NATIONAL WETLAND CONDITION ASSESSMENT 2011

A Collaborative Survey of the Nation's Wetlands

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A Collaborative Survey of the Nation's Wetlands

U.S. Environmental Protection Agency
Office of Wetlands, Oceans and Watersheds
Office of Research and Development
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Table of Contents

Tables and Figures

State and Partner Highlights

Executive Summary

The National Wetland Condition Assessment (NWCA) 2011: A Collaborative Survey of the Nation's Wetlands presents the results of the first national evaluation of the ecological condition of the nation's wetlands. The NWCA is part of a broader effort by EPA and state, tribal, and federal partners to conduct national scale assessments characterizing the ecological condition of the nation's waters. Under the National Aquatic Resource Survey (NARS) program, studies have been completed for wadeable streams (2004), lakes (2007), rivers and streams (2008-2009), and coastal waters (2010). The issuance of the NWCA 2011 report marks the completion of the first full-cycle of assessments by EPA and its partners under the NARS program.

Wetlands are a vital component of our nation's waters, providing a wide array of benefits that contribute to the overall health and integrity of aquatic ecosystems and people's well-being. Wetlands help improve water quality by filtering pollutants, protecting downstream or coastal areas from floods and erosion, serving as homes or sources of food for a diverse and abundant range of species including humans, and offering places for recreation and scientific and cultural exploration. Though we are aware of the important benefits wetlands provide, we know very little about the overall ecological condition of these systems nationally. The NWCA begins to address some of the gaps in our understanding of wetland health by providing information about the ecological condition of the nation's wetlands and stressors most commonly associated with poor condition.

During the spring and summer of 2011, more than 50 field crews sampled 1,179 wetland sites across the country. Each crew used standardized field protocols to sample vegetation, soils, hydrology, algae, water chemistry, and potential stressors at each site. Most sites were selected using a random sampling technique that ensures that the results of the survey reflect the range of wetlands in the target population across the U.S. Data collected at these randomly selected sites are used to produce national and regional estimates of wetland condition.

Key Findings

Biological Condition

Vegetation is a major component of the biodiversity and structure found in wetlands, provides important habitat and food sources for birds, fish, and other wildlife, and both responds to and influences other physical features (e.g., soils, hydrology) and chemical processes (e.g., nutrient cycling) in wetland systems. Thus, vegetation can reflect and integrate different components of wetland ecosystem integrity and serve as an effective indicator of wetland condition. NWCA 2011 uses vegetation to assess the condition of wetlands across the conterminous U.S. and in four major ecoregions. Vegetation data collected at each sampling site was used to develop a national Vegetation Multi-Metric Index (VMMI), which indicates "good," "fair," or "poor" condition based on properties of vegetation that vary in relation to human-mediated disturbance. For NWCA 2011, "good" condition generally reflects diversity and abundance levels for species and plant traits (e.g., native species, tolerance for disturbance) appropriate to ecoregion and wetland type.

NWCA 2011 found that nationally, 48% of the wetland area is in good condition, 20% is in fair condition and the remaining 32% of the area is in poor condition. Of the four major ecoregion-based units reported on by NWCA, the West has the lowest percentage of wetland area, 21%, in good condition. The

Coastal Plains, Eastern Mountains and Upper Midwest, and Interior Plains have a range of 44% to 52% wetland area in good condition.

Indicators of Stress

Wetland condition can be influenced by physical, chemical, and biological factors that impact (i.e., cause stress to) a wetland's physical structure or ecological processes. NWCA 2011 developed and measured a number of physical, chemical, and biological indicators of stress that reflect potential negative impact to wetland condition. At each site, all of these indicators were evaluated in a core assessment area and within a surrounding 100 meter radius buffer. Indicators of stress at each wetland site are assigned to "low," "moderate," or "high" stressor levels depending on criteria established for each indicator.

Physical

Six physical indicators of stress are assessed for NWCA using field-based observational data collected at each site. These indicators represent physical alterations to vegetation (removal and replacement) or hydrologic alterations (damming, ditching, surface hardening, and filling/erosion) observed at the sampling site. Vegetation removal, surface hardening (e.g., pavement, soil compaction), and ditching are found to be the most widespread stressors nationally. Vegetation removal and hardening stressors are high for 27% of wetland area, while the ditching stressor is high for 23% of wetland area.

Chemical

Two chemical indicators of stress are assessed for NWCA using soil data collected at each site: a Heavy Metal Index and soil phosphorus concentration. Stressor levels for both of these indicators are low for the majority of wetland area nationally. However, stressor levels for the Heavy Metal Index are moderate for 47% of wetland area in the West and 31% of wetland area in the Eastern Mountains and Upper Midwest. Stressor levels for soil phosphorus are high for 13% of wetland area in the Eastern Mountains and Upper Midwest.

NWCA conducted the first national study of algal toxins in wetlands. Microcystin, a chemical toxin that can harm people, pets, and wildlife, was detected in 12% of wetland area nationally. However, based on recreational exposure risk levels established by the World Health Organization, very little wetland area (<1%) poses either moderate or high risk levels.

Biological

A Nonnative Plant Stressor Indicator developed for NWCA is used to assess the level of biological stress in wetlands. Nationally, 61% of wetland area has low stressor levels for nonnative plants. These results are not uniform across the country, however. The Eastern Mountains and Upper Midwest and the Coastal Plains have similar percentages of low stressor levels, 74% and 66% of wetland area, respectively, for the nonnative plant stressor indicator. In contrast, the West and Interior Plains have only 14% and 27% of wetland area, respectively, with low stressor levels.

Implications

For resource managers and other decision-makers, the NWCA provides important information about the condition of wetlands and several wide-spread stressors influencing their biological condition. Additionally, the results point to potential improvement in condition that might be seen nationally by reducing these stressors. The NWCA found that wetlands with high levels of vegetation removal and surface hardening stress are about twice as likely to have poor biological condition as those with low or moderate levels of these stressors. Further analysis that looks at how condition might improve if these two stressors are reduced, called attributable risk, suggests a possible 20% reduction in wetland area with poor biological condition if the stressor level changed from high to moderate or low.

The NWCA developed a robust VMMI that was successfully used to evaluate the condition of wetlands across major ecoregions and wetland types. In addition, NWCA developed several indicators of stress based on readily collected field data and used these to evaluate the relationship between common stressors and biological condition. NWCA scientists also conducted research into other potential indicators of wetland condition, and while not highlighted in this public report, findings from this research will help inform future scientific studies.

The NWCA marks a beginning in our endeavors to assess wetland condition nationally. Work conducted under the NWCA has advanced the state of science into indicators of wetland condition and improved our ability to evaluate wetland condition at national and regional scales. Subsequent studies and research by EPA, states, and other partners will continue to build upon the knowledge gained through the NWCA and allow us to further explore and evaluate the condition of wetlands at multiple scales. We will be better able to answer important policy and management questions about the overall health of this critical resource, and design effective strategies to fulfill the objectives of the federal Clean Water Act—to restore and maintain the chemical, physical, and biological integrity of the nation's waters.

Chapter 1: Introduction

The National Wetland Condition Assessment (NWCA) 2011 is the first national evaluation of the ecological condition of the nation's wetlands. The survey encompassed both tidal and nontidal wetlands ranging from the expansive marshes of our coasts to inland forested swamps and meadows, and the waterfowl-rich prairie potholes and playas of the interior plains.

The NWCA is part of a broader effort by EPA, state, tribal, and federal partners to conduct national-scale assessments characterizing the ecological condition of the nation's waters. Under the National Aquatic Resource Survey (NARS) program, studies have been completed for wadeable streams (2004), lakes (2007), rivers and streams (2008-2009), and coastal waters (2010). NWCA 2011 marks the completion of the first full cycle of NARS assessments. EPA and its partners plan to continue to conduct the surveys on a five-year basis, rotating through each of the aquatic resources beginning with lakes and ending each cycle with wetlands.

Similar to the other NARS studies, the NWCA identified the following key goals for the project:

- Produce a national report describing the ecological condition of the nation's wetlands and 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.

The NWCA builds not only upon the groundbreaking work of its sister NARS studies, but also that of the U.S. Fish and Wildlife Service's (FWS) Wetland Status and Trends (S&T) program, which has been documenting changes to the extent of wetland area in the U.S. for more than 30 years. Taken together, these two efforts provide government agencies, wetland scientists, and the public with comparable, scientifically-defensible information documenting the current status and, ultimately, trends in both wetland quantity (i.e., area) and quality (i.e., ecological condition). These studies help us to better understand the overall condition and health of all of our nation's waters and provide information to more effectively manage and protect this valuable resource.

This report presents the major findings of NWCA 2011. It begins with an introduction on wetlands and the importance of these aquatic systems. Subsequent chapters provide information on the design and implementation of the study, national and regional results, and the study's implications and next steps. Key concepts and study components are emphasized in special text boxes throughout the report. In addition, there are a number of highlights provided by states and other partners detailing studies and work associated with NWCA. The report underwent an extensive review by study partners, external peer-review by a panel of distinguished wetland science and policy experts, and an official public comment period.

What are wetlands?

"Wetlands" is the collective term given to areas of the landscape that are transitional between land and water. Some wetlands occur alongside streams, rivers, lakes, and coastal waters, while others occur in depressions and other low-lying areas apart from surface waters, and still others are associated with springs high in the mountains. Wetlands can be saturated with water at varying intervals throughout the day and year, and have plant and animal communities adapted to live in conditions ranging from permanently wet to fluctuating wet and dry. Wetlands are defined by three important attributes:

- plants that have adapted to survive and thrive in wet conditions (known as hydrophytes);
- soils that exhibit features of prolonged saturation and changing wet and dry cycles; and
- the presence of water at or near the surface of the ground for a time sufficient to produce soils and plant communities characteristic of wetlands.

Scientific and regulatory definitions for wetlands can differ in the criteria used to incorporate these three attributes. The NWCA, like the FWS S&T program and many other wetland monitoring studies, uses a scientific definition for wetlands described by Cowardin *et al*. (1979) that is broader than the regulatory definition of wetlands used in the federal Clean Water Act (CWA). Thus, NWCA includes wetlands that may not be considered jurisdictional for purposes of the CWA.

Wetlands take on a variety of different forms and are known by many different names depending on their principal characteristics and location in particular regions of the country. Some examples include marsh, wet meadow, swamp, bog, and prairie potholes. See Figure 1-1 for pictures and descriptions of several common wetland types.

A number of classification systems have been developed based on distinctive wetland characteristics to organize the many kinds of wetlands into groups that share similar attributes. The two most common systems used nationally are the Cowardin and the Hydrogeomorphic (HGM) classification systems. The Cowardin system considers water regime, the underlying substrate and vegetation communities to catalog wetland and deep water habitats (Cowardin *et al*. 1979). The HGM system considers the wetland's location in the landscape (i.e., proximity to a lake, stream, or topographic setting), along with its morphology, primary water sources, and hydrodynamics (Brinson 1993).

COWARDIN DEFINITION OF WETLANDS

Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.

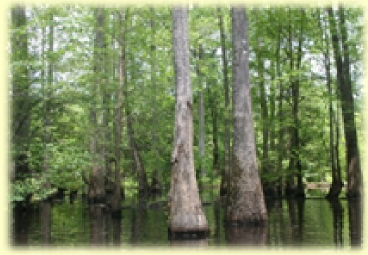
For purposes of this classification wetlands must have one or more of the following three attributes:

(1) at least periodically, the land supports predominantly hydrophytes;
(2) the substrate is predominantly undrained hydric soil; and
(3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Why are wetlands important?

Wetlands are found on every continent and make up an estimated 5 to 8% of the Earth's land surface (Mitsch and Gosselink 2007; Zhu *et al*. 2014). In the U.S., wetlands are found in every state, from the tundra of Alaska to the playas of the Great Plains and the swamps of the Florida Everglades. Wetlands even occur in the driest areas of the American West. Wetlands often occur on the edges of lakes, rivers, streams, coastal seas, and other surface water bodies, but also occur independent of these waters where precipitation or groundwater is abundant enough to sustain plants, soils, and animals that are characteristic of wetlands.

Freshwater Swamps



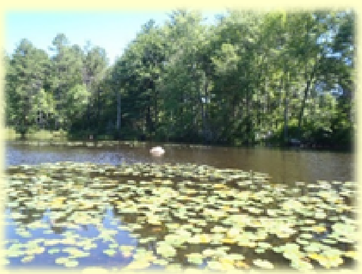
Occurring in low-lying areas, such as floodplains, throughout the United States, these tidal and nontidal freshwater wetlands are dominated by shrubs or trees that thrive under saturated conditions. Other common names include bottomland hardwood, tupelo, or bald cypress swamps.

Freshwater Marshes and Meadows

Occurring alongside lakes, streams, rivers, or in poorly drained depressional areas throughout the United States, these freshwater wetlands are dominated by grasses and other non-woody plants. Certain types like wet meadows and prairies are often dry during some parts of the year.

Peatlands, Bogs, and Fens

These freshwater wetlands are characterized by spongy peat deposits, growths of evergreen trees and shrubs, and ground cover of *sphagnum* moss. They are usually found in glaciated areas of the northern United States but a special type called a pocosin, occurs throughout the southeast coastal plain.



Shallow Ponds

These wetlands are covered by surface water that can be up to two meters deep. Common vegetation includes lily pads and other floating and submerged water plants that survive in deeper water. Prairie potholes in the north central United States and playa lakes in the southern great plains are other common types.

Salt Marshes

Occurring along the coastlines of the United States, these saltwater wetlands are influenced by ocean tides and dominated by grasses and other non-woody plants such as smooth cordgrass, saltgrass, and saltmeadow rush.

Mangrove Swamps

Occurring in brackish and saline tidal waters along the coast of the southeastern United States, these wetlands are dominated by species of mangroves and serve as valuable nurseries for a variety of recreationally- and commercially-valuable marine fish.

Figure 1-1. Examples of wetlands commonly found across the U.S.

Believed to be an obstacle to development for much of our country's history, wetlands were often drained and filled to make way for other uses. The FWS estimates that more than 220 million acres of wetlands existed in the conterminous U.S. prior to European settlement. Since then, extensive losses have occurred and over half of those wetlands have been drained and converted to other uses (Dahl 1990). Beginning in the 1970s, the rate of wetland losses slowed substantially as a result of changes in national and state wetland policies and heightened awareness of the important benefits aquatic systems, including wetlands, bring to society.

We now know that wetlands are a vital component of the nation's waters and provide many crucial benefits including water quality improvement, flood abatement and carbon storage, biodiversity support, plus aesthetic, recreational, educational, and scientific opportunities. Today these benefits are part of the decision process when permits are issued for activities that result in the loss or degradation of wetlands.

Wetlands play a critical role in sustaining healthy surface and ground waters. The physical structure of wetlands can allow them to intercept the flow of surface water, resulting in the retention and filtration of nutrients, sediment, and pollutants. Microbes living in wetlands can break down or transform potentially toxic compounds. Plants and microbes also consume and transform excess nutrients, improving water quality and slowing eutrophication of downstream waters. Together these wetland processes often reduce the amount of undesirable substances entering other surface water bodies (e.g., rivers, streams, lakes, coastal waters) where they can degrade water quality and pose environmental and human health risks.

Wetlands can act as natural sponges, capturing and slowly releasing surface water resulting from heavy rains, snow melt, and other floodwaters. Trees, grasses, and other wetland plants help slow the speed of floodwaters and disperse the excess water across floodplains. These processes lower flood heights, reduce erosion, and decrease the otherwise destructive effects of swiftly moving floodwaters. In addition, wetlands at the edges of lakes, rivers, bays, and the ocean buffer shorelines from the damaging effects of storm surges caused by hurricanes, tropical storms, and other powerful weather events.

The position of wetlands at the interface of land and water make them some of the most biologically diverse and productive ecosystems in the world. Many unique plant communities provide diverse plant species, physical structure, and distinct aesthetics to wetlands. A great variety of life from the tiniest microbes to plants, birds, fish, and mammals inhabit and depend upon wetlands for part or all of their life-cycles. Chemical and biological processes occurring within wetlands provide abundant supplies of food for a diverse range of species. Microbes and small aquatic insects break down dead plant material, forming small particles of organic material that feed larger aquatic insects and shellfish. These, in turn, feed fish and wildlife. Wetland dependent fish species make up 71% of the commercial and recreational fisheries in the U.S. (Fisheries and Water Resources Policy Committee 2004). Ducks and other waterfowl depend on wetlands for food and shelter. For example, prairie potholes and marshes dotting the Midwest are rich in plant and aquatic life vital for breeding waterfowl. Bogs and fens are important habitat for rare plants and animals. About 50% of threatened or endangered animal species in the U.S. depend on wetlands for their survival and 28% of threatened or endangered plant species are associated with wetland ecosystems (Mitsch and Gosselink 2007).

Wetlands provide plentiful opportunities for recreation and enjoyment by people. Bird and other wildlife watchers are drawn to wetlands to view or photograph the diverse species that call wetlands home. Hunters wade or boat through wetlands to hunt waterfowl. The abundance of fish in some types of wetlands attracts fishermen to these habitats. Marsh ecosystems line our coasts and provide food supply, shelter, and nursery areas for both marine and freshwater species, fueling a commercial and recreational fishery economy worth billions of dollars (Fisheries and Water Resources Policy Committee 2004). The 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation revealed that over 90 million U.S. residents participated in wildlife-related recreation such as fishing, hunting, or wildlife watching. This recreation is entirely dependent on having clean and healthy waters, including wetlands, to support the fish and wildlife at the center of these activities.

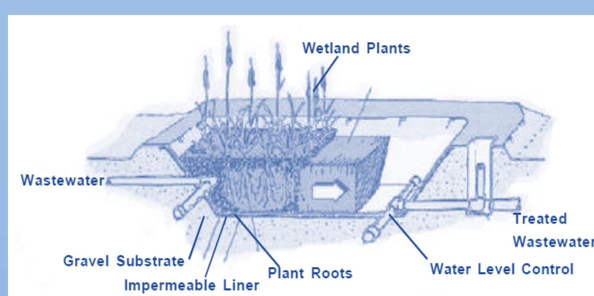
Wetlands are important settings for scientific research. Tens of thousands of research papers have been published about wetlands by scientists since the 1950s, and today, wetlands continue to be the subject of much scientific research, including studies on nutrient cycling, global climate change, bird migration, unique plant communities, and countless others. Despite all of the historic and current wetlands research, the NWCA is the first assessment to characterize the ecological condition of wetlands on a national scale. The NWCA also has inspired dozens of researchers to conduct novel scientific research that will add to our knowledge of wetlands and their importance in our national, global, and human environments.

WATER CLEANSING PROCESSES OF NATURAL WETLANDS AND THEIR USE IN ENGINEERED WATER TREATMENT SYSTEMS

Wetlands are vital to the health of waterways and downstream communities. Wetlands can naturally remove excess nutrients, sediment and other pollutants, keeping them from reaching lakes, streams and the ocean. The result is cleaner water resources and a healthier aquatic ecosystem.

After being slowed by the vegetation in a wetland, incoming water moves around plants, allowing suspended sediment to drop out and settle to the wetland bottom. Nutrients dissolved in water—which reach wetlands from various sources including anthropogenic ones such as fertilizer application, manure, leaking septic tanks, and municipal sewage—are often absorbed by plant roots and microbes in the soil while other pollutants adhere to soil particles. In many cases, this filtration process removes much of the water’s nutrient and pollutant load by the time it leaves a wetland.

