclude that the risk of poor condition is 1.61 times greater in streams with poor TN stressor condition than in streams with good TN stressor condition.

[15] The numbers used in this example are hypothetical and were not measured as part of any USEPA NARS assessment.

These calculations are repeated for each appropriate indicator of stress so relative risk can be reported for each of them. If the stressor has no effect on condition, the relative risk is 1. Confidence intervals are also used in reporting to express uncertainty in the estimate of relative risk (see Van Sickle et al. 2006).

15.3.2.2 *Considerations When Calculating and Interpreting Relative Risk*

It is important to understand that contingency tables are created using a categorical, two-by-two matrix; therefore, only two condition categories can be used. There are multiple methods by which condition categories can be used for contingency tables.

For **wetland condition categories based on the VMMI / condition categories for stressor indicators**, three methods of calculating contingency tables may be considered:

- Good vs. Poor / Good vs. Poor,
- Good vs. Not-Good / Good vs. Not-Good, or
- **Not-Poor vs. Poor / Not-Poor vs. Poor***

where, "Not-Good" combines fair and poor condition categories, and "Not-Poor" combines good and fair condition categories.

For **NNPI condition categories / condition categories for stressor indicators**, five methods of calculating contingency tables may be considered:

- Good vs. Very Poor/ Good vs. Poor
- Good vs. Poor + Very Poor / Good vs. Poor
- Good vs. Not-Good / Good vs. Not-Good
- **Good + Fair vs. Poor + Very Poor / Not-Poor vs. Poor***
- Not-Very Poor vs. Very Poor / Not-Poor vs Poor

where, "Not-Good" combines fair, poor, and very poor condition categories, and "Not-Very Poor" combines good, fair, and poor condition categories.

In the first bulleted method, "Good vs. Poor / Good vs. Poor", for example, data associated with the fair condition categories are excluded from the analysis. Therefore, the results of the associated calculation of relative risk are affected by which one of the above combinations is used to make the contingency tables, and it is crucial that the objectives of the analysis are carefully considered to help guide this decision.

A second consideration is that relative risk does not model joint effects of correlated stressors. In other words, each stressor is modeled individually, when in reality, stressors may interact with one another potentially increasing or decreasing impact on condition. This is an important consideration when interpreting the results associated with relative risk.

The two **bold**, asterisked (*) methods (one for each the VMMI and the NNPI condition categories) indicate the method used for the NWCA analysis.

15.3.2.3 *Application of Relative Risk to the NWCA*

For each site sampled as part of the NWCA:

- Wetland condition is assigned as good, fair, or poor using the Vegetation Multimetric Index (VMMI) thresholds as described in **Chapter 9:**;

- Nonnative Plant Indicator (NNPI) condition is assigned as good, fair, poor, or very poor, using exceedance values as described in **Chapter 10:**; and
- Stressor conditions of 11 physical and chemical indicators are assigned as good, fair, or poor using thresholds as described in **Chapter 11: through Chapter 14:**.

For each indicator of stressor condition, a contingency table was created, comparing:

- the Not-Poor VMMI condition category (i.e., a combination of good and fair wetland conditions) to Poor condition category, and Not-Poor stressor condition category (i.e., a combination of good and fair stressor conditions) to Poor stressor condition; and
- the combination of Good and Fair NNPI condition categories to Poor and Very Poor NNPI condition categories, and Not-Poor stressor condition category (i.e., a combination of good and fair stressor conditions) to Poor stressor condition.

These decisions for the contingency tables were made because the objective of reporting relative risk in the NWCA is to indicate which stressors policy makers and managers may want to prioritize for management efforts to improve poor wetland condition. After creating contingency tables, relative risk for each indicator of stress was calculated. **Figure 15-4** provides the relative risk reported for the 2016 NWCA; with stressor extent, relative risk provides an overall picture of the relative importance of individual stressors on condition.

A relative risk value of 1.0 indicates that there is no association between the stressor and the VMMI or NNPI, while values greater than 1.0 suggest greater relative risk. For example, if 30% of the population is in poor condition based on the VMMI or NNPI, but the population is equally divided among sites with Poor and Not-Poor stressor conditions (15% in each), then the RR = 0.15/0.15 = 1, and there is no association between condition and the stressor. Conversely, if the 30% in poor condition was observed as 25% in sites with Poor stressor condition and 5% in sites with Not-Poor stressor condition, then the RR = 25/5 = 5.0. The higher the relative risk value for a given stressor, the greater the risk of poor wetland condition. A relative risk of 5 indicates that we are five times more likely to see a wetland in poor condition when the stressor is poor than when it is not poor (Herlihy et al. 2019).

15.3.3 *Attributable Risk*

Attributable risk provides an estimate of the proportion of the resource population (i.e., extent) in poor condition that might be reduced if the effects of a particular stressor were eliminated. Attributable risk (AR) combines relative stressor extent with relative risk into a single index using the following formula (see Van Sickle et al. 2008 for details):

$$AR = \frac{\Pr(Extent\ with\ Poor\ Stressor\ Condition) * (RR - 1)}{1 + \Pr(Extent\ with\ Poor\ Stressor\ Condition) * (RR - 1)}$$

where RR is relative risk and Pr is probability.