Engineers have designed water treatment facilities to use similar processes to remove pollutants through coagulation, settling (in sedimentation tanks), filtration, and disinfection. Just as with the natural processes in wetlands, stormwater and sewage go through physical, chemical and biological processes at treatment facilities which clean the wastewater. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. Around the world, thousands of constructed wetlands have been created to replicate the water cleaning abilities of natural wetlands.



Picture from USEPA 2004

Why do we need a national assessment of wetland condition?

Efforts by the FWS S&T program have provided national scale information on the location and extent of wetlands (i.e., the areal coverage on the landscape) since the 1950s. Their most recent report, published in 2011, found a slight decrease in wetland area between 2004 and 2009. While the report noted gains for some wetland types, such as freshwater ponds, it found continued declines in area of forested wetlands and salt marshes. Companion reports focused specifically on wetlands in coastal watersheds (2013) and the prairie pothole region (2014) also found that wetland area is decreasing in these areas. See "The U.S. Fish and Wildlife Service's Wetland Status and Trends Program" highlight at the end of Chapter 5 for more information on this program.

While the S&T reports provide invaluable information on wetland extent and change among wetland types, they do not provide data on wetland condition. Compared to other aquatic systems, such as lakes, streams, rivers, and coastal waters, wetlands have not been comprehensively assessed to determine their condition or ability to meet water quality goals under the CWA. In a 2002 Water Quality Report to Congress, information provided by states addressed only 1% of the estimated area of wetlands, compared to approximately 20% of streams and rivers, 40% of lakes, and 35% of coastal waters (USEPA 2007). The lack of data makes it difficult to answer basic questions about the condition of our wetlands nationwide and to support key management decisions for most effectively protecting and restoring this valuable resource.

The NWCA is designed to address the gaps that exist in our understanding of wetland condition. EPA and its state, tribal, academic, and federal agency partners, are collaborating to provide improved environmental information about wetlands at national and regional scales. The NWCA, like all NARS assessments, is a statistical survey that provides a cost-effective and scientifically-valid way for informing the public and decision-makers about wetland quality because it:

- Is nationally consistent,
- Produces data representative of the resource being sampled,
- Uses standardized field and laboratory protocols, and
- Follows rigorous quality assurance protocols.

The findings of the NARS are not water quality reports prepared by the states under Section 305(b) of the CWA, nor are they impaired water determinations under Section 303(d) of the CWA. Such determinations are made by states on specific water body segments using applicable state water quality standards. State CWA monitoring and assessment approaches may vary significantly from those used in NARS and may yield different results (see text box "How Does NARS Reporting Differ from State Water Quality Reports Required by the CWA?").

Rather, the NARS are designed to answer such questions as:

- What percent of waters support healthy biological and recreational condition?
- How widespread are major stressors that impact water quality?
- How is condition changing over time?
- Are our national investments in the protection and restoration of aquatic systems working?

The focus of the surveys is on water bodies as groups or populations, rather than as individual waters. Accordingly, this report does not provide wetland managers with information on the condition of a specific wetland. Instead, the NWCA allows us to assess the percent of wetland area within particular condition classes (e.g., good, fair, poor) at the national scale and in four major ecoregions across the U.S. As additional surveys are implemented, we will be able to track changes in condition over time as well.

HOW DOES NARS REPORTING DIFFER FROM STATE WATER-QUALITY REPORTS REQUIRED BY THE CWA?

Under Section 305(b) of the CWA, states are expected to monitor, and are required to assess and report on the condition of their waters, including the extent of waters that support the goals of the Act. Under Section 303(d), states are to identify waters that are impaired, do not meet state water quality standards, and require additional pollution controls. States use a variety of monitoring and assessment approaches to meet these requirements of the CWA and to address state-specific information needs for managing state waters.

States usually collect information for many parameters at locations of importance to the state, such as swimming beaches, near dischargers, or at drinking water sources using methods developed for the state's specific purposes. However, state methods of collecting and assessing data can change over time and vary widely between states; so too do the state water quality standards used to determine impairment. This makes it difficult to aggregate this information for the nation as a whole, or over time. State monitoring programs are not designed to answer national-level questions such as whether or not U.S. water quality is improving.

One of the long-term goals of the NARS is to determine trends for the nation as a whole. To do this, the surveys use a set of standardized methods to monitor for a discrete set of stressors. Field crews collect the same data at each of the randomly selected, representative sites across the country; results are compared to conditions at least-disturbed sites in the ecoregions (and not to state water quality standards). Survey results are then aggregated into an overall assessment of water quality. It is the intent of EPA that these surveys complement state-specific CWA information and provide national and regional context to decision-makers.

To learn more about state CWA reporting, visit www.epa.gov/waters/ir/.

How was the national assessment developed?

EPA began planning for the NWCA in 2006. Throughout the planning process, EPA engaged with a broad group of stakeholders from state environmental and natural resource agencies, tribes, federal agencies, academia, and other organizations to help inform different aspects of the assessment. Planning the first-ever national survey of wetland condition entailed a number of steps, each with its own set of challenges to overcome, including, but not limited to, creating a survey design, selecting efficient, scientifically valid indicators, developing new field protocols, and piloting protocols. The development and selection of the NWCA field methods were also influenced by logistic considerations, such as the need to complete sampling for each site in one day.

In addition to reporting on the condition of wetlands nationally, another objective of the NWCA is to provide support to states and tribes that are interested in pursuing research to develop assessment methodologies and undertake statistically valid surveys of wetlands at finer geographic scales (i.e., within state or tribal boundaries). To accomplish this, EPA encouraged and provided support for states to do more intensive sampling in conjunction with the NWCA at state or regional scales. These intensifications involved sampling additional sites, parameters, or both within a state or region. States worked closely with EPA to develop intensification survey designs. This resulted in projects throughout the country, with state-driven focuses such as:

- Designing state-scale assessments that inform state-level management and policy needs;
- Testing additional indicators or assessment procedures.

These intensifications serve to augment the national and ecoregion results of the NWCA 2011. Some of these projects, as well as their findings, are highlighted throughout this report.

Gulf of Mexico Coastal Wetlands Pilot Project: Setting the Stage for the NWCA

Janet Nestlerode, U.S. EPA Office of Research and Development, Gulf Ecology Division

Objectives: The EPA, in collaboration with the United States Geological Service (USGS), implemented a pilot project along the northern coast of the Gulf of Mexico (GOM) in order to evaluate the effectiveness of a three-tier survey framework for regional wetland assessment. The results of the pilot study provided insight into the usefulness of the chosen indicators in determining condition and provided several "lessons learned" that were beneficial to the development of the NWCA 2011.

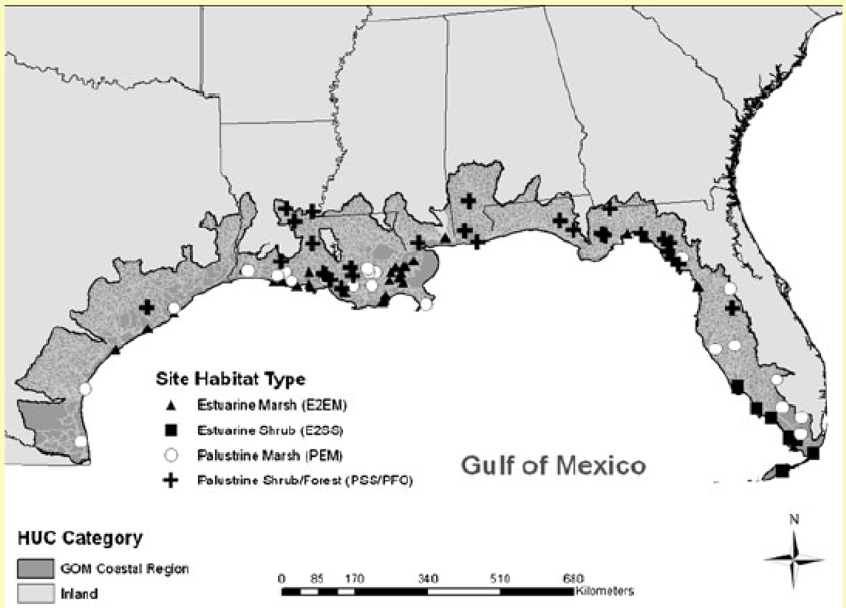


Figure 1. GOM coastal wetland survey sites shown with in the boundary of GOM coastal watersheds as defined by all USGS 8-digit hydrologic unit code (HUC) system segments that abut the coast and modified by NOAA's Estuarine Drainage Areas where needed.

Overview: One hundred wetland points along the GOM Coastal Region, which includes five states and 2,500 km of coastal lands, were selected for the pilot study and included five wetland classes (Figure 1). Five hundred oversample sites were also generated to replace original points that had to be dropped due to inaccessibility, or for other reasons. A 3-tier assessment framework was implemented during the 2007 and 2008 field seasons. Landscape-level (tier 1) assessments were conducted off-site and (tier 2 and 3) sampling was undertaken by crew members for each site, typically within one field day. Crews utilized a tier 2 rapid assessment, called the Gulf Rapid Assessment Method (GRAM), based on the California Rapid Assessment Method (CRAM). Tier 3 (intensive site assessments) included the collection of physical, chemical, and biological data at each site. This included soil and water chemistry, vegetation and macrophyte samples, as well as other measures. Between the first and second field seasons for the pilot, minor modifications were made to the field protocols.

Planning, logistics, and field conditions presented several challenges for the team before and during the field season. These ranged from identifying landowners, obtaining permission to sample a site, and determining how best to reach remote sites. Identifying landowners and gaining access to sites often proved difficult, as the team had to take into consideration both land ownership at the sample site and ownership of lands that had to be crossed to access the site. Landowner records and access to those records differed by localities, and it was a learning curve to find contact information and coordinate access permissions.

During GOM pilot implementation, crews sampled sites that were often remote and/or difficult to access. In South Florida, for example, getting to some sites required hiking for miles through waist-deep waters and mucky soils, transportation by boat, 4-wheel drive sport utility vehicles, or swamp buggies with balloon tires, or some combination of these modes of transportation. The team coordinated with local experts to determine the best ways to access remote sites, but in some cases sites were inaccessible and had to be dropped altogether.

Through data collection and analysis, the pilot project identified gear and equipment needed by survey crews, as well as an appropriate division of responsibilities among crew members. Implementation of the pilot study also provided an opportunity to determine the time needed for various data collection protocols, and helped gauge what could realistically be accomplished by crews within a single field sampling day, once factoring in travel times. This information was used in the planning and protocol development for the NWCA.

Swamp buggy used to access a remote wetland site in Big Cypress National Preserve.

Overall, the GOM coastal wetlands pilot project highlighted the great cooperation and effort necessary to conduct a regional condition assessment, and it provided critical information and lessons learned that informed planning efforts and development of the NWCA 2011.

To learn more, contact Janet Nestlerode (Nestlerode.Janet@epa.gov; 850-934-2492), EPA Office of Research and Development, Gulf Ecology Division.

Chapter 2: Design of the National Wetland Condition Assessment

The NWCA is designed to answer basic questions about the condition of our nation's wetlands and the prevalence of key stressors at national and regional scales. As noted, it is intended to complement and build upon the achievements of the FWS S&T Program, which characterizes changes in wetland acreage across the conterminous U.S.

Which wetlands are included in the NWCA?

This report covers the conterminous U.S., which currently contain an estimated 110 million acres of wetlands (Dahl 2011). Neither Alaska nor Hawaii are included in the national results presented in this report. Wetlands in Hawaii were not sampled, but the State of Alaska conducted sampling on the North Slope of the Alaskan coastal plain, using protocols similar to those used in the NWCA. A summary of the results of the North Slope assessment are presented as a special highlight later in the report (see "Alaska's Arctic Wetlands Assessment").

The specific wetlands targeted for sampling in the NWCA include tidal and nontidal wetlands within the conterminous U.S. with rooted vegetation and, when present, shallow open water less than one meter deep, that are not currently being used in the production of crops[1]. EPA used the same digital map of wetland locations that FWS uses in their Wetlands S&T Program to select sites for sampling. The S&T Program defines and classifies habitats into wetland, deep water, and upland categories and groups wetlands into S&T categories based on hydrology, geomorphology, vegetation, and water chemistry (Dahl 2011, Dahl and Bergeson 2009, Cowardin *et al*. 1979). EPA uses a subset of the S&T wetland categories for the NWCA. Table 2-1 provides detailed descriptions of the seven S&T wetland categories that are included in the target wetland population for NWCA.

Two major S&T wetland categories, Marine Intertidal (near shore coastal waters) and Estuarine Intertidal Unconsolidated Shore (beaches, bars, and mudflats), are not included in the NWCA because they are outside of the NWCA target population. They typically occur in deeper water (> 1 meter), or are unlikely to contain rooted wetland vegetation. Unique wetland types with more limited extents across the conterminous U.S. may also not be included, or may be underrepresented, in the NWCA 2011 if they are not included in the S&T Program or due to inherent constraints associated with the number and locations of the sites randomly selected for sampling.

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[1] Wetlands that have been mechanically or physically altered for the production of crops, but where wetland plants would become reestablished if farming is discontinued, are identified in the FWS S&T Program as "farmed wetlands." NWCA included these wetlands in its target population only if they were not currently being used for the production of crops.

Table 2-1. FWS S&T Wetland Categories that comprise the NWCA Target Wetland Types. Descriptions adapted from Dahl (2006) and Dahl and Bergeson (2009). See NWCA 2011 Technical Report (USEPA 2016), Chapter 1 for more details.

S&T Categories included in NWCA (NWCA Aggregated Wetland Type)	Common Name	Technical Description
Estuarine Intertidal Emergent (Estuarine Herbaceous)	Salt marsh	Emergent wetlands in estuarine system characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.
Estuarine Intertidal Scrub Shrub/Forested (Estuarine Woody)	Mangroves Other estuarine shrub or forest wetlands	Shrub or forested wetlands in estuarine system dominated by woody vegetation less than 20 feet (6 meters) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. Forested wetlands are characterized by woody vegetation that is 6 meters or taller.
Palustrine Emergent (Inland Herbaceous)	Inland marshes Wet meadows	Emergent wetlands in the palustrine* system and characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.
Palustrine Scrub Shrub (Inland Woody)	Shrub wetlands	Shrub wetlands in the palustrine* system and dominated by woody vegetation less than 20 feet (6 meters) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions.
Palustrine Forested (Inland Woody)	Forested swamps	Forested wetlands in the palustrine* system and characterized by woody vegetation that is 6 meters tall or taller.
Palustrine Farmed (Inland Herbaceous)	Farmed wetland	Farmed wetlands in the palustrine* system and having the soil surface mechanically or physically altered for production of crops, but where hydrophytes will become reestablished if farming is discontinued.
Palustrine Unconsolidated Bottom/Aquatic Bed (Inland Herbaceous)	Ponds Bog lakes Vernal pools Kettle ponds Beaver ponds Alligator holes Farm ponds Recreation ponds Golf course ponds Residential lakes Water retention ponds Aquatic beds Pondweeds	Aquatic beds in the palustrine* system dominated by plants that grow principally on or below the surface of the water for most of the growing season in most years. Examples include pondweeds (*Potamogeton spp.*), wild celery (*Vallisneria americana*), waterweed (*Elodea spp.*), and duckweed (*Lemna spp.*). Unconsolidated bottom wetlands in the palustrine* system and with at least 25% cover of particles smaller than stones, and a vegetative cover less than 30%. Examples of unconsolidated substrates are: sand, mud, organic material, and cobble gravel. Aquatic bed and unconsolidated bottom wetlands must also have the following four characteristics: (1) area less than 20 acres (8 ha); (2) an active wave formed or bedrock shoreline features are lacking; (3) water depth in the deepest part of a basin less than 6.6 feet (2 meters) at low water; and (4) salinity due to ocean derived salts less than 0.5 parts per thousand.

* Due to differences in classifying and mapping wetlands under the Cowardin system, these S&T categories may include wetlands in shallow riverine and lacustrine systems.

How are the NWCA results presented?

The NWCA reports on wetlands at two scales. The broadest scale is nationwide. Results are also reported for ecoregions that correspond to major climate and landform patterns, because the patterns of response to stress, and the stressors themselves, are often better understood in this context.

Ecoregions developed and described by Omernik (1987, USEPA 2011a) are used in this report, as well as in other NARS studies. Omernik Level III ecoregions across the conterminous US were combined into nine Aggregated Ecoregions to analyze data and report results in previous NARS studies of wadeable streams (2004), lakes (2007), and rivers and streams (2008-2009) (see left map in Figure 2-1). Ideally, NWCA would have used this same set of nine ecoregions to analyze and report results. However, attempting to evaluate each of the seven NWCA Target Wetland Types within each of the nine Aggregated Ecoregions would have required sampling nearly three times as many sites to achieve statistically valid results, which was beyond the logistical capacity of the NWCA. To allow assessment of condition for distinct wetland types across ecoregions with an acceptable degree of statistical certainty (i.e., a sufficient number of sampled sites by wetland type), NWCA further combined the nine Aggregated Ecoregions into four NWCA Aggregated Ecoregions (see right map in Figure 2-1):

- Coastal Plains
- Eastern Mountains and Upper Midwest
- Interior Plains
- West

Figure 2-1. Nine Aggregated Ecoregions used in other NARS (map on left) further combined into the four NWCA Aggregated Ecoregions (map on right).

The seven S&T wetland categories included in the NWCA Target Wetland Types (see Table 2-1) sampled also had to be combined to allow a sufficient number of sites in each reporting group. This was done by maintaining the distinction between estuarine and inland wetland types, and within these two groups distinguishing wetlands by herbaceous-dominated or woody-dominated vegetation, resulting in four NWCA Aggregated Wetland Types:

- **Estuarine Herbaceous** – emergent wetlands
- **Estuarine Woody** – scrub-shrub and forested wetlands
- **Inland Herbaceous** – emergent, unconsolidated bottom/aquatic bed, and farmed wetlands not in crop production
- **Inland Woody** – forested and scrub-shrub wetlands

Chapter 3 presents the results at the national level and in comparison to the four NWCA Aggregated Ecoregions. Chapter 4 presents the condition and stressor results for each NWCA Aggregated Ecoregion and, within each ecoregion, for inland herbaceous and inland woody wetland types. Results for estuarine herbaceous and woody wetlands are presented nationally. While aggregating wetland types allows for the reporting of statistically valid national and ecoregional results, differences among unique wetland types across the conterminous U.S. may be obscured by combining the various wetland types into the four wetland types used for this NWCA 2011 report.

How were the sampling sites chosen and what do they represent?

NWCA sampling locations were randomly selected using a survey design commonly applied in a variety of research fields (e.g., ecological assessments, health surveys, election polls, monthly labor estimates) to determine the status of populations using a representative sample of relatively few members of the group. This approach is especially cost-effective if the population is so numerous that all members cannot be sampled, or if it is not necessary to sample the entire population to reach a desired level of statistical precision.

To identify a group of wetland sites to be sampled in the NWCA, also known as the target population (i.e., potential sample points), it was necessary to know the location of the NWCA Target Wetland Types. The NWCA design team used the same digital map of wetland locations as the FWS S&T Program in their 2005 survey to select wetland sample points and to facilitate comparisons of the findings from both programs. The S&T Program updates wetland mapping for a fixed set of statistically selected locations across the conterminous U.S. every five to ten years. While not a comprehensive map of all wetlands throughout the U.S., these mapped locations are used to statistically represent the extent of wetlands nationally and, at the time of the survey, was the most consistent and up-to-date source of digitally mapped wetlands available on a national scale for the NWCA 2011. Sample points for the NWCA were distributed based on the prevalence of wetlands across the U.S. and the seven NWCA Target Wetland Types (see Table 2-1). For example, more sample points were located in regions with greater wetland area.

The 967 sites sampled based on the NWCA design were identified using a technique called Generalized Random Tessellation Stratified (GRTS) survey design (see NWCA 2011 Technical Report, Chapter 1 (USEPA 2016)). In such a design, every element in the population has a known probability of being selected for sampling. This important feature ensures that the results of the survey reflect the full range of wetlands in the target population across the U.S. Site selection rules were implemented to provide balance in the number of wetlands from each class. Site selection was also controlled for spatial distribution to ensure each state received a minimum number of sites, which also improved the national spatial balance of the sites (see Figure 2-2). The statistical design accounts for the distribution of wetlands across the country – some areas have far fewer wetlands than others- so that, even in areas of the country where there are few sample sites (e.g. southern Appalachian Mountains), regional and national results still apply to the broader target population.

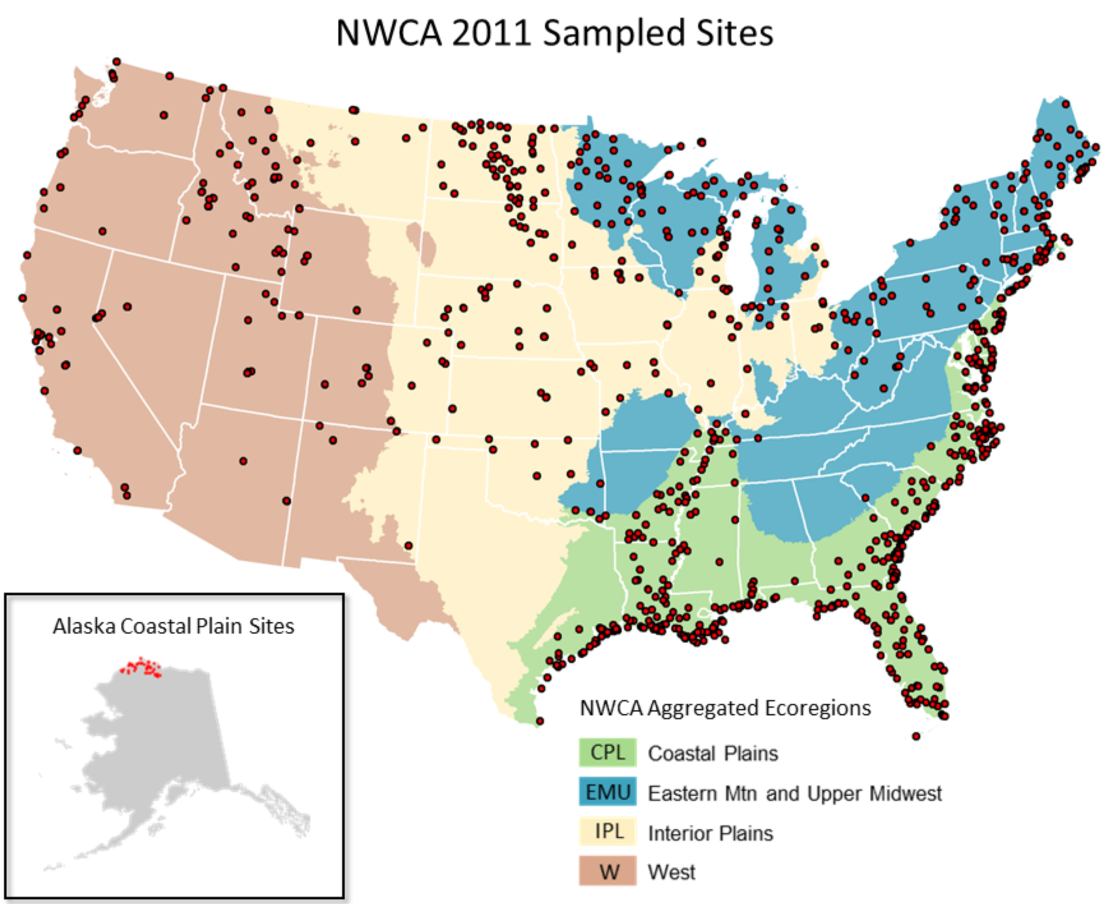
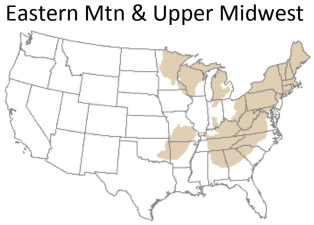
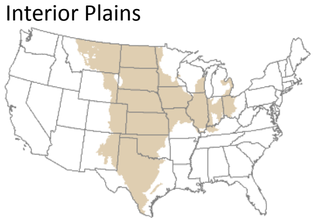


Figure 2-2. NWCA Sample Sites. The inset shows the sample sites for the study in the North Slope of Alaska described in a highlight later in this report.

Research teams from EPA and the states screened the points identified for sampling by the survey design using aerial photo interpretations and Geographic Information System (GIS) analyses to eliminate locations not suitable for NWCA sampling (e.g., wetlands converted to dry land or upland due to development). Next, field reconnaissance was conducted to determine if the sites met established criteria for inclusion in the survey. If a site was eliminated by the screening process or determined in the field to be a non-target wetland type or inaccessible (e.g., the landowner denied access to the site, the site was unsafe to access, the site was too remote to access under the logistical constraints of the survey), it was removed from the sampling effort and systematically replaced with another site from a pool of replacement sites within the random design.

The treatment of sites eliminated from sampling, as either non-target or inaccessible, affects how the final population results for the NWCA are estimated and reported. Taking into account the sites identified, during screening and field reconnaissance, as non-target (e.g., wetlands in active crop production, deeper water ponds, mudflats, uplands), the NWCA estimated there are 95 million acres of wetlands in the NWCA target population. The area represented by sites that are part of the target population, but not sampled because of accessibility issues, is not included for reporting on assessment of condition and stress. As a result, the final acreage represented by the probability sites sampled and reported on in the NWCA is 62 million acres. In addition, not all wetland types included in the FWS S&T studies (estimated wetland area 110 million acres) are included as wetland types in the NWCA target population. Table 2-2 provides the distribution of sampled probability sites and the acres and percent of wetland area they represent within the NWCA ecoregions and aggregated wetland types.

Table 2-2. Number of probability sites sampled nationally and within each of the NWCA Aggregated Ecoregions and acres of wetland area these sites represent. Number of sites sampled and the acres represented is also shown for the aggregated wetland types used in NWCA.

Region	Sampled Sites in Population	Acres Represented by Sampled Sites, (% of Population)	NWCA Wetland Type	Sampled Sites in Population	Acres Represented by Sampled Sites, (% of Population)
National 	967	62,156,199 (100%)	Estuarine Herbaceous	258	4,987,824 (8%)
			Estuarine Woody	69	497,821 (1%)
			Inland Herbaceous	302	13,599,611 (22%)
			Inland Woody	338	43,070,943 (69%)
Coastal Plain 	513	30,893,305 (50%)	Estuarine Wetlands	288	5,283,489 (9%)
			Inland Herbaceous	62	3,750,551 (6%)
			Inland Woody	163	21,859,265 (35%)
Eastern Mtn & Upper Midwest 	152	19,956,668 (32%)	Estuarine Wetlands	14	29,173 (0.04%)
			Inland Herbaceous	55	3,762,089 (6%)
			Inland Woody	83	16,165,406 (26%)
Interior Plains 	156	7,659,166 (12%)	Estuarine Wetlands	0	0
			Inland Herbaceous	115	4,598,831 (7%)
			Inland Woody	41	3,060,335 (5%)
West 	146	3,647,060 (6%)	Estuarine Wetlands	25	172,985 (0.3%)
			Inland Herbaceous	70	1,488,139 (2%)
			Inland Woody	51	1,985,936 (3%)

How were wetlands sampled?

NWCA field work was conducted during the spring and summer of 2011 by more than 50 crews composed of four or more trained personnel from state and tribal environmental agencies, EPA, universities, and contract staff. Wetland sites were sampled using standardized field protocols (see NWCA Field Operations Manual, USEPA 2011a; NWCA Laboratory Operations Manual, USEPA 2011b; and the NWCA Quality Assurance Project Plan, USEPA 2011c) to collect data relevant to describing the ecological condition of wetlands and quantifying indicators of stress to condition. Protocols were designed to allow sampling at each site to typically be completed in one day.

During each site visit, field crews collected ecological data in a standard 0.5-hectare assessment area, representing the sample point from the survey design, and in the immediately adjacent 100 meters extending from the assessment area edge, designated as the buffer (Figure 2-3). The crews collected data on vegetation, soils, hydrology, algae, and water chemistry from the assessment area. In the buffer crews collected data on habitat and the presence of stressors that could impact the assessment area. Some sites were not conducive to use of the standard layout shown in Figure 2-3 because of the size and shape of the wetland (e.g., long and narrow) or because parts of the assessment area contained deep water, non-target wetland types, or upland. In such cases, the NWCA protocols provided specifications for alternate assessment area layouts.

The use of standardized field and laboratory protocols is a key feature of the NWCA and all NARS studies, and allows the data to be combined to produce a nationally consistent assessment. As part of the quality assurance procedures, each field crew was trained and evaluated on applying the NWCA protocols by wetland experts. Field checks were conducted at the beginning of the sampling season to ensure that the protocols were being correctly implemented by the crews, thereby minimizing human error in data collection. In addition, roughly 10% of the sites were resampled two to four weeks after the initial visit to a site to evaluate sampling variability.

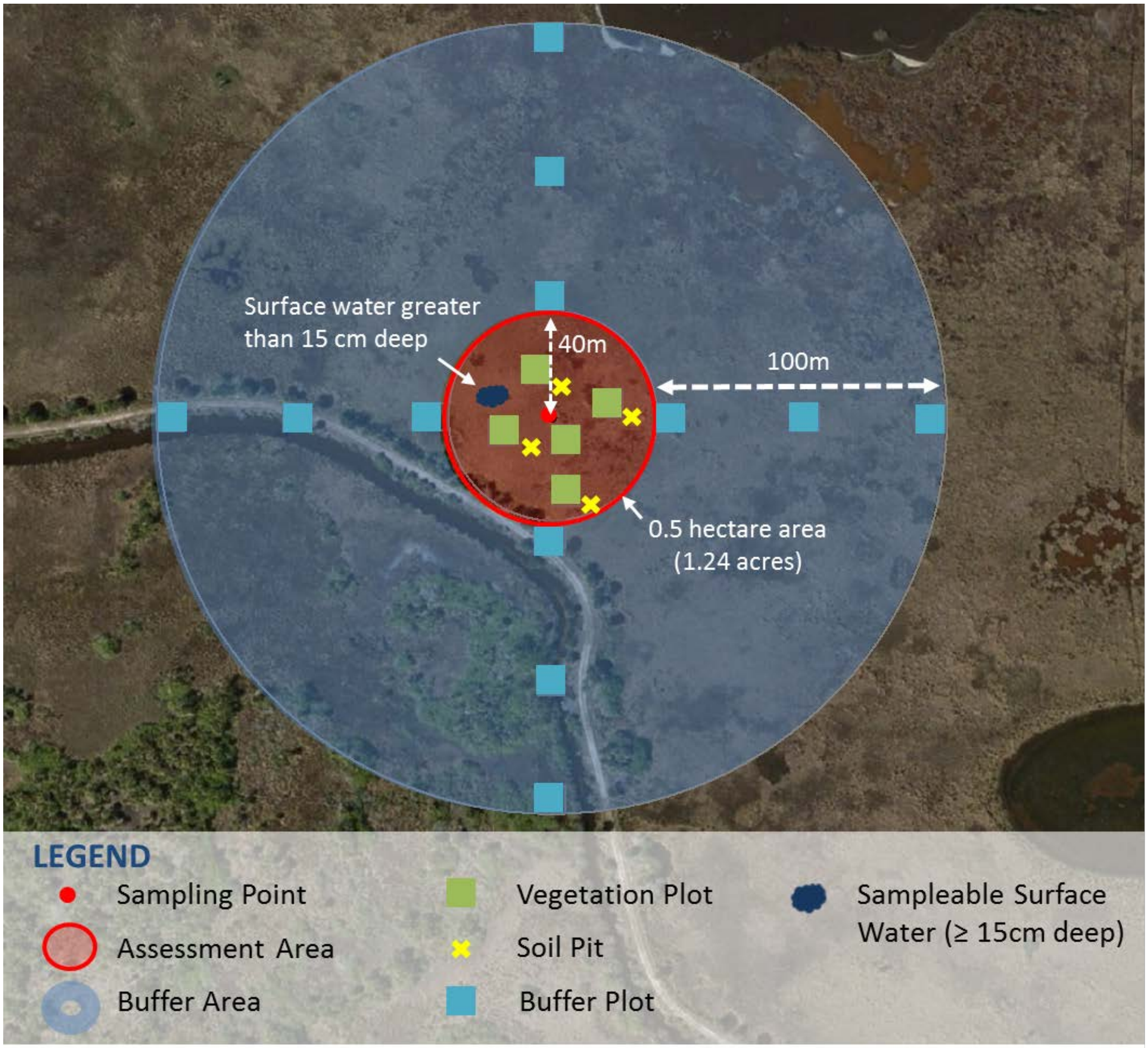


Figure 2-3. Standard NWCA assessment area and buffer sampling layout

California's Intensification Project: Learning More about California's Wetlands and Refining Monitoring Techniques

Cara Clark, Moss Landing Marine Laboratories

Estuarine Wetland Site sampled in China Camp State Park, San Rafael, CA.

California has a great diversity of wetlands. Different wetland types provide different services and support diverse wildlife, such as water birds, birds of prey, otters, bears, deer, and a wealth of fish species. California has lost more than 90% of its historical wetlands and today, many remaining wetlands are threatened. Wetlands continue to be drained for agriculture, filled for development, or disturbed by modifications to the watershed such as dams or water diversions. Climate change poses a significant threat, as many wetlands today are dependent on artificial water delivery systems or high groundwater levels, and may be impacted by changing climatic conditions. Further, wetlands along the coast face flooding from potential sea level rise.

Project Objectives: California's intensification project augmented the NWCA 2011 survey to support two primary goals. First, California increased the number of sites sampled to produce a statistically valid state-level assessment of California wetland quality. Second, the data collected for NWCA were used to further validate the California Rapid Assessment Method (CRAM) - an important tool in California's toolbox for assessing wetland health - and examine additional associations between CRAM and potential stressors to wetland quality.

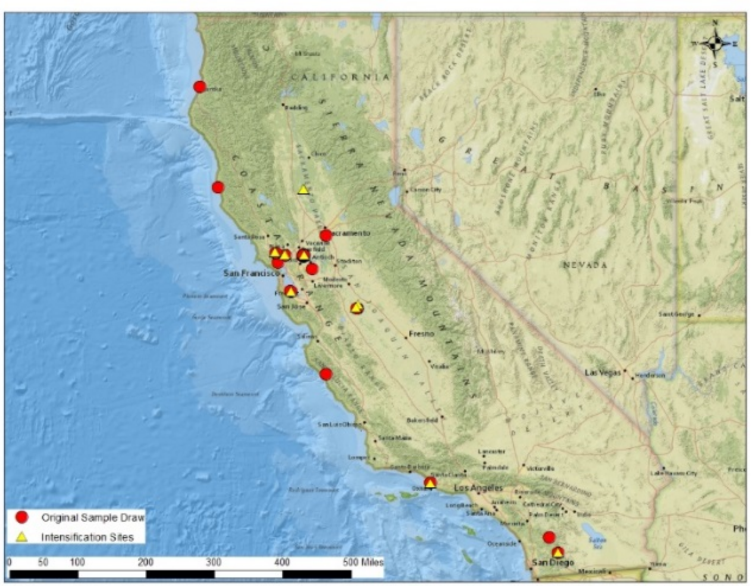


Figure 1. Sampled NWCA sites in California.

Sampling and Protocols: The NWCA 2011 survey included 23 sites in California and California added 22 additional sites bringing the total to 45. The additional California intensification project sites were selected from the same framework as the NWCA, so that the two sets of sites could be combined for analysis and reporting. NWCA data and protocols were used at all 45 sites and the state also conducted the CRAM (Figure 1).

The CRAM is a standardized tool for wetland monitoring in California, developed with support from EPA. It is based on the concept that the structure of a wetland is indicative of its capacity to provide important functions. Four general attributes, Buffer and Landscape Context, Hydrology, Physical Structure, and Biotic Structure, are assessed visually in the field. The scores for each attribute are compiled into an overall score, with higher scores relating to better condition. This project served as a valuable opportunity to further validate CRAM by comparing CRAM scores to the more intensive parameters in the NWCA including water nutrient concentrations.

What They Have Learned: Although assessment of the information from the California intensification is still ongoing, staff have begun looking at the site-specific information from the CRAM, including a comparison of estuarine and depressional wetlands. California's estuarine wetlands are often large, connected salt marsh systems, in contrast to depressional wetlands which are usually smaller or more fragmented. As a result, estuarine wetlands have fewer direct landscape stressors putting pressure on them, and so tend to be in better condition. This is borne out by CRAM results from 2011.

The sites sampled in 2011 indicate that estuarine wetlands tended to have higher CRAM scores (indicating better condition) than depressional wetlands. The median (50^{th} percentile) CRAM score of depressional wetlands was 62, whereas the median score for estuarine wetlands was 79 (Figure 2). Additionally, depressional wetlands tended to have lower scores than estuarine wetlands for all of the attributes included in CRAM, indicating they are subject to more stressors.

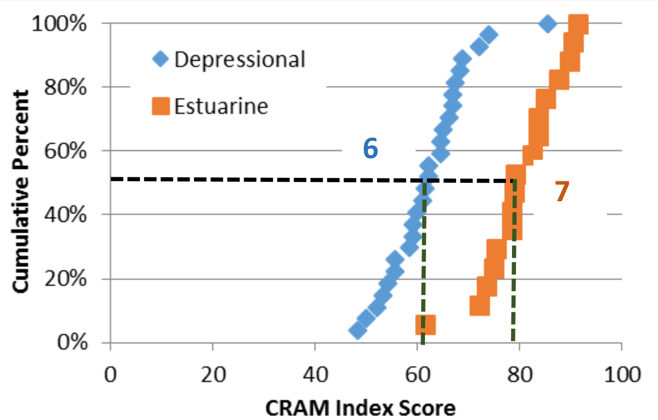


Figure 2. Cumulative Frequency of CRAM scores for depressional and estuarine wetlands, based upon unweighted data.