Similar to the consideration presented in **Section 15.3.1.2**, it is critical to define relative extent (i.e., percent of the resource) and relative risk in the same way. Therefore, for the NWCA data, the same categories were used for calculating attributable risk as relative risk (e.g., Not-Poor was compared to Poor) for VMMI and NNPI condition categories vs. stressor condition categories).

The ranking of stressors according to attributable risk (e.g., **Figure 15-4**) represents their relative magnitude or importance relative to decreased ecological condition and can be used by policy makers and managers to inform prioritization of actions for specific stressors, geographic area, and/or wetland type.

15.3.3.1 *Considerations When Interpreting Attributable Risk*

To appropriately interpret attributable risk, it is important to understand that attributable risk is associated with the following three major assumptions:

- ***Causality***, or that the stressor causes an increased probability of poor condition;
- ***Reversibility***, or that if the stressor is eliminated, causal effects will also be eliminated and damage is reversible; and,
- ***Independence***, or that stressors are independent of each other, so that individual stressor effects can be estimated in isolation from other stressors.

These assumptions should be kept in mind when applying attributable risk results to management decisions. Attributable risk provides much needed insight into how to prioritize management for the improvement of our Nation's aquatic ecosystems – wetlands, in the case of the NWCA. While the results of attributable risk estimates are presented as percent area in poor condition that could be reduced if the effects of a particular stressor were eliminated, these estimates are meant to serve as general guidance as to what stressors are affecting condition and to what degree (relative to the other stressors evaluated).

15.4 Where to Find the Summary of NWCA Results

All of the methods presented in this document are the scientific basis for what is reported in *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (USEPA 2022a) and future peer-reviewed manuscripts. *National Wetland Condition Assessment: The Second Collaborative Survey of Wetlands in the United States* (USEPA 2022a) report provides an overview of the important results from the 2016 NWCA. The presentation of results in that document is geared toward the lay public, environmental managers, and government decision makers.

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Glossary

Abiotic disturbance class– disturbance class assignments to sites based on only the physical and chemical disturbance gradient screens (and not the biological disturbance gradient screen); the parameter name for these abiotic disturbance class assignments is REF_NWCA_ABIOTIC

Assessment Area (AA) – the 0.5 ha area that represents the location defined by the coordinates generated by the NWCA sample draw, and in which most of the data collection for the NWCA occurs

Attributable Risk – an estimate of the proportion of the population in poor condition that might be reduced if the effects of a particular stressor were eliminated[16]

Buffer – the area (representing a prescribed measurement area) surrounding the Assessment Area

Coefficients of Conservatism – (C-values, also called CCs) describe the tendency of individual plant species to occur in disturbed versus near pristine conditions; C-values for individual species are state or regionally specific and scaled from 0 to 10

Condition Category – describes the ecological condition of wetlands based on a biological indicator, a Vegetation Multimetric Index (VMMI); classes include "Good", "Fair", or "Poor"

Condition Extent – estimates of the wetland area in good, fair, and poor condition categories

Contingency table – a two-by-two table that relates condition and stress used to calculate relative risk; results of the contingency table are expressed as probabilities

Disturbance Class – classes reflecting the gradient of anthropogenic disturbance across all sampled wetland sites, and used for the Vegetation Multimetric Index (VMMI) development and to set thresholds for indicators of stress and condition

- *Least Disturbed* – a disturbance class describing sites that represent the best available physical, chemical, and biological conditions in the current state of the landscape[4]; used as "reference" for the NWCA Survey

- *Most Disturbed* – a disturbance class describing sites defined as most disturbed relative to "least disturbed"; typically representing 20-30% of sites in an NWCA Reporting Group

- *Intermediately Disturbed* – a disturbance class used to describe sites that fall between "least disturbed" and "most disturbed"

Disturbance gradient – a continuous gradient of anthropogenic disturbance, divided into three disturbance classes to which wetland sites are assigned

[16] Van Sickle J, Paulsen SG (2008) Assessing the attributable risks, relative risks, and regional extents of aquatic stressors. Journal of the North American Benthological Society 27: 920-931

Duration – longevity for plants, described by annual, biennial, and perennial life cycles or combinations thereof (see **Table 7-2** for details)

Exceedance value – for the NNPI, the exceedance of a threshold value for a particular condition category for any one of the three metrics, resulting in the assignment of the metric condition to next lower (better to worse) category; the NNPI condition for a site is based on the lowest observed condition category among the metrics

Final disturbance class – disturbance class assignments to sites based on physical, chemical, and for least-disturbed sites, biological disturbance gradient screens; the parameter name for these final disturbance class assignments is REF_NWCA

Growth habit – Primary growth-habit types for the plant taxa (see **Table 7-1** for details)

Handpicked sites – sampled sites suggested by states, tribes, and other partners based on the expectation that they are minimally disturbed and can be used as least-disturbed (or “reference”) sites

Indicator – a metric or index that reflects anthropogenic (human-mediated) disturbance to wetland condition, vegetation condition, or stressor condition