Other stressors: Excess nutrients in wetlands often have anthropogenic sources, as nutrients drain to wetlands from high intensity land uses, such as agriculture or urban development. Excess nutrients entering the wetland can have direct impacts, causing eutrophication and excess growth of algae, which leads to hypoxia. When algae die and decompose, oxygen is depleted from the water, and the lack of oxygen can kill fish and other organisms. Researchers found weak, but statistically significant, correlations between water nutrient concentrations and CRAM scores in California's wetlands. Wetlands with higher nitrate and nitrite concentrations in surface water samples tended to have lower CRAM scores. The correlation observed between CRAM scores and nitrate/nitrite concentrations validates that the CRAM score reflects environment factors that can cause wetland degradation. Higher total phosphorous in surface water was also associated with wetlands having lower Buffer and Landscape Context scores (one of the CRAM components). Like nitrogen, excess phosphorous in wetlands is often due to intensive anthropogenic activities in the surrounding area, which is suggested by the lower Buffer and Landscape Context scores.

What's Next: The California intensification project provided valuable information for state-level wetland condition, as well as validation for the CRAM tool that is utilized throughout the state. In addition to continued analysis of this dataset, implementation of the NWCA encouraged the state to develop its own wetland status and trends program with the goal of augmenting the FWS Status and Trends wetland area mapping information with consistent and complete state-level wetland maps. While the sites selected for the NWCA survey were spread across the state, there were clusters of sites in the San Francisco Bay area and the Central Valley. At the time of NWCA 2011 site selection, California did not have comprehensive or consistently-scaled wetland maps or a state level wetland mapping program. While this program is still under development, it is hoped that wetland monitoring and assessment goals will be better met with improved wetland maps for the state providing a more robust characterization of the entire population of wetlands in California.

To learn more, contact Cara Clark (cclark@mlml.calstate.edu; 831-771-4428), Central Coast Wetlands Group at Moss Landing Marine Laboratories.

What data were collected and why?

The NWCA collected data to characterize biological, chemical, and physical features of each site. Vegetation, soil, hydrology, water chemistry, algae, and buffer characteristics were chosen for evaluation based on their utility in reflecting ecological condition of wetlands or key indicators of stress that may influence condition across broad national and regional scales (see NWCA 2011 Technical Report (USEPA 2016)). Data for each of these indicator groups were obtained from field observations and laboratory analyses of samples collected in the field. Vegetation characteristics were used in the development of a biological indicator of condition. Data collected on vegetation, soils, hydrology, buffer characteristics, and algae were used to develop core indicators of stress for the NWCA.

Brief descriptions of key NWCA data that were collected and why each data type is important to the determination of wetland condition or stress class are provided in the remaining paragraphs of this section. Additional data, not discussed here, were collected in the NWCA 2011 primarily for research purposes. For information on these other data, see the NWCA 2011 Field Operations Manual (USEPA 2011a) and the NWCA 2011 Technical Report (USEPA 2016).

Vegetation: The status of natural vegetation has been increasingly and effectively used to evaluate ecological integrity in wetlands. In wetland ecosystems, vegetation provides biodiversity, primary productivity, habitat for other organisms, and responds to and influences hydrology, water chemistry, and physical and chemical properties of soils. Because plants respond directly to physical, chemical, and biological factors at multiple temporal and spatial scales, they can be excellent indicators of ecological condition or stress. For example, wetland plant species represent diverse adaptations, ecological tolerances, and life history strategies, and 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 or in the types of plants occurring at a particular location. Data describing plant species identity, presence, and abundance were collected in the field for the NWCA 2011. Information on plant species traits was compiled from a variety of sources including the PLANTS database (USDA-NRCS 2013), National Wetland Plant List (USACE 2014), regional and state floristic databases and floras, state and regional lists of coefficients of conservatism (describing species sensitivity to disturbance) and other published literature (see NWCA 2011 Technical Report (USEPA 2016) for details). Field and trait data describing vegetation characteristics are powerful and robust, and can be summarized into myriad candidate metrics or indices of ecological condition. Some plant species or plant groups also can be indicators of stress to wetlands. Nonnative plant species, in particular, are recognized as indicators of stress or declining ecological condition, or as direct stressors to condition.

Soils: Wetland soils cycle nutrients, store pollutants, mediate groundwater, are a growth medium for plants, and provide habitat for microbes and macroinvertebrates (e.g., insects, worms, crayfish, crabs). Wetland soils develop distinct characteristics as a result of the hydrology and biota (e.g., microbes, vegetation) associated with wetlands, as well as other factors that affect soil development across all environments (e.g., climate, geology). These characteristics can be altered by chemical, physical, and biological stressors, which impacts the ability of the soil to perform functions necessary to healthy wetlands. Field crews described soil morphology (characteristics such as color, texture, and evidence of saturation) and collected soil samples to be analyzed for chemical and physical properties to identify disturbance and indicators of stress. The Natural Resources Conservation Service (NRCS), the federal agency that provides technical assistance in the management and protection of natural resources including soils, worked in partnership with the EPA to provide laboratory analysis for soil samples collected.

Hydrology: Wetland hydrology is a primary driver of wetland formation and persistence. Hydrology describes the movement, distribution, and physical and chemical characteristics of surface and subsurface water. How water moves in or out of a wetland, how long water remains in a wetland, and how much water is in a wetland impacts many wetland characteristics, including the plant community composition and productivity, nutrient cycling, and the loss and retention of sediment. Water levels and patterns of water movement within a wetland can be very dynamic, changing over a period of hours, days, months, and/or years, making it difficult to assess hydrology with a single site visit (such as in the NWCA). Field crews collected information about the hydrology of each site by observing the presence or absence of specific water sources and evidence of alterations to water flow and retention (e.g., drainage ditches, damming features, evidence of sedimentation or erosion, impervious surfaces).

Water Chemistry: Characterizing water chemistry is an integral part of the assessment of aquatic resources, because the physical and chemical properties of water directly reflect the surrounding environment, including anthropogenic influences. However, wetlands differ from lakes, streams, and coastal waters in that standing water is not necessarily present (Mitsch and Gosselink 2007). At sites with standing water greater than 15 centimeters deep, water samples were collected and analyzed for a number of water quality parameters. Field crews also made qualitative assessments of water clarity. Data were analyzed to investigate relationships between water measurements and natural conditions and anthropogenic stressors.

Algae: Algae respond quickly to ecological change in wetlands and have been widely used as indicators of recent changes in wetland condition because of their rapid reproduction rates, short life cycles, broad distribution, and sensitivity to changes in nutrient levels (McCormick and Cairns Jr. 1994). In addition, diatom species can provide insights into past hydrology such as recent flooding, standing water, or droughts (McCormick and Cairns Jr. 1994, USEPA 2002, Lane and Brown 2007). Algae samples from the water column, sediment, and vegetation were collected from sites with standing water and those without standing water that had evidence of recent inundation. Samples were analyzed to characterize the algal communities present at sites and to investigate relationships between certain communities and ecological condition of wetlands.

Blue-Green Algae: Toxins produced by some blue-green algae species can pose potential human health risks or limit human recreational use of aquatic resources when they occur above specific concentrations. Microcystin is the algal toxin believed to be most common in lakes, and it was evaluated in the NWCA to determine how frequently and at what concentrations, it might occur in wetlands. At sites with standing water present, a composite sample from the water column, sediment, and vegetation was collected and analyzed to detect the presence and concentration of microcystin.

Buffer: The presence and condition of the habitat in the area surrounding a site can influence the ecological condition of the site. For example, natural vegetation cover in the buffer can protect the wetland by trapping and absorbing incoming sediments, nutrients, and pollutants before they reach the wetland. The buffer can also reduce wetland disturbance from activities in adjacent areas and mitigate stressors that may affect wetland condition. In contrast, human-mediated disturbances to the buffer can be indicators of stress to wetland condition, or may directly cause stress. An example of this would be surface hardening (e.g., pavement, soil compaction) in the buffer which could alter the hydrology of a wetland by limiting the natural ability of soils in the buffer (and potentially the wetland) to soak up stormwater, thus increasing the potential for flooding or erosion to the wetland. Field crews collected observational data on the presence or absence of a variety of disturbance types within the assessment area and the wetland or upland area extending 100 meters around the assessment area (termed the buffer area).

Each of these categories of data collected by NWCA were evaluated to determine their utility in describing the ecological condition of wetlands or defining indicators of stress to condition at broad national and regional scales. The specific properties measured and how they were used to evaluate wetland stress and condition are discussed in the next section.

How were the NWCA core data used to report on ecological condition and stress?

The raw data from the field and laboratories were combined into a number of metrics and indices to evaluate NWCA 2011 data for this report. A metric is an individual measure of a particular property for an individual site, while an index is a combination of metrics used to generate a single score for a particular site. Indicators of condition or stress can be based on single metrics or on indices. An index of biological condition based on vegetation was created using plant species data collected at each site and information on plant traits. Indicators of stress were also developed using biological, chemical, or physical data collected for the NWCA.

Figure 2-4 illustrates the relationships of the core NWCA data types to the 1) development of indicators of condition and stress for wetlands, 2) calculation of extent estimates for wetland condition and for indicators of stress, and 3) calculation of relative and attributable risk associated with each of the indicators of stress. Core data types are indicated by gray boxes in the figure. The gray arrows represent analyses leading from these core data types to the development of final indicators of stress or condition used in NWCA 2011, and also show the sources of data for the NWCA indicators of condition and stress. Further documentation describing the technical aspects of the analysis process used in NWCA is available in the NWCA 2011 Technical Report (USEPA 2016).

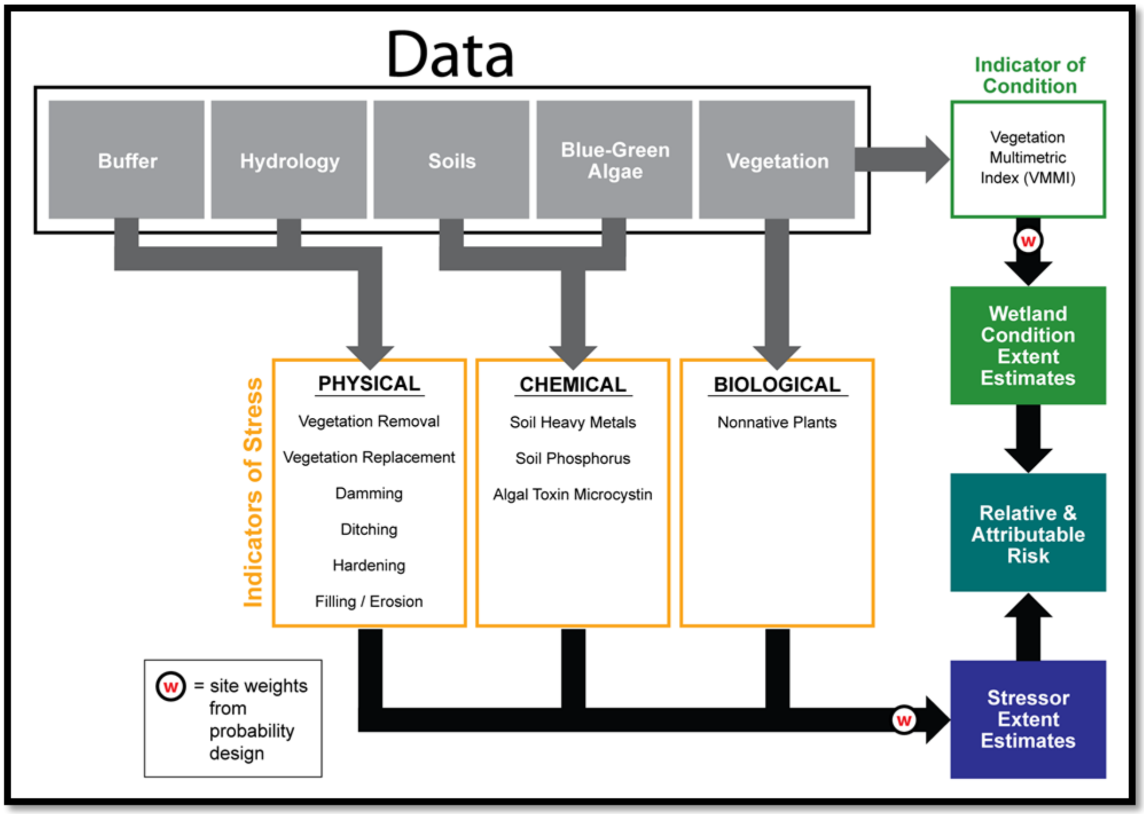


Figure 2-4. Core data types and relationships to how they are used to develop indicators of condition and stress. Core data types (gray boxes) and relationships to how they are used to develop indicators of condition (open green box) and stress (open yellow boxes), and how the indicators are used to determine wetland condition (green box) and stressor extent (purple box) estimates and relative and attributable risk (teal box).

After appropriate indicators of condition and stress were determined from the data and calculated, each probability site was assigned to a condition or stressor class, based on the value of the indicator for that site. For the indicator of biological condition, each site was assigned to a good, fair, or poor condition class. For the metrics or indices describing the indicators of stress, each site was assigned to a low, moderate, or high stressor level. The thresholds values used to assign sites to the different condition classes and stressor levels were defined using either a fixed or distribution based approach.

Fixed thresholds are based on accepted values from peer-reviewed, scientific literature and are well-established and/or widely and consistently used by government agencies. An example of the latter is the World Health Organization (WHO) risk levels for recreational exposure to the algal toxin, microcystin. Fixed thresholds are also sometimes based on the best professional judgment of scientific analysts by incorporating field and research experience with other knowledge from the collective scientific community.

Distribution based thresholds are determined using the distribution of values of a particular index or metric found at a designated set of reference sites. NWCA defines reference as “least-disturbed condition” and used field data collected from probability sites and additional handpicked sites believed to be in reference condition to identify a set of reference sites with the least amount of human disturbance. Data from this set of reference sites is then used to determine the distribution of values for each indicator of condition or stress. The threshold values for good, fair, and poor condition, or low, moderate, and high stressor level are set based on defined percentiles from the distribution of values observed in the least disturbed sites (see text box below on “Use of Reference Site Approach” and NWCA 2011 Technical Report (USEPA 2016)).

The good, fair, and poor condition classes and the low, moderate, and high stressor levels reported by NWCA have no regulatory implications and are not replacements for the evaluation of the quality of wetlands with respect to water quality standards set by states and tribes.

USE OF REFERENCE SITE APPROACH

To interpret the data collected by the NWCA field crews and to assess current ecological condition, scientists need to compare the collected data to benchmarks — an estimate of what scientists would expect to find in wetlands with the best natural condition. Because it is difficult to estimate historical conditions for many indicators, the NWCA's benchmark, or reference, is characterized as the "least-disturbed condition": the best available physical, chemical, and biological conditions given today's state of the landscape. Least disturbed condition is defined based on data from sites selected according to a set of explicit screening criteria. These criteria vary from region to region and among wetland types to account for differences in natural variability and anthropogenic disturbance across the American landscape*. For the NWCA, separate screening criteria were defined based on combinations of the NWCA Aggregated Ecoregions and Aggregated Wetland Types. The screening criteria were developed with the goal of identifying reference sites with the least amount of human disturbance for each reporting group (e.g., estuarine herbaceous wetlands, Interior Plains inland woody wetlands). Reference criteria, in essence, allow identification of the set of sites with the least-disturbed condition across the target population of wetlands.

The NWCA compares specific physical, chemical, and biological stressor data collected at each site to the reference site screening criteria to determine whether any given site meets the definition of least disturbed condition for its combined Aggregate Ecoregion/Wetland Type. The group of sites passing all the screening criteria are considered to be in reference condition. Good ecological condition and low stressor levels are characteristic of reference sites. These reference sites are then used to set thresholds against which the broader population of wetlands can be compared and assigned to condition or stressor classes. The range of conditions found in the group of reference sites for an ecoregion describes a distribution of values expected for least-disturbed condition or stress. The thresholds used to define distinct condition classes (e.g., good, fair, poor) or stressor levels (e.g., low, moderate, high) are drawn from this reference condition distribution. The 5th percentile of the reference distribution was used to separate the sites in poor biological condition from those in fair. Similarly, the 25th percentile of the reference distribution was used to distinguish between sites in fair biological condition from those assessed in good condition. For stressor classes, the 95th percentile of the reference distribution was used to separate the sites considered to have high stress from soil phosphorus concentrations from those with moderate, and the 75th percentile was used to separate the moderate and low stressor classes.

This approach for establishing reference condition is well documented and consistent with current science, EPA guidelines, state practice, and established protocols for ecological assessment (Bailey *et al*. 2004; Barbour *et al*. 1999; Carter and Resh, 2013; Hughes, 1995; Reynoldson *et al*. 1997; Stoddard *et al*. 2006; and USEPA, 2011d).

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*Within the reference site distribution, there are two sources of variability:

Natural variability includes a wide range of habitat types naturally found within each ecoregion. This range is captured in the reference sites representing those different habitats. For this reason, reference condition thresholds were set based on the distribution of least disturbed sites, rather than from a single site. Capturing natural variability in reference sites helps establish reference conditions that represent the range of natural environments in the ecoregions.

Human activities have altered habitats in the U.S., with natural landscapes transformed by cities, suburban and rural development, agricultural development, and resource extraction. The extent of those disturbances varies across regions. Some reference sites are in watersheds with little to no evidence of human impact, such as mountain streams or rivers in areas with very low population densities. Others have been highly influenced by human activities. The least-disturbed reference sites in regions with more human activity will usually have lower screening criteria than those in areas with little human disturbance.

Evaluating Wetland Biological Condition

Vegetation is a fundamental component of wetlands. The composition and abundance of plant species at a site reflect and influence other ecological processes related to hydrology, water chemistry, and soil properties. Vegetation integrates different wetland processes and plants respond to physical, chemical, and biological disturbances. These properties make vegetation a particularly good indicator of wetland condition. Using field data describing species composition and abundance in combination with species trait information, numerous candidate metrics were developed and evaluated as potential components of a **Vegetation Multimetric Index (VMMI).** A national-scale VMMI was then developed as the indicator of biological condition for the NWCA.

The VMMI is called a multimetric index because it combines more than one metric. After careful screening of many candidate metrics, four were chosen for inclusion in the VMMI:

- A Floristic Quality Assessment Index (FQAI),
- Relative Importance of Native Plant Species,
- Number of Plant Species Tolerant to Disturbance, and
- Relative Cover of Native Monocot Species.

Each metric in the VMMI is based on combinations of data types describing species composition (identity and/or abundance) and species traits. These metrics were chosen because they 1) best reflect ecological condition of wetlands across the conterminous U.S. for the different NWCA Aggregated Ecoregions and NWCA Aggregated Wetland Types, 2) detect differences between the least and most-disturbed sites, and 3) were not strongly related to one another (see NWCA 2011 Technical Report (USEPA 2016)). Each metric is scored from 0 to 10 for consistency in scaling the metric value ranges. VMMI values are scaled from 0 to 100.

The **FQAI** is often considered as a standalone index for describing floristic quality, but is used here as one metric contributing to the VMMI. It captures information about plant community composition based upon all unique plant species occurring at a given site and a value given to each plant species based on its sensitivity to human-mediated disturbance. This value is known as the Coefficient of Conservatism or C-value. C-values range from 0 to 10 where a value of 0 is assigned to plant species that occur in highly disturbed habitats and a score of 10 is assigned to species found only in minimally disturbed habitats. C-values may vary by state or region to account for natural differences in habitat and plant community composition. C-values were compiled from existing state and regional lists of values, or, for states and regions where lists did not exist, by assigning values based on those of ecologically similar neighboring states or regions.

The second metric in the VMMI is the **Relative Importance of Native Plant Species**. Relative importance combines information on how much of the sampling location is covered by native wetland plants in relation to all plants present (e.g., relative cover) and how many occurrences of native plant species there are across a site compared to the number of all plant species occurrences (i.e., relative frequency). Native status of a given species-site occurrence was based on whether the species was indigenous to the state in which the sample site was located. As disturbance at a site increases, the native plant community is often altered—a change that is often related to declining condition.

The **Number of Plant Species Tolerant to Disturbance** is the third metric in the VMMI. The number of tolerant species increases with increasing disturbance, indicating a potential shift in plant community dynamics. Such a shift could reflect competitive pressure or other stress to disturbance-intolerant species that are often indicative of good ecological condition. C-values are used to describe sensitivity or tolerance of plant species to disturbance. Tolerance can be indicated by the presence or abundance of plant species with low C-values. Species tolerant to disturbance are defined in NWCA as those with a C-value of 4 or less.

Finally, the fourth metric in the VMMI is the **Relative Cover of Native Monocot Species**. Monocots are one of two groups into which flowering plants are divided. They are common to many wetland types, and are represented by plants like grasses, sedges, rushes, lilies, irises, orchids, etc. Native monocots represent dominant natural components of many emergent (non-woody) wetland types. In other wetland types, they may reflect species that are indicative of relatively undisturbed conditions.

The final VMMI score is calculated based on the combination of values for all four metrics for each site, with the overall value indicating the level of biological condition. Good, fair, or poor condition thresholds were set using a distribution-based approach based on the VMMI values for reference sites (see "Use of Reference Sites" text box) in each combination of NWCA Aggregated Ecoregion by NWCA Aggregated Wetland Type. The 5th percentile of the reference distribution for each NWCA Aggregated Ecoregion and NWCA Aggregated Wetland Type combination was used to separate the sites in poor condition from those in fair condition. Similarly, the 25th percentile of the reference distribution was used to distinguish between sites in fair condition and those assessed as being in good condition (Figure 2-5). Specific threshold values for each NWCA Aggregated Ecoregion and NWCA Aggregated Wetland Type combination are provided in the NWCA 2011 Technical Report (USEPA 2016).

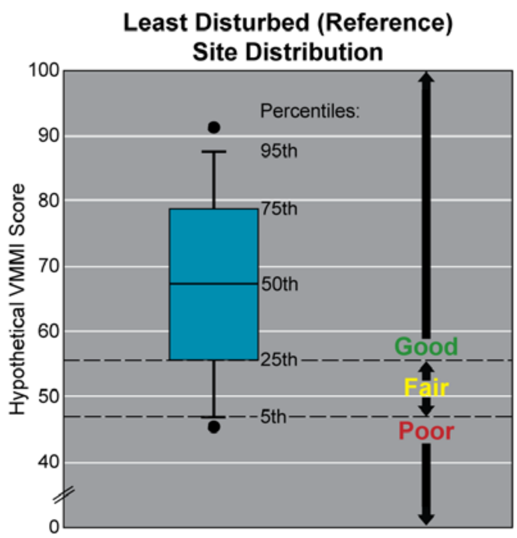


Figure 2-5. Criteria for setting VMMI thresholds for good, fair, and poor condition classes based on VMMI values observed for Least Disturbed (Reference) sites.

Wisconsin's Intensification Study: A Floristic Characterization of Wetlands in Eastern Wisconsin

Thomas Bernthal, Wisconsin Department of Natural Resources

Overview: Plant community composition can provide a detailed picture of wetland health, and the differences between a pristine and a degraded habitat may be partially characterized by looking at the presence and abundance of plant species. The main objective of the Wisconsin intensification study was to compare the Floristic Quality Index (FQI) currently used with an adjusted index to determine if it may be a better predictor of wetland ecosystem health.

Main Story: The Wisconsin Department of Natural Resources (DNR) chose to do a more intensive study of wetlands in the Lake Michigan basin of Eastern Wisconsin. As part of the NWCA 2011 survey, 34 unique sites were sampled in Wisconsin, 12 of which were in the Lake Michigan basin. An additional 38 sites were sampled in 2012 for the intensification project, for a total of 50 sites in the project area (Figure 1).

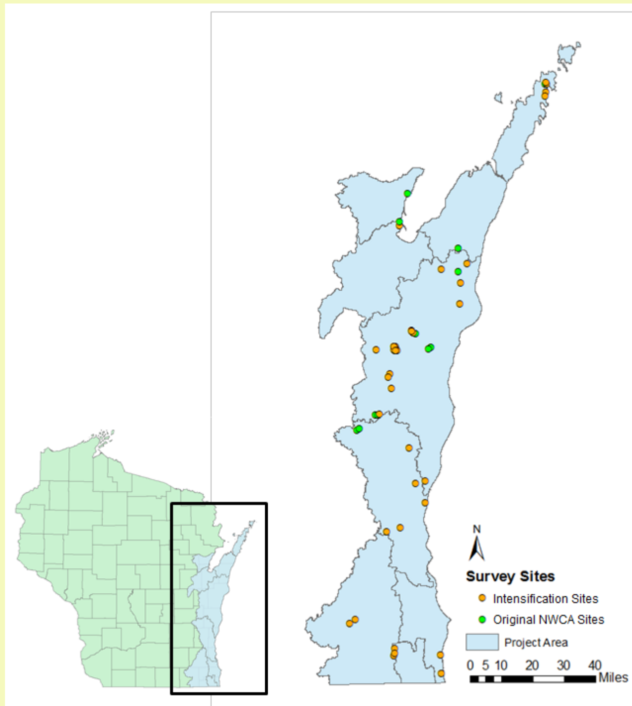


Figure 1. Intensification study project area in eastern Wisconsin.

Using vegetation data collected at each site, the Wisconsin DNR employed a Floristic Quality Assessment (FQA) framework to examine wetland health. The FQA uses species richness or the number of different species present (N) and the Coefficient of Conservatism (C) to calculate the Floristic Quality Index (FQI). The *C* is an assigned number between 0 and 10 for each plant species, which reflects the response to disturbance. A species that is considered tolerant of disturbance is assigned a lower C value. Conversely, a species that disappears from a community following a disturbance is given a higher C value. Invasive species are assigned a C value of 0.

A plant community with a high species count scores well on a FQI. In some habitats this high FQI score may not be indicative of healthy natural conditions, as excess nutrients like phosphorous and nitrogen can stimulate excessive plant growth and increase the number of plant species leading to an impaired community. Though these nutrients are basic building blocks of plants and are needed in a wetland plant community, in high concentrations these nutrients can degrade wetlands.

To counter the inflating effects of species richness on the FQI, the Wisconsin DNR employed a weighted mean Coefficient of Conservatism metric ($w\bar{C}$). This weighted metric accounts for species abundance, which may allow for a better picture of the composition of a plant community.

What They Found: The main objective of the study was to compare $\bar{C}$ and $w\bar{C}$ to determine which method would give a more accurate assessment of wetland ecological condition when incorporated into the FQI. Figure 2 shows comparison boxplots of the calculated $\bar{C}$ and $w\bar{C}$ for the wetland community types sampled in the intensification study, including Palustrine Emergent (PEM), Palustrine Forested (PFO) and Palustrine Shrub/Scrub (PSS). The PEM showed the greatest difference between $\bar{C}$ and $w\bar{C}$. Among the other community types (PFO and PSS), where sampled wetlands were not dominated by invasive graminoid (i.e., grass or grass-like plant) species as often, the differences between $\bar{C}$ and $w\bar{C}$ were less pronounced.

Wisconsin found that lower $w\bar{C}$ values were correlated with an increase in the relative cover of invasive graminoids, (R^2=0.754), including reed canary grass (*Phalaris arundinacea*), hybrid cattail (*Typha x glauca*), narrow-leaf cattail (*Typha angustifolia*), and common reed (*Phragmites australis*). They found that the $w\bar{C}$ metric was especially useful for capturing differences between sites with sparse invasive plant populations and sites overrun by invasive species. More PEM sites were dominated by invasive reed canary grass or hybrid cattail stands than in the other community types, which could explain the difference between $\bar{C}$ and $w\bar{C}$ for the PEM wetlands, as noted in Figure 2.

Although $w\bar{C}$ is a useful way to describe some wetland plant communities in Wisconsin, it may not be the best metric for all communities. The conventional methods of calculating the FQI using $\bar{C}$ may be better suited for communities that are characteristically more species-rich, such as cedar swamps. Communities that tend to be naturally species-poor, such as bogs or muskegs, may be better characterized by using the $w\bar{C}$. The conventional FQI used by Wisconsin currently and the adjusted index using $w\bar{C}$ were found to be valuable metrics to describe the vegetation condition in wetlands. Scientists and wetland managers may use the plant community attribute information gained in this intensification study in order to better evaluate Wisconsin's wetlands based on vegetation condition.

To learn more, contact Thomas Bernthal (Thomas.Bernthal@wisconsin.gov), Wisconsin Department of Natural Resources.

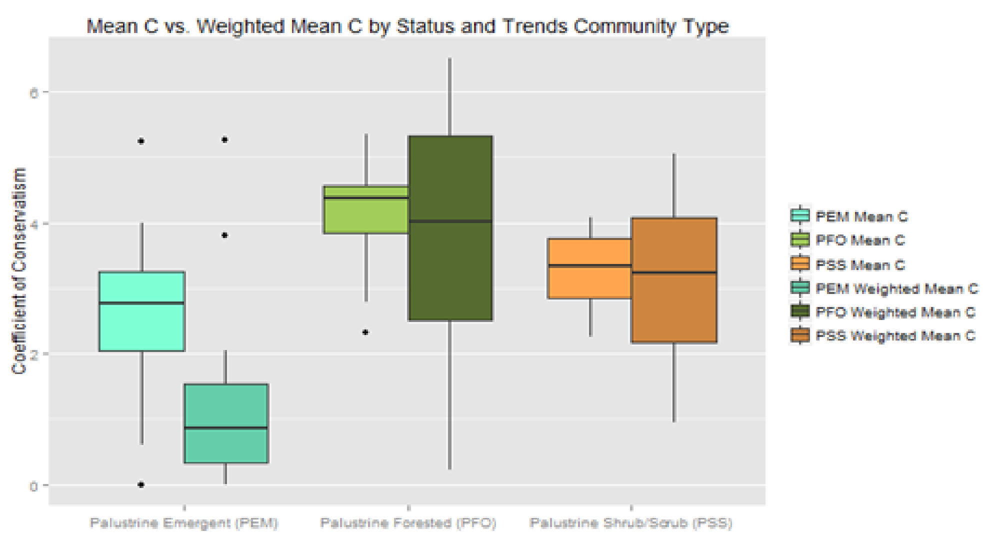


Figure 2. Comparison of $\bar{C}$ and $w\bar{C}$ by Status and Trends community type.

Evaluating Indicators of Stress

Indicators of stress are physical, chemical, or biological factors that have the potential to reflect anthropogenic impacts on wetland ecological condition. Indicators of stress do not necessarily directly cause ecological decline, but are often associated with changes in wetland condition. NWCA evaluated the extensive set of data collected in the field to identify and develop appropriate indicators of stress and quantify their national and regional extents. While these are expected to be associated with effects on wetland condition, the exact relationship cannot be explicitly determined from the data collected in NWCA. For simplicity of language, in this report "indicators of stress" are also referred to as "stressors."

It was not possible to evaluate all potential stressors affecting wetland condition. NWCA 2011 indicators of stress are derived from field data collected at the site-level within the assessment area and the 100 meter buffer immediately surrounding it. Due to this, potential effects on condition from stressors occurring outside of the vicinity of the assessment area and buffer may not be fully considered in the NWCA reported results and could have significant influences on wetland condition.

Six physical, three chemical, and one biological indicator of stress were developed for the NWCA report. The following sub-sections summarize the development of the indicators pertaining to each of these three categories.

Physical Indicators of Stress

Wetlands can be impacted by human-mediated activities that cause physical changes to wetland systems. These may be stressors that are occurring in the wetland itself or many miles away. Due to the limitations of the survey, NWCA 2011 focused on physical stressors occurring in the assessment area and in the area immediately surrounding the assessment area (i.e., buffer). Physical indicators of stress include vegetation alterations that occur through removal or replacement, or hydrologic alterations that occur through damming, ditching, surface hardening, filling or erosion. These alterations can disrupt wetland structure and function. Data reflecting indicators of physical stress were evaluated as part of the hydrology and buffer protocols both within the wetland assessment area and the 100 meter buffer immediately surrounding it. The indicators evaluated were placed into different stress indicator groups based on whether they resulted primarily in vegetative or hydrologic alteration to a wetland.

Vegetation alteration included two indicators of stress:

- **Vegetation Removal** – any field observation related to loss, removal, or damage of vegetation (e.g., mowing/shrub cutting, herbicide use, highly grazed grasses, recently burned forest); and
- **Vegetation Replacement** – any field observation of a change in the plant species present due to anthropogenic activities (e.g., tree plantation, nursery, golf course, lawn/park, row crops, pasture/hay, rangeland).

Changes in vegetation at the sampling site and the surrounding area can indicate effects of activities that could impact the ecological condition of the wetland. Removal of vegetation may increase sediment, nutrient, and pollutant loads entering or residing in a wetland. Replacement reflects conversion from one vegetation type to another in the buffer and assessment area and can decrease biodiversity, simplify the vertical structure, and reduce habitat quality on the site. Not all instances of vegetation removal or replacement (e.g., moderate grazing by native wildlife, natural wildfire regimes in ecosystems adapted to fire) result in stress to a wetland or poor ecological condition. The relationship between vegetation alteration stressors and biological condition as indicated by the VMMI are evaluated through the concepts of relative and attributable risk later in the report.

Hydrologic alteration included four indicators of stress:

- **Damming** – any field observation related to impounding or impeding water flow from or within the site (e.g., dikes, dams, berms, railroad beds);
- **Ditching** – any field observation related to draining water within the site (e.g., ditches, corrugated pipe, excavation-dredging);
- **Hardening** – any field observation related to soil compaction, including activities and infrastructure that primarily result in soil hardening (e.g., parking lots, suburban residential development, roads, pavement); and
- **Filling/Erosion** – any field observation related to soil erosion or deposition (e.g., soil loss/root exposure, fill/spoil banks, freshly deposited sediment).

Changes in how water moves in or out of a wetland, or water levels within the wetland resulting from hydrologic alterations can affect plant productivity, nutrient cycling in the soil and water, and the physical habitat, thereby impacting the overall ecological condition of the wetland. For example, a nearby parking lot or impervious surface could increase the volume of water entering the wetland. Higher water tables may limit the plant species that can grow in the wetland.

Stress-level thresholds were established for each stressor group (vegetation alteration and hydrologic alteration) and applied to each individual indicator of stress (see NWCA 2011 Technical Report (USEPA 2016)). Thresholds reflecting low stress were set to indicate the complete absence of the given physical indicator of stress at the site. Thresholds reflecting high stress were set using best professional judgment. Indicator values between the established low and high threshold levels were placed into the moderate stress class. These thresholds were used across all NWCA sites (See Table 2-6 for a complete list of indicators and summary information on how thresholds were set).

Chemical Indicators of Stress

Chemical stressors that can impact the ecological condition of wetlands include excess nutrients, metals, organic toxins, and other chemical compounds that can disrupt nutrient cycles, affect plant and animal growth, and be detrimental to human health. Two chemical indicators of stress were developed for NWCA using data from soil samples collected at each site: a Heavy Metal Index and soil phosphorus concentration. Another potential indicator of stress, microcystin (an algal toxin), was evaluated based on concentrations from a composite sample of surface water and algal scrapings from vegetation stems and leaves.

The **Heavy Metal Index**, developed for the NWCA as a chemical indicator of stress, was comprised of 12 different heavy metals closely associated with anthropogenic activities: antimony (Sb), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), nickel (Ni), silver (Ag), tin (Sn), tungsten (W), vanadium (V), and zinc (Zn). Stress-level thresholds were set for each metal using a combination of published estimates of background concentration and natural breaks in the frequency distributions for each metal in the NWCA data set (Table 2-3, see NWCA 2011 Technical Report (USEPA 2016) for further details). It should be noted that the thresholds established for heavy metals do not reflect toxicity; rather, they are indicators of human disturbance. Sites where all 12 metal concentrations were equal to or below the stress-level threshold established for each metal were placed into the low stress-level class. Sites where three or more metal concentrations were above the stress-level thresholds were placed into the high stress class. Sites not placed into either the low or high stress-level classes were put into the moderate stress class. The same thresholds were used across all NWCA sites.

Table 2-3. Heavy metals included in the Heavy Metal Index as a chemical indicator of stress. Background concentrations are based on Alloway (2013). Thresholds were set using background concentration and natural breaks in the frequency distributions for each metal in the NWCA data set.

Metal	Primary Anthropogenic Association	Natural Background Concentration (mg/kg)	Stress-Level Threshold (mg/kg)
Silver (Ag)	Industry	0.05 – 1.00	1.0
Cadmium (Cd)	Agriculture	0.1 – 1.0	1.0
Cobalt (Co)	Industry	< 50	25
Chromium (Cr)	Industry	0.5 – 250	125
Copper (Cu)	Agriculture / Industry / Roads	2 – 50	50
Nickel (Ni)	Industry / Agriculture	0.2 – 450	225
Lead (Pb)	Roads / Industry	Mean of 18	35
Antimony (Sb)	Industry	0.1 – 1.9	1.0
Tin (Sn)	Industry / Agriculture	1.7 – 50	17
Vanadium (V)	Industry / Roads	36 – 150	150
Tungsten (W)	Industry / Agriculture	< 2	2.0
Zinc (Zn)	Industry / Agriculture	10 – 150	150

Soil phosphorus concentrations were measured from samples collected at each site. Naturally-occurring soil phosphorus concentrations vary widely across wetlands due to differences in soil types, wetland types, climate, and other factors. Soil phosphorus concentration can also be influenced by and reflect human activity on the landscape. No nationally-accepted soil phosphorus criteria exist to assign stress classes. Therefore, NWCA used a distribution-based, or reference site approach, paralleling that of the VMMI, to set soil phosphorus concentration stress classes for each combination of NWCA Aggregated Ecoregion by NWCA Aggregated Wetland Type (see “Use of Reference Site Approach” text box). Soil phosphorus concentrations above the 95th percentile of reference sites were considered to have high stress, while those below the 75th percentile of reference sites were considered to have low stress (Table 2-4, see NWCA 2011 Technical Report (USEPA 2016) for further details).

Table 2-4. Soil phosphorus concentration thresholds as chemical indicators of stress. Stress-level thresholds were set for estuarine wetland types nationally and for inland wetland types by NWCA Aggregated Ecoregion based on the 75th percentile (low stress) and 95th percentile (high stress) of reference sites for the group.

NWCA Reporting Group (NWCA Aggregated Ecoregion, Wetland Type)	"Low" Threshold (mg P/kg soil)	"High" Threshold (mg P/kg soil)
Estuarine (Herbaceous and Woody)	≤ 519	> 969
Coastal Plains (Inland Herbaceous and Woody)	≤ 582	> 1,180
Eastern Mountain and Upper Midwest (Inland Herbaceous and Woody)	≤ 914	> 1,280
Interior Plains (Inland Herbaceous and Woody)	≤ 1,110	> 1,810
West (Inland Herbaceous and Woody)	≤ 1,140	> 2,090

Microcystin is a toxic substance produced by cyanobacteria, a group of microbes also called blue-green algae. Cyanobacteria are a natural part of aquatic ecosystems, but under certain environmental conditions, can proliferate into algal blooms that can be unsightly, smelly, and in some instances cause severe health issues for wildlife, people, and domestic animals.