Index – a combination of metrics used to generate a single score to describe a particular property (disturbance, stressor condition, or wetland condition in the case of the NWCA) for a site

Index period – the temporal range when sites were sampled for the 2011 NWCA; the peak growing season (April through September, depending on state) when most vegetation is in flower or fruit

Index Visit – the sampling event used when conducting analyses on the set of unique sites sampled

Inference population – final wetland area represented by sampled probability sites; ultimately used by the NWCA for reporting condition and stressor extent

Metric – an individual measurement or combinations of data types to describe a particular property (e.g., soil phosphorus concentration, species richness, species cover by growth form, etc.) for a site

Native Status – state level designations of plant taxa nativity for the NWCA, designations include:

- *Native* –plant taxa indigenous to specific states in the conterminous US
- *Alien* – combination of introduced and adventive taxa
- *Introduced* – plant taxa indigenous outside of, and not native in, the conterminous US
- *Adventive* – plant taxa native to some areas or states of the conterminous US, but introduced in the location of occurrence
- *Cryptogenic* – plant taxa that includes both Native and Alien genotypes, varieties, or subspecies
- *Undetermined* – taxa identified at level of growth form, most families, or genera with both native and alien species

Nonnative plants – for the NWCA, includes both alien and cryptogenic taxa

Oversample sites – a panel of additional sites selected by the survey design to provide replacements for any sites that were either not part of the target population or could not be sampled

Parameter Names – specific code names (usually written in all caps) used to reference data in the official NARS databases and in the NWCA raw datasets

Points – site coordinates selected by the survey design

Population – see the definition for "Target Population" in this Glossary

Population estimates – estimates of characteristics of the target or inference population of wetlands in the conterminous US (or smaller reporting groups), usually described in acres or percent total area

Probability sites – sites defined by the NWCA sample draw (i.e., NWCA design sites) and some state intensifications using the same design as NWCA

Reference – analogous to "least disturbed". Sites that represent least disturbed ecological condition[17] and the associated functional capacity typical of a given wetland type in a particular landscape setting (e.g., ecoregion, watershed)

Relative Extent – shows the percent of the resource estimated to be in a given condition category for an indicator

Relative Risk (RR) – the probability (i.e., risk or likelihood) of having poor condition when the magnitude of a stressor is high (i.e., poor stressor condition) relative to when the magnitude of a stressor is low (i.e., good stressor condition)

Resample sites – probability sites that were originally sampled in the field in the previous NWCA survey and selected to be sampled again in the current survey

Resource – the population of the aquatic resource (i.e., wetlands) evaluated in the NWCA

Revisit sites – a site sampled twice within the same year to assess within-season-variability in the collected data

Sample frame – the geographic data layers that identify locations and boundaries of all wetlands that meet the definition of the target population

Screen – the method for determining threshold (a.k.a., "cutoff" or "exceedance") values for assigning disturbance class or condition category

Stressor Condition Extent – an estimate (by percent of the resource or relative ranking of occurrence, or stressor-level class) of how spatially common a stressor is based on the population design

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[17] Stoddard JL, Larsen DP, Hawkins CP, Johnson PK, Norris RH (2006) Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16: 1267-1276

Stressor Condition Category – describes the stress to wetlands associated with physical and chemical indicators as "Good", "Fair", or "Poor"

Subpopulations – individual units within a subpopulation group

Subpopulation Group – the descriptive name for a parameter name and set of individual subpopulations

Survey design – the methods by which sites are selected for the survey; in the case of the NWCA, a Generalized Random Tessellation Stratified (GRTS) survey design is used,which provides spatially-distributed samples that are more likely to be representative of the population than other common spatial survey designs

Target population – also called "the population", all wetland area included in the NWCA Wetland Types and used in the survey design; defined as all tidal and nontidal wetted areas with rooted vegetation and, when present, shallow open water less than 1 meter in depth, and not currently in crop production, across the conterminous US

Taxon-location pair – A particular plant taxon occurring at a particular location:

- *X-region pairs* – where *X* can be any particular ***taxon***, ***species***, or ***name*** (e.g., one of several potential taxonomic names) that occurs or was observed in a given region
- *X-state pairs* – where *X* can be any particular ***taxon***, ***species***, or ***name*** (e.g., one of several potential taxonomic names) that occurs or was observed in a given state
- *X-site pairs* – where *X* can be any particular ***taxon***, ***species***, or ***name*** (e.g., one of several potential taxonomic names) that occurs or was observed in a given site
- *X-plot pairs* – where *X* can be any particular ***taxon***, ***species***, or ***name*** (e.g., one of several potential taxonomic names) that occurs or was observed in a given plot

Thresholds – similar to "exceedance values" and analogous to "benchmarks", thresholds are specific values used to delineate boundaries to assign sites to specific disturbance classes or condition categories

Unique sites – each unique site occupies the same coordinates but may have up to four sampling visits (revisit sites (Visit 1 and Visit 2 in the same year) and resample sites (sites sampled in both 2011 and again in 2016)

Wetland Indicator Status (WIS) – hydrophytic status for plants designated as one of seven WIS Categories (see **Table 7-3** for details)