EPA collected samples and tested them for the presence and concentration of microcystin. The results are categorized using a fixed threshold approach based on recreational exposure guidelines established by the World Health Organization (Table 2-5). Concentrations of microcystin have not been previously documented over a spatial area or for as many wetland types as sampled in the NWCA, consequently, more research is likely to be needed to appropriately interpret how these results relate to wetland condition.

Table 2-5. World Health Organization thresholds of risk associated with exposure to microcystin.

Indicator (units)	Low Risk of Exposure	Moderate Risk of Exposure	High Risk of Exposure
Microcystin (µg/L)	< 10	10 - ≤ 20	> 20

Biological Indicators of Stress

EPA used the presence and abundance of nonnative plants to develop a biological indicator of stress. Nonnative plants are often related to human-mediated disturbance, and can also be direct or indirect stressors to wetland ecosystems by competing with or displacing native plant species or communities, or by altering wetland structure and processes.

The **Nonnative Plant Stressor Indicator (NPSI)** was developed for the NWCA using collected plant data and information describing the native status of each species (see NWCA 2011 Technical Report (USEPA 2016) for definition of nonnative plant concepts). The NPSI included three complementary nonnative species metrics that describe different avenues of potential impact to ecological condition:

- Relative Cover of Nonnative Species
- Richness of Nonnative Species (number of unique nonnative species)
- Relative Frequency of Occurrence of Nonnative Species

Relative Nonnative Cover reflects preemption of space and resources, changes in species composition, and alteration of ecosystem processes. Higher values are often associated with decreases in ecological condition. **Total Richness of Nonnative Species** can be an indicator of potential risk for ecological impact; greater numbers of individual nonnative plant species increases risk that one or more may be or become invasive or cause ecosystem alterations. Greater **Relative Frequency of Occurrence of Nonnative Species** reflects increasing numbers of locations for further nonnative incursions and a decreasing proportion of the species composition that is native.

These three metrics are used together to assign low, moderate, high, and very high stress levels for the NPSI. Stress-level thresholds were set for each metric in the NPSI using best professional judgment. The addition of a "very high" stressor class was made because of the greater range in values for this stressor indicator compared to other stressor indicators. The same threshold values were used across all NWCA sites (see NWCA 2011 Technical Report (USEPA 2016) for details on NPSI development and application).

Table 2-6. Summary of NWCA 2011 indicators of condition and stress and information on how thresholds were set.

Indicator	Reference Approach	General Assessment Notes
Biological Condition		
Vegetation MMI	Regionally specific (NWCA ecoregion / wetland type) distribution-based threshold	Data on specific plants and abundance collected from five plots systematically distributed in assessment area. Index developed based on species composition (presence and abundance) and species traits.
Indicators of Stress		
Physical – Vegetation Alteration:		
Vegetation Removal	Nationally consistent fixed threshold	Field observations related to loss, removal, or damage of vegetation (e.g., mowing / shrub cutting, herbicide use, highly grazed grasses, recently burned forest, pasture/hay, rangeland) collected from plots systematically distributed in assessment area and 100 meter buffer area.
Vegetation Replacement		Field observations of a change in the plant species present due to anthropogenic activities (e.g., tree plantation, golf course, lawn/park, row crops, fallow field) collected from plots systematically distributed in assessment area and 100 meter buffer area.
Physical – Hydrologic Alteration:		
Damming	Nationally consistent fixed threshold	Field observations related to impounding or impeding water flow (e.g., dikes, dams, berms, railroad beds) collected in the assessment area and from plots systematically distributed in the 100 meter buffer area.
Ditching		Field observations related to draining water within the site (e.g., ditches, corrugated pipe, excavation-dredging) collected in the assessment area and from plots systematically distributed in the 100 meter buffer area.
Hardening		Field observations related to soil compaction, including activities and infrastructure that primarily result in soil hardening (e.g., roads, suburban residential development, pavement) collected in the assessment area and from plots systematically distributed in the 100 meter buffer area.
Filling/Erosion		Field observations related to soil erosion or deposition (e.g., soil loss/root exposure, fill/spoil banks, freshly deposited sediment) collected in the assessment area and from plots systematically distributed in the 100 meter buffer area.
Chemical:		
Heavy Metal Index	Nationally consistent fixed threshold	Samples collected from upper 10 centimeters of soil in the assessment area. Measured concentrations compared to thresholds that were based on background concentrations and natural breaks in frequency distributions within the NWCA data set of heavy metals.
Soil Phosphorus	Regionally specific (NWCA ecoregion) distribution-based threshold	Samples collected from upper 10 centimeter of soil in the assessment area. Measured concentrations compared to thresholds based on reference sites.
Microcystin	Nationally consistent fixed threshold	Samples collected from surface water, sediment, and vegetation surfaces. Measured concentrations compared to World Health Organization (WHO) algal toxin threshold for recreation.
Biological:		
Nonnative Plant Stressor Index	Nationally consistent fixed threshold	Data on specific plants and abundance collected from five plots systematically distributed in assessment area. Index developed based on species composition (presence and abundance) and species traits.

Estimating the extent of wetland area for condition classes or stress-level classes

The NWCA 2011 results presented in the subsequent chapters of the report are calculated by estimating the extent of wetland area in each of the different condition classes or stressor levels established for each indicator. The process used to accomplish this is briefly described below for the NWCA indicators of condition and stress. More detailed information is provided in the NWCA 2011 Technical Report (USEPA 2016).

Condition: There are three different classes to describe wetland condition: good, fair, and poor. The VMMI thresholds for each condition class are used with site weights to calculate extent estimates of wetland area in good, fair, and poor condition using a two-step process:

1) Each NWCA probability site is assigned good, fair, or poor biological condition based on its VMMI value and the thresholds appropriate to the site.

2) Next, the site weights from the probability design, which reflect the number of acres each site represents across the total population of NWCA Target Wetland Types, are summed within condition class to estimate the wetland area in good, fair, and poor condition.

In Figure 2-4, this process is illustrated by the arrows between the Vegetation Data, VMMI, and Wetland Condition Extent Estimate boxes. The survey design also allows evaluation of the statistical certainty of these condition estimates.

Stress: For each stress indicator, its designated threshold values are used to assign a low, moderate, or high stress level to each site. An additional stress-level of very high was designated for the Nonnative Plant Stressor Index. The process for estimating the extent of wetland area with low, moderate, high, or very high stress for each of the NWCA indicators of stress, parallels the approach used for making condition estimates. In Figure 2-4, this process is illustrated by the arrow between each group of indicators of stress and the Stressor Extent Estimate box.

Other data collected as part of NWCA 2011 but not reported in national and regional results

Water Chemistry

The NWCA 2011 survey is the first national-scale survey of wetland surface water chemistry. Water chemistry data were collected for chlorophyll-a, conductivity, ammonia, nitrate-nitrite, total nitrogen, total phosphorus, and pH. Water temperature and dissolved oxygen levels also were measured at some sites at the option of the states involved. The objectives of the NWCA water chemistry data analyses were to examine the extent to which water chemistry could be sampled and evaluated across different wetland types, to explore any patterns found in water chemistry for wetlands across the nation and relate them to possible classification variables and natural and anthropogenic drivers, and to generate recommendations concerning further research and protocols for future NWCA assessments.

Water chemistry samples could only be collected from approximately 55% of the sites sampled in NWCA 2011 due to a lack of sufficiently deep standing water at the sampling site. This confounded efforts to assess and report results for the water chemistry data using the analytic approaches adopted by NWCA 2011 for its core data indicators. For this reason, water chemistry results are not presented in the NWCA

2011 report. Analysis and interpretation of the data collected is discussed in the NWCA 2011 Technical Report (USEPA 2016) and, as opportunities arise, will be further disseminated through scientific journals.

Algae Species Data

NWCA 2011 collected composite algae samples from the water column, sediment, and vegetation surfaces at sites with standing water greater than 15 centimeters deep and sites that had evidence of recent inundation. Samples were analyzed to characterize the algal communities present at sites and to investigate relationships between certain communities and ecological condition of wetlands. Though algae taxonomic data were obtained from approximately 80% of the sites sampled in NWCA 2011, issues with data consistency arising from sample collection in the field and taxonomic identification in the lab raised questions about the efficacy of evaluating wetland condition using this algae species data for the NWCA 2011 report.

Highlight

Nebraska's Intensification Project: Impacts of Land Use and Management on Wetland Condition

Ted LaGrange, Nebraska Game and Parks Commission

Overview and Goals: Through the intensification project, participating state, federal, and regional agencies wanted to learn more about 11 priority landscape regions in the state of Nebraska. Most of these regions have been identified in the state's Wildlife Action Plan as Biologically Unique Landscapes, and the information gained from the project will help direct conservation and management efforts in these key landscapes found in Nebraska and throughout the Great Plains.

Since settlement, Nebraska has lost an estimated 35% of its total wetland area due to land-use conversion, and 97% of the remaining wetlands occur on private lands. In the Rainwater Basins (an important region within the Central Flyway as a major bird migration route in North America), wetland losses may be as high as 90%. In order to obtain more data on these important and diverse wetland habitats, an intensified sampling effort was conducted in 11 wetland complexes in Nebraska. This included isolated playa wetlands in landscapes dominated by row-crop agriculture in the Rainwater Basin, Central Table Playas, and Southwest Playas; wet meadows and freshwater and alkaline marshes in the Nebraska Sandhills (includes the Elkhorn River Headwaters, Cherry County Sandhills Wetland, and Sandhills Alkaline Lake regions); wet meadows and alkaline wet meadows located along the North Platte (Western Alkaline), Platte (Central Platte), and Niobrara Rivers; Eastern Saline wetlands located near Lincoln, NE; and forested wetlands along the lower Missouri River (Figure 1).

Information Collected: 109 sampling locations were visited across the 11 regions during the growing seasons of 2011-2013. At each site, Level 1, 2, and 3 assessment data were collected using the NWCA 2011 protocols.

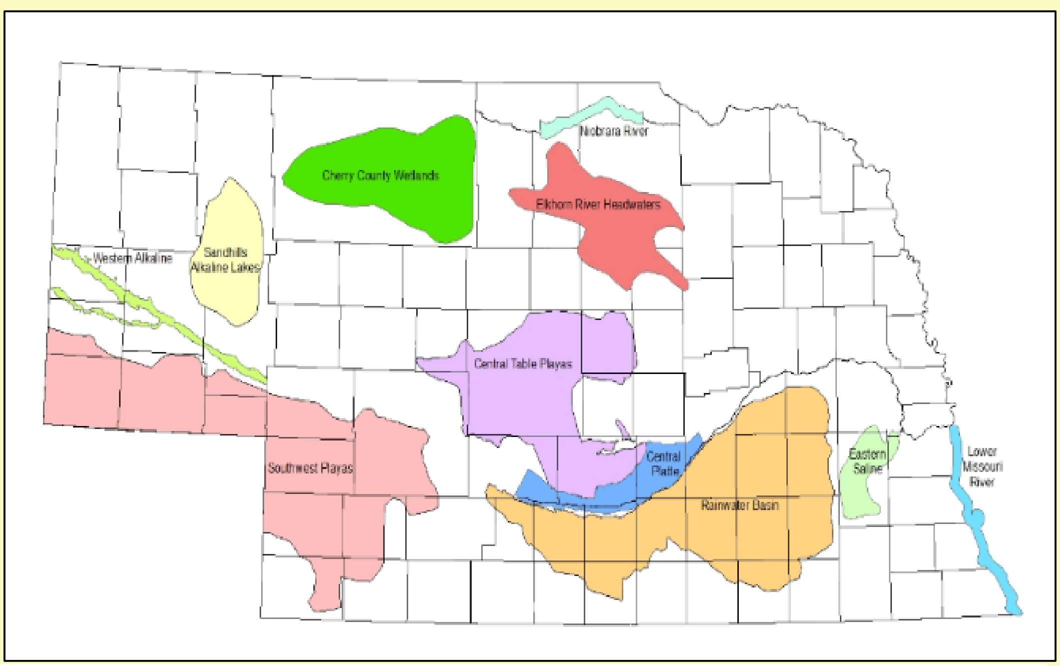


Figure 1. Priority landscape regions identified for the intensification project.

As part of the study, the team developed the Nebraska Wetland Rapid Assessment Method (NeW_RAM), which was tested at 40 of the sites in 2013 and compared to Level 3 assessments. Additionally, amphibian community surveys were conducted at 125 sites in the Rainwater Basin complex with the goal of developing a sampling protocol for long-term amphibian community monitoring and to assess how wetland management practices might affect the presence and health of frog and toad species. Wetlands surveyed for amphibians were grouped according to land use: Wildlife Management Areas (WMA), Waterfowl Production Areas (WPA), Wetlands Reserve Program (WRP), privately owned wetlands, and agricultural reuse pits.

What They Have Learned: Sample processing and data analysis is still underway, but preliminary results have already provided useful information about wetland condition across landscape regions in Nebraska. The draft NeW_RAM, developed in early 2013, was used at 40 sites sampled in 2013. Overall, the NeW_RAM worked well in the field and showed good agreement with level 3 measurements, including the FQAI. It is hoped the NeW_RAM will be a useful tool for agencies and organizations to quickly assess wetland condition, improving Nebraska wetland protection and restoration efforts.

Differences in wetland vegetation condition, measured by the FQAI, varied among landscape regions and with respect to reference condition within each region (Figure 2). Given the high diversity of Nebraska's wetlands, reference wetland FQAI scores may be very different in each of the regions, and direct comparisons of FQAI scores between regions may not be appropriate.

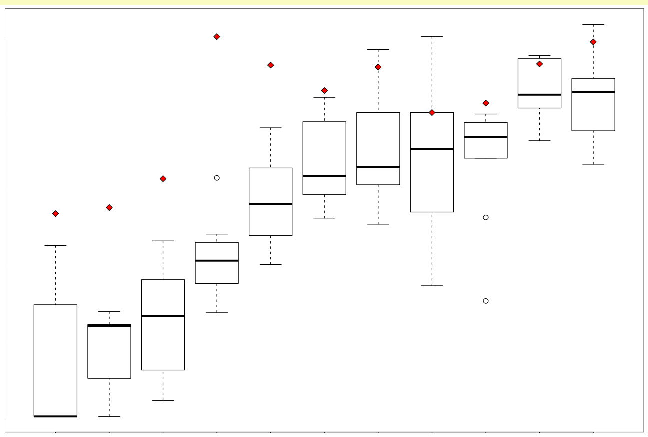


Figure 2. Floristic Quality Assessment Index (FQAI) scores for each of the wetland complexes studied. The top and bottom of the boxes show the 75th and 25th percentile of scores and the line inside the box represents the median score for each region. Reference standard condition FQAI scores for each landscape region are shown as red dots.

Within each region, high and low FQAI scores with respect to reference condition may be linked to land use. In regions where sites scored well below reference, high quality sites may no longer exist on the landscape due to historical and contemporary land use change or disturbance. Two of the lowest scoring regions, the Southwest Playas (SWP) and Central Table Playas (CTP), included shallow playa wetlands in areas dominated by intensive agriculture and recently affected by a period of extreme drought. Low scores were also observed in wetlands along the lower Missouri River (MR), which had been highly altered during historic flooding in 2011. Slightly higher FQAI scores (although still below reference condition) were documented in the Western Alkaline (NPR) and Eastern Saline (SAL) regions, both areas that have been altered, but where some restoration efforts have occurred. The Central Platte (CP), Sandhills Alkaline Lakes (SALK), Rainwater Basin (RWB), Niobrara River (NR), Cherry County Sandhills Wetlands (CCWM), and Elkhorn River Headwaters (EHW) regions have large areas of unmodified land or have been the focus of intensive management and conservation efforts. FQAI scores in these regions tended to be closer to the reference standard, evidence that current management practices are effective in maintaining and restoring wetland condition. This project is providing baseline data of wetland condition within these regions of Nebraska, and offers insight towards the direction of future conservation efforts within the state.

Chorus Frog (*Pseudacris maculata)*.

Seven species of frogs and toads were observed at wetlands sampled in the Rainwater Basin, including the Chorus Frog, *Pseudacris maculata*.

While data analysis is continuing, a few general trends have started to emerge. Differences in amphibian species diversity among wetlands within WMAs, WPAs, WRP land, and privately owned land seem to be minimal, but somewhat lower species diversity has been observed in the agricultural reuse pits. This may suggest that many of the amphibian species are generalists, adaptable to any habitat with water, but prefer actual wetlands over the agricultural reuse pits. Once data analysis is complete, researchers hope to have a better idea of how land use impacts amphibian communities. The team hopes to continue monitoring amphibian communities in wetlands within the Rainwater Basin to document community trends and develop a long-term data set.

To learn more, contact Ted LaGrange (ted.lagrange@nebraska.gov; 402-471-5436), Nebraska Game and Parks Commission.

Nebraska's Intensification Project was a joint effort among the Nebraska Game and Parks Commission, the University of Nebraska-Lincoln, U.S. EPA, U.S. Fish & Wildlife Service, U.S. Army Corps of Engineers, Natural Resources Conservation Service, U.S. Geological Survey, Nebraska Department of Environmental Quality, the Rainwater Basin Joint Venture, the Playa Lakes Joint Venture, the Saline Wetland Conservation Partnership, and The Nature Conservancy.

Chapter 3: National Results

The goal of the CWA is to restore and maintain the "chemical, physical, and biological integrity" of the nation's waters. NWCA examines these three aspects of the ecological quality of aquatic systems through a set of commonly used and widely accepted indicators. It does not include all aspects of ecological integrity or all possible chemical, physical, or biological stressors known to affect wetland systems.

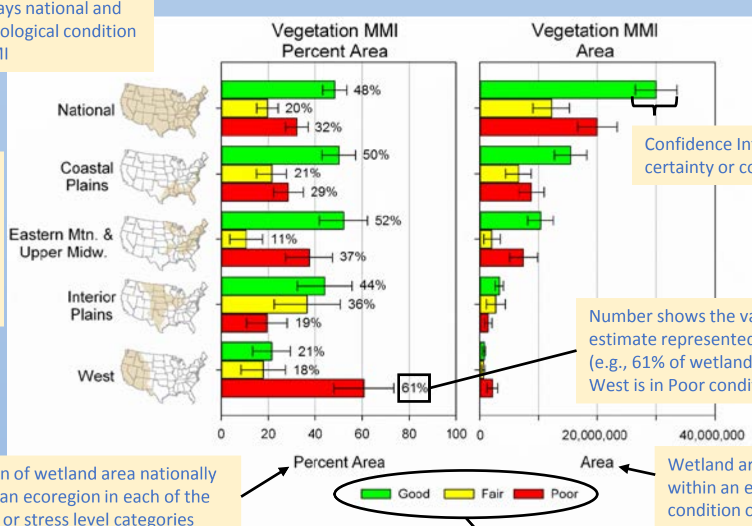
This chapter presents the results from the NWCA 2011 using: 1) an indicator of biological condition, 2) physical, chemical, and biological indicators of stress, and 3) a ranking of the relative importance of the stressors in affecting biological condition. Results for each indicator are shown for wetlands nationally and for the four NWCA Aggregated Ecoregions established for reporting. Regional results are presented in Chapter 4.

Results for wetland condition are estimates of the extent of wetland area (presented as percent area and numbers of acres) in three condition classes (good, fair, and poor). Results for the indicators of stress are presented as estimates of the percent wetland area in a particular stressor-level class (generally, low, moderate, and high). See Chapter 2 of this report, and the NWCA 2011 Technical Report (USEPA 2016) for details on how these estimates are made. The estimated wetland area results are often referred to as population estimates, and each estimate is accompanied by a confidence interval that conveys the level of certainty or confidence in the estimate (see text boxes "How to Read and Interpret NWCA Results Figures" and "Confidence Interval" below).

HOW TO READ AND INTERPRET NWCA RESULTS FIGURES

This example figure displays national and ecoregion estimates of biological condition as measured by the VMMI

National estimates of condition or stress level are shown by the first group of bars, followed by estimates for each of the NWCA Aggregated Ecoregions



Confidence Interval – displays level of certainty or confidence in the estimate

Number shows the value of the estimate represented by the bar (e.g., 61% of wetland area in the West is in Poor condition)

Proportion of wetland area nationally or within an ecoregion in each of the condition or stress level categories

Wetland area, in acres, nationally or within an ecoregion in each of the condition or stress level categories

Condition classes (this example) or stressor levels are indicated by colors:

Condition Class:	Stressor Level:
Green = Good	Green = Low
Yellow = Fair	Yellow = Moderate
Red = Poor	Red = High
	Dark Red = Very High

Gray = Unassessed (area that could not be sampled)

CONFIDENCE INTERVALS

Confidence intervals convey the level of certainty or confidence in the estimates presented in this report. For example, for the VMMI, NWCA found that 48% of the nation's assessed wetland acres are in good condition, with a confidence interval of +/- 5%. This means that there is a 95% certainty that the real value is between 43% and 53%. The confidence interval is influenced by the number of sites sampled. As more wetland sites are sampled, the confidence interval becomes narrower, meaning there is more confidence in the findings. Figure 3-1 shows an example of this pattern, in which the confidence interval for the national results (the largest sample size) is narrowest, whereas the confidence intervals for the NWCA Aggregated Ecoregions (smaller sample sizes), are generally broader. Ultimately the number of sites sampled is a tradeoff between the need for increased certainty to support management and policy decisions, and the cost in money and resources to perform more extensive monitoring activities. Note, confidence intervals are shown in the results figures for all NWCA population estimates presented in this report.

Biological Condition Based on Vegetation MMI

Vegetation is a major component of the biodiversity found in wetlands and also provides habitat for a broad range of microbes, insects, amphibians, reptiles, birds, and mammals. The composition and abundance of plant species reflects, as well as influences, the hydrology, water chemistry, and soil properties of wetlands. Vegetation is a particularly good indicator of wetland condition because of its ability to integrate different wetland processes and because plants respond to physical, chemical, and biological disturbances at multiple temporal and spatial scales. Using field collected data and plant trait information, a national **Vegetation Multimetric Index (VMMI)** was developed. (See Chapter 2 in this document, and the NWCA 2011 Technical Report (USEPA 2016) for more details). The VMMI serves as the indicator of biological condition for the NWCA.

The condition of wetlands at national and ecoregional scales is shown in Figure 3-1. This figure presents both the percentage of wetland area and the number of wetland acres in different condition classes (good, fair, and poor). The NWCA found nationally, 48% of the wetland area (29,998,957 acres) is in good condition, while 20% (12,179,915 acres) is in fair condition. The remaining 32% (19,977,327 acres) of the wetland area is in poor condition.

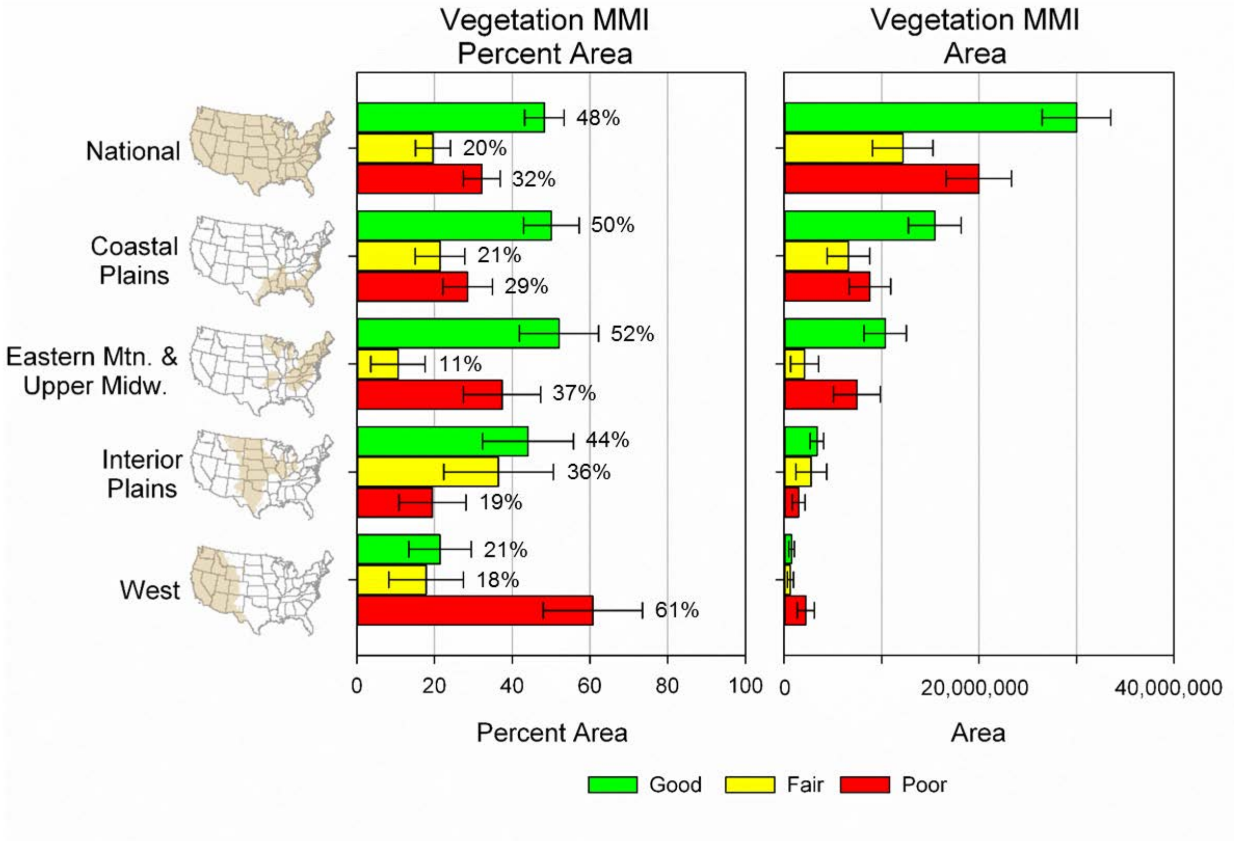


Figure 3-1. Estimated extent of wetland biological condition by condition classes (good, fair, poor) based on the VMMI. Results are reported for the nation and by NWCA Aggregated Ecoregion.

The regional results apply to specific NWCA Aggregated Ecoregions, and care must be taken when comparing results across the four ecoregions. It is important to note that the level of human-mediated disturbance for reference (least disturbed) sites varied by region and wetland type. For example, in the Interior Plains and West, reference sites have the highest level of disturbance. Reference sites for estuarine wetlands, which are predominantly found in the Coastal Plain, have the lowest level of disturbance. See NWCA 2011 Technical Report (USEPA 2016) for details.

Wetland area varies significantly among the NWCA Aggregated Ecoregions. For example, in the NWCA survey, the West represents only 6% of the total assessed wetland area of the target wetland types sampled across the country. In the West, 61% of the wetland area (2,214,806 acres) is in poor condition, representing a major proportion of the wetland area for that ecoregion, but a small proportion of the total wetland area nationally. The West has 21% and 18% of wetland area (782,525 and 649,729 acres) in good and fair condition, respectively.

The Coastal Plains, Eastern Mountains and Upper Midwest, and Interior Plains have a range of 44% to 52% wetland area in good condition. The Eastern Mountains and Upper Midwest has 11% of wetland area (2,117,215 acres) in fair condition and 37% (7,462,851 acres) in poor condition. In the Coastal Plains, 21% of wetland area (6,620,942 acres) is in fair condition and 29% (8,808,894 acres) is in poor condition. In the Interior Plains, 36% of wetland area (2,792,028 acres) is in fair condition while 19% (1,490,777 acres) is in poor condition.

As future NWCA surveys are implemented, we will be able to use the 2011 results as a point of comparison to track whether wetland areas are getting better (i.e., moving to good condition) or worse (i.e., moving to poor condition) within each aggregated ecoregion.

Indicators of Stress

The NWCA also includes measurements of **indicators of stress**, which are physical, chemical, and biological factors that have the potential to reflect human-mediated impacts on wetland condition. The indicators of stress do not necessarily directly cause ecological decline, but are often associated with changes in wetland condition. While these stress indicators are expected to be associated with effects on wetland condition, both in their presence and magnitude, the exact relationship between them and condition cannot be explicitly determined from the data collected in the NWCA. A goal of the NWCA was to characterize indicators of stress that are common in wetlands to help inform priorities for management actions. See Chapter 2 in this document, and the NWCA 2011 Technical Report (USEPA 2016) for more detail on the development of each indicator of stress.

For simplicity of language, in the remainder of this chapter, “indicators of stress” are sometimes referred to as “stressors.” The results report the extent of the NWCA 2011 stress indicators by stressor levels (low, moderate, or high). **Stressor extent** is an estimate of how spatially common an indicator of stress is nationally or within each NWCA Aggregated Ecoregion.

Physical

Wetlands can be influenced by physical changes to the ecosystem and its immediate surroundings. For the NWCA, physical data collected by crews were categorized and assigned to one of six indicators representing alteration of wetland vegetation or hydrology: vegetation removal, vegetation replacement, damming, ditching, surface hardening, and filling/erosion (see Figure 2-4).

Vegetation Alteration

Vegetation alteration was identified by either the removal or replacement of vegetation. The **vegetation removal** indicator evaluated the loss, removal, or damage of vegetation either within the assessment area or the assessed buffer area immediately surrounding it. Nationally, the vegetation removal stressor is low for 56% of the wetland area and high for 27% (Figure 3-2). However, this varied greatly by NWCA Aggregated Ecoregion. In the Coastal Plains and Eastern Mountain and Upper Midwest, the degree of vegetation removal for most of the wetland area fell into the low stressor level. In contrast, a large proportion of the wetland area in the Interior Plains and West have high stressor levels from vegetation removal, encompassing 44% and 61% of the wetland area in the Interior Plains and West, respectively.

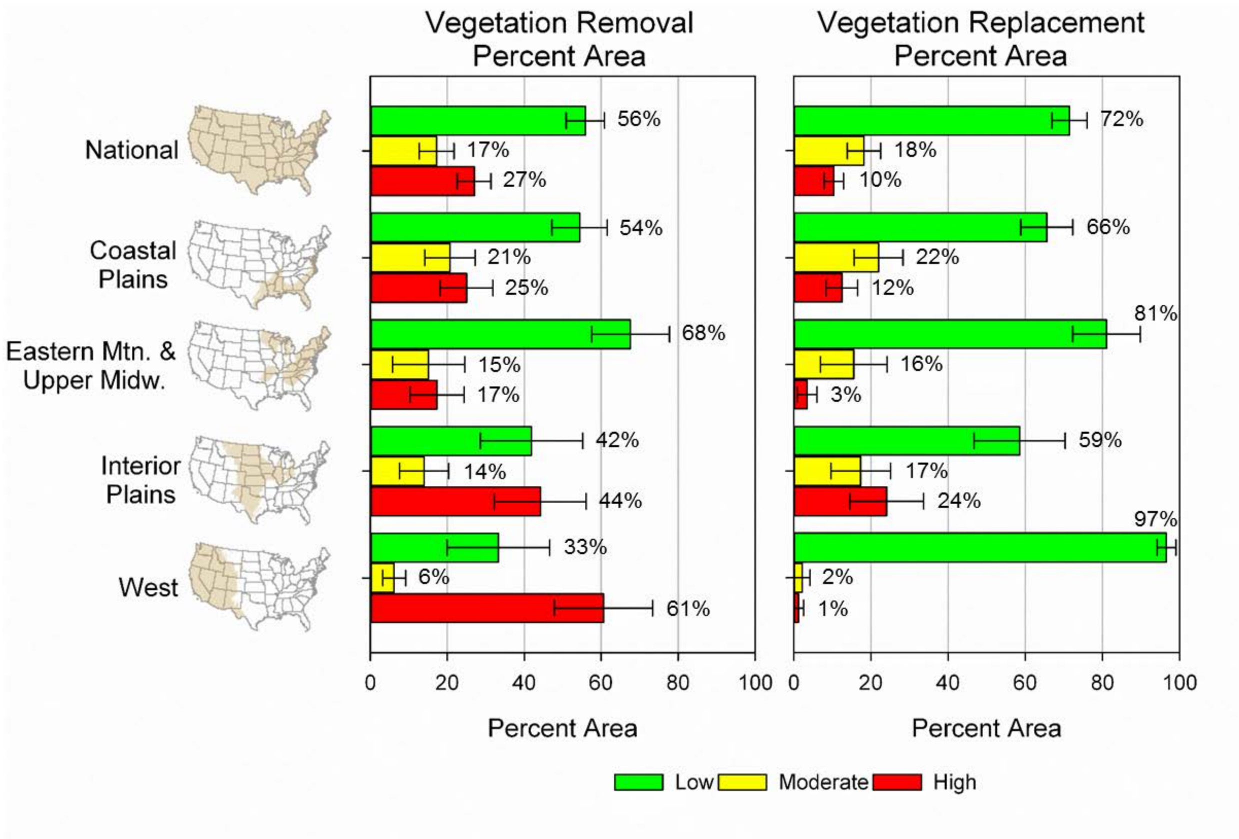


Figure 3-2. Estimated extent of vegetation alteration in wetlands by stressor levels as indicated by vegetation removal and vegetation replacement. Results are presented nationally and by NWCA Aggregated Ecoregion.

The **vegetation replacement** indicator documented major changes to the natural vegetation structure and composition due to anthropogenic activities (e.g., conversion of natural plant communities to golf course, lawn, park, row crops, nursery, etc.). Nationally, and within each of the NWCA Aggregated Ecoregions, wetland area is predominantly found at low stressor levels related to vegetation replacement (Figure 3-2). Moderate and high stressor levels associated with vegetation replacement are found in 18% and 10% of national wetland area, respectively.

Hydrologic Alteration

Information collected by crews pertaining to alterations of wetland hydrology were used to develop four stressor indicators: **damming**, **ditching**, **hardening**, and **filling/erosion**. For each of these four indicators, the majority of wetland area nationally have low stressor levels (Figure 3-3). Of these four, ditching and surface hardening are found to have the largest extent of wetland area at high stressor levels nationally, 23% and 27%, respectively. Among the ecoregions, the West has the largest proportion of wetland area at high stressor levels for damming, ditching, and surface hardening. In the other ecoregions, the majority of wetland area have low stressor levels for the evaluated hydrologic stressors.

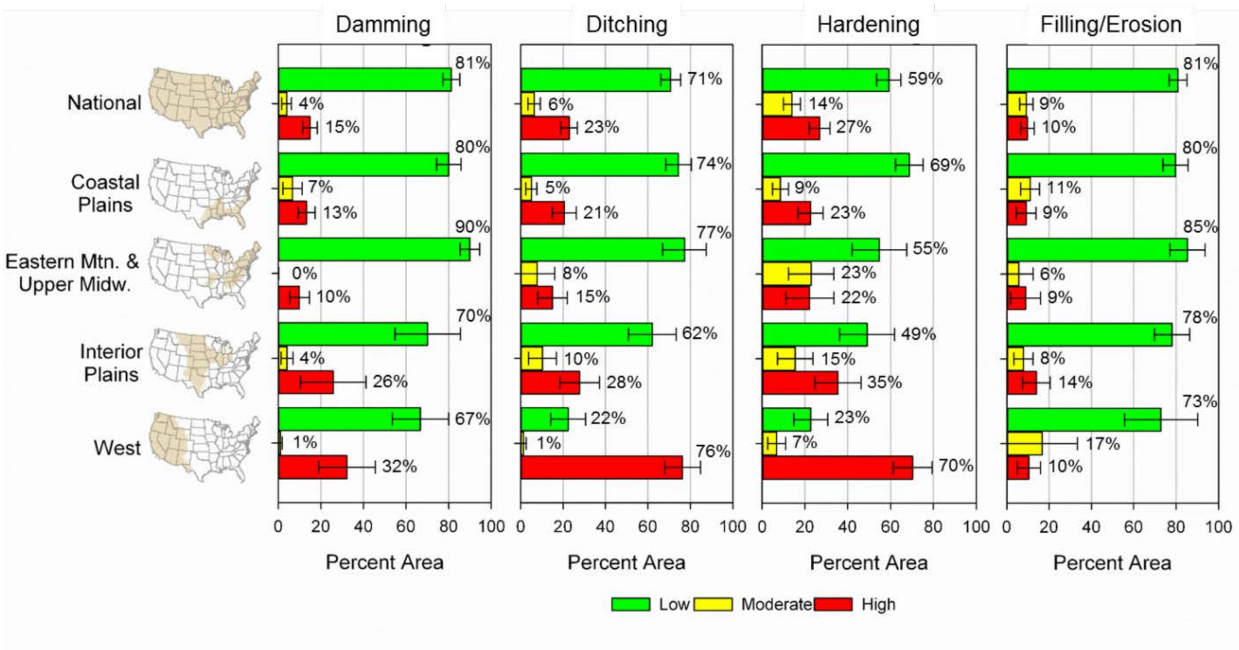


Figure 3-3. Estimated extent of hydrologic alteration in wetlands by stressor levels as indicated by damming, ditching, hardening, and filling/erosion. Results are presented nationally and by NWCA Aggregated Ecoregion.

Chemical

Chemical stressors that can impact the condition of wetlands include excess nutrients, metals, organic toxins, and other chemical compounds that can disrupt nutrient cycles, affect plant and animal growth, and be detrimental to human health. Two chemical indicators of stress were developed for NWCA using data from soil samples collected at each site: a Heavy Metal Index and concentration of soil phosphorus. At some sites it was not possible to collect a soil sample because of ponded water or other site conditions on the sampling day. Additionally, at some sites in the Interior Plains ecoregion soil samples were not analyzed using NWCA laboratory protocols. As a result, these sites could not be evaluated for the chemical stressors. Another potential indicator of stress, microcystin (an algal toxin) concentration, is discussed separately at the end of this chapter.

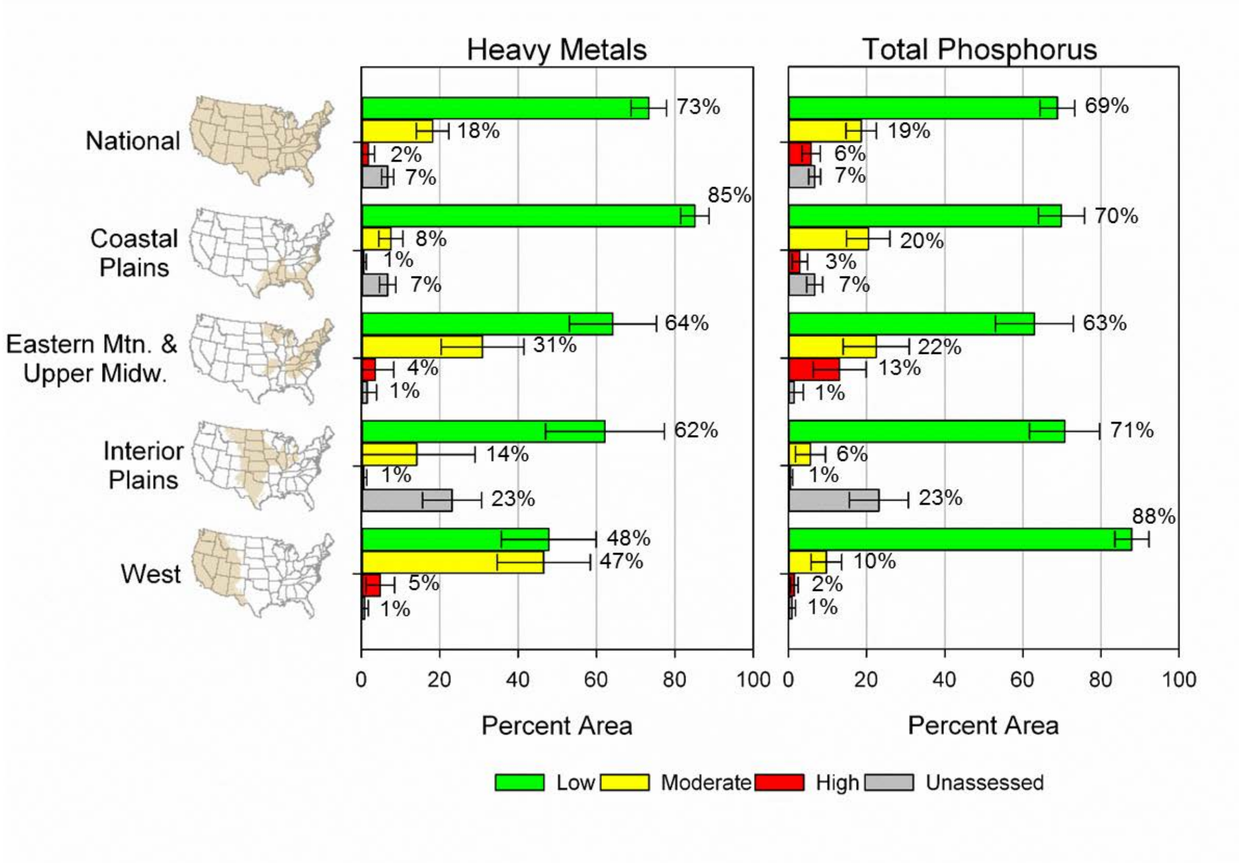


Figure 3-4. Estimated extent of chemical indicators of stress in wetlands by stressor levels as indicated by a Heavy Metal Index and soil phosphorus concentrations. Results are presented nationally and by NWCA Aggregated Ecoregion.

Concentrations of twelve heavy metals found in soils and closely associated with human activities comprised the **Heavy Metal Index**. Heavy metals have measured concentrations below background levels across most sites. Consequently, the majority of assessed wetland area nationally, 73%, is at low levels for this stressor (Figure 3-4). Moderate levels are found in 18% of wetland area nationally, and high levels in only 2%. Soil samples could not be collected or were not analyzed for heavy metal concentrations for 7% of wetland area nationally. Of the four NWCA Aggregated Ecoregions, Eastern Mountains and Upper Midwest and West have the greatest estimated percentage of wetland area at high stressor levels (4% and 5%, respectively).

Soil phosphorus is a necessary plant nutrient, but at high levels can indicate human-mediated impacts. **Soil phosphorus concentration** thresholds were determined using a distribution-based approach (see Chapter 2). Nationally, the majority of wetland area, 69%, is at low stressor levels (Figure 3-4), while 19% of wetland area is at moderate stressor levels. Soil phosphorus concentrations are not assessed for 7% of the wetland area due to difficulties in collecting soil samples or because some soil samples were not analyzed using NWCA lab protocols. Among the NWCA Aggregated Ecoregions, wetland area with soil phosphorous concentrations at low stressor levels ranges from 63 to 88%. The greatest estimated extent of wetland area at high stressor levels is found in the Eastern Mountain and Upper Midwest (13%) and in the Coastal Plains (3%).

Biological

In addition to looking at the chemical and physical stressor indicators that can impact wetland systems, the NWCA developed a **Nonnative Plant Stressor Indicator (NPSI)** to assess the level of biological stress in wetlands. Nonnative plants can have numerous direct and indirect effects on native vegetation and ecosystem components. This indicator used three metrics: the **relative cover of nonnative species**, **richness of nonnative species** (the number of unique nonnative species), and **relative frequency of occurrence of nonnative species**. Wetlands were assessed as having low, moderate, high, or very high stressor levels based on the potential impact of nonnative plants on the native vegetation of the site.

Nationally, 61% (37,709,004 acres) of the wetland area are estimated to have low stressor levels from nonnative plants, but results are not uniform across the country (Figure 3-5). In the Eastern Mountains and Upper Midwest and the Coastal Plains stressor levels based on the NPSI are low for 74% (14,761,495 acres) and 66% (20,358,855 acres) of the wetland area, respectively. In the Interior Plains and West, the extent of wetland area at low stressor levels is much smaller, 27% and 14%, respectively. In the Interior Plains, the extent of wetland area is distributed more uniformly across the four NPSI stressor levels, with relatively similar proportions of area having low, moderate, high, and very high stressor levels. In the West, the majority of wetland area, 71% (2,602,079 acres) is estimated to have high or very high stressor levels as indicated by the NPSI.

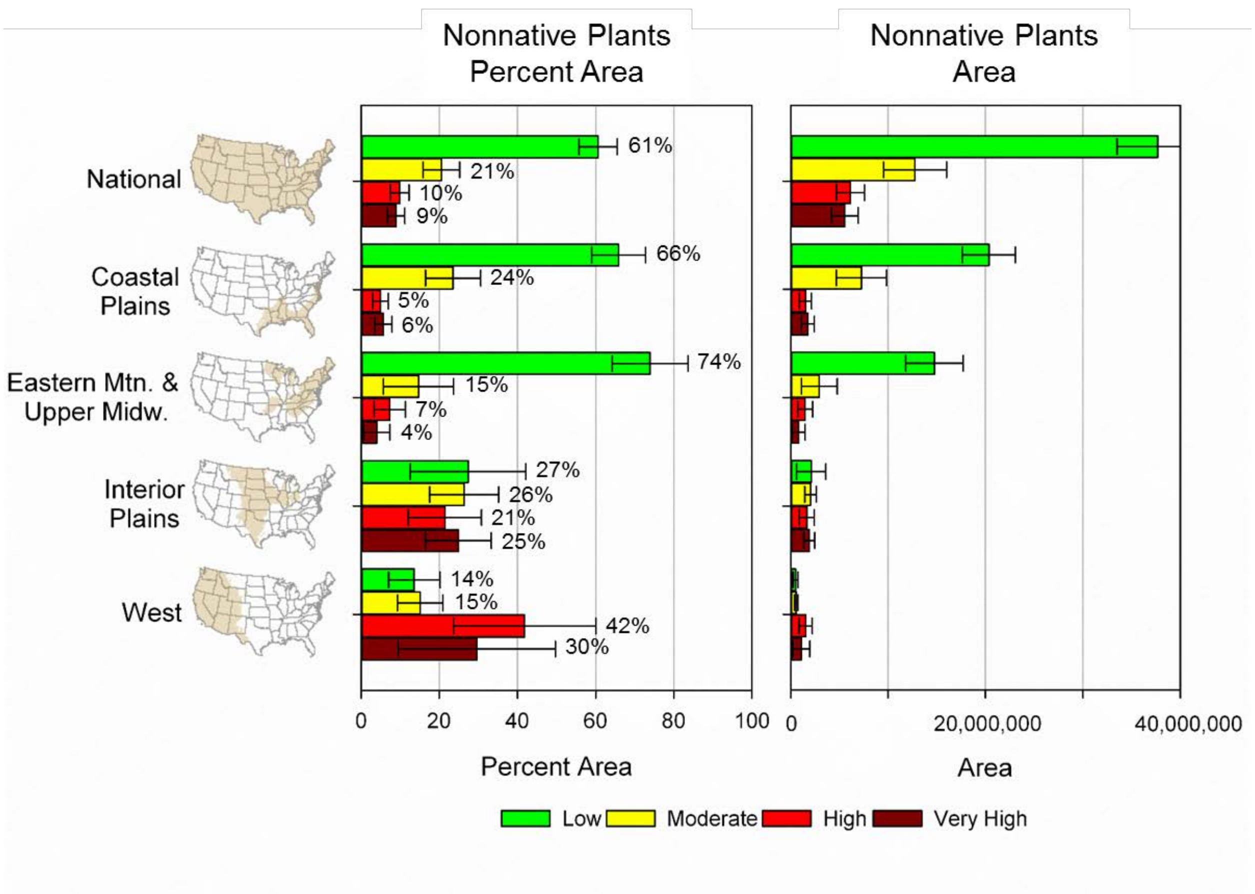


Figure 3-5. Estimated extent of biological stress in wetlands by stressor levels as indicated by the Nonnative Plant Stressor Indicator. Results are presented nationally and by NWCA Aggregated Ecoregion.

Ranking of Stressors

An important function of the NWCA is to provide information for sound policy and decision-making to support the maintenance and improvement of wetland ecological quality. It is important for resource managers to understand not only which stressors are present nationally and in various regions, but to have information on the potential impact of stressors on ecological condition and to be able to rank those stressors in terms of the estimated improvements we might expect by reducing or eliminating them. To meet these objectives, the NWCA uses **relative extent**, **relative risk**, and **attributable risk** to consider how stressors could influence the ecological condition of wetlands. An overview of these three concepts is provided here. Further details on their calculation can be obtained in the NWCA 2011 Technical Report (USEPA 2016, Chapter 9).

Relative extent ranks the stressor indicators in terms of the amount of wetland area affected by a high level of each stressor indicator evaluated. **Relative risk** is the probability or likelihood of having poor biological condition when the magnitude of a stressor indicator is high relative to when it is low. Relative risk analysis is commonly employed in medicine where it has been used to describe the risk of having a health problem relative to a potential cause or its indicator. For example, a person who smokes has a greater risk of developing lung cancer. Often this is presented as a relative risk ratio; for example, a person who smokes is 15 to 30 times more likely to get or die of lung cancer than someone who does not (CDC 2015). Similarly, the relative risk value for an ecological stressor measures the likelihood that a wetland will have poor ecological condition if the wetland has high levels of the stressor rather than if the wetland had low or moderate levels of the stressor. Finally, calculation of **attributable risk** provides an estimate of the proportion of the wetland area in poor condition that could be reduced if the effects of a particular stressor were eliminated.

It is important to note that while the NPSI was reported with the other indicators of stress in the previous section, it is not used in the analyses to describe risk. Because relative and attributable risk specifically relate stressors to condition, and both the NPSI and VMMI use related data, it is not appropriate to include the NPSI in reporting relative and attributable risk. Although nonnative plant species likely confer risk to wetland condition (see the wetland area extent estimates for the NPSI in the previous section), this risk cannot be evaluated using the relative and attributable risk approach.

National results for relative extent, and relative and attributable risk for each stressor indicator are presented in the following sections of this chapter. Specifics on stressor indicators for each of the NWCA Aggregated Ecoregions are given in Chapter 4.

Relative Extent and Relative Risk

Relative extent is a way to evaluate how widespread and common a high stressor level for each stressor is across the wetland area. A stressor with a high relative extent suggests a national concern. Figure 3-6 (left panel) shows the proportion of wetland area in the U.S. with high stressor levels for each of the stressor indicators. Vegetation removal, surface hardening, and ditching are the most pervasive stressors across the nation. High levels of vegetation removal and surface hardening stressors are found for 27% of the wetland area, while 23% of wetland area has high levels of the ditching stressor.

NARS and the NWCA use the concept of relative risk to estimate the severity of stressor effects. Relative risk is the probability or likelihood of having poor resource condition when a stressor level is high relative to when the stressor is low or moderate. For the NWCA, biological condition is described by the VMMI. A relative risk value of 1 indicates that the stressor indicator has no effect on condition. Relative risk values greater than 1 suggest that the stressor has a greater impact on biological condition (e.g., the vegetation removal indicator has a relative risk of 1.9, indicating that the likelihood of having a poor VMMI score is 90% greater in wetlands with high levels of vegetation removal).

Figure 3-6 (central panel) shows the relative risk, or relative effect, of each stressor on wetland condition. At the national level, vegetation removal, surface hardening (e.g., soil compaction), ditching, damming, filling/erosion, and vegetation replacement are highly associated with poor biological condition in wetlands with relative risk ranges from about 1.5 to 1.6. There does not appear to be a clear relationship between high soil phosphorus or heavy metal concentrations and poor biological condition.

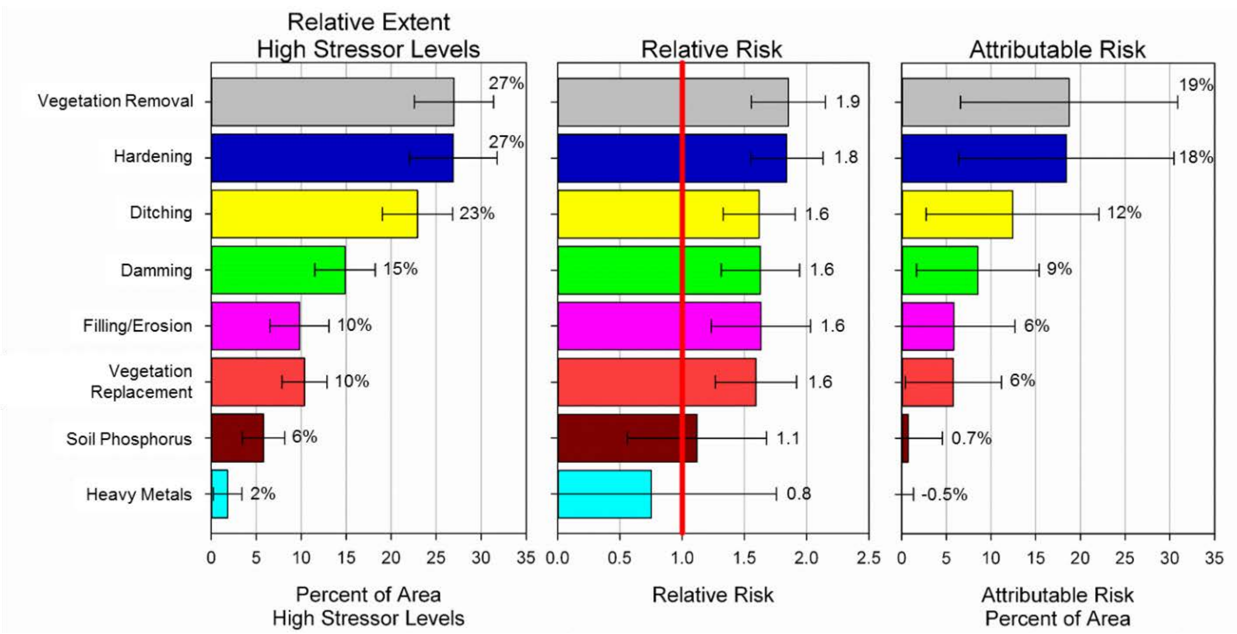


Figure 3-6. National level estimates for relative extent of stressor indicators when stressor level is high, relative risk associated with each stressor indicator, and attributable risk for each stressor indicator relative to wetland biological condition.

Attributable Risk

NWCA uses the calculation of attributable risk to estimate the proportion of wetland area in poor condition that could be reduced if the effects of a particular stressor indicator were eliminated. Attributable risk combines relative extent and relative risk into one value to evaluate the impact of a stressor across the assessed area. The calculation of attributable risk assumes that the stressor causes poor condition, the effects of the stressor can be reversed, and that the stressor's impact on condition is independent of other stressors. These assumptions are difficult to meet with survey data like those collected in the NWCA. Despite these limitations, estimates of attributable risk can provide general guidance as to what stressors are affecting condition and to what degree (relative to the other stressor indicators evaluated). This information can provide an indication of how policymakers and resource managers could prioritize actions and the use of limited resources by stressor, geographic region, and/or wetland type.

Figure 3-6 (right panel) shows the attributable risk for each of the stressor indicators across the nation. The stressors are ranked according to their attributable risk. The stressor categories with the highest attributable risk values are vegetation removal and surface hardening, with 19% and 18%, respectively, of the wetland area potentially affected by each. This estimate suggests, for example, that if high levels of vegetation removal are eliminated as a stressor, one would expect to see 19% of wetland acres improve to good or fair biological condition. Ditching has the next highest relative risk, potentially affecting 12% of the wetland area. It is also important to note that some stressors can have large relative risk values but small attributable risk estimates because the relative extent is small. For example, filling/erosion is found at high levels in only 10% of the wetland area. Although the relative risk number is about 1.6, the attributable risk estimate indicates that nationally only about 6% of wetland acres may improve to good or fair biological condition by eliminating filling/erosion.

These attributable risk estimates indicate the need to continue efforts to reduce the impact of vegetation removal, surface hardening, and ditching nationally. Although some stressors, such as filling/erosion, might not be as widespread nationally, that does not mean that localized management actions targeting these stressors are not needed.

Microcystin Presence and Risk

Microcystins are one group of naturally occurring toxins produced by various cyanobacteria (blue-green algae) that are common in surface waters. Microcystins have been detected nationally in lakes and reservoirs and are considered to be the most commonly occurring class of cyanobacteria toxins (cyanotoxins). 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. As in other NARS assessments, the microcystin results reported here focus on risks associated with recreational contact. Information on other exposure risks is discussed in the NWCA 2011 Technical Report (USEPA 2016, Chapter 10).

Although there are relatively few documented cases of human health effects from exposure to cyanotoxins through recreational activities, exposure to cyanobacteria or their toxins may produce allergic like reactions such as skin rashes, eye irritations, respiratory symptoms, and in some cases gastrointestinal illness, liver and kidney damage, and in rare cases even death. During recreational activities, exposure for humans may occur through accidental ingestion, inhalation or direct contact. Cyanotoxins can also be a concern in drinking water.[2] In addition to human impacts, livestock, pets and wildlife are also exposed to cyanotoxins when consuming scum or drinking cyanotoxins-contaminated water. The probability of adverse recreational health effects for humans due to cyanobacteria and/or microcystin exposure is frequently assessed based on World Health Organization (WHO) guidance thresholds (see Table 2-5). Many states have developed harmful algal bloom (HAB) guidance thresholds in the event of a cyanobacterial bloom and cyanotoxins in recreational waters.

The occurrence of microcystins in wetlands at national and ecoregional scales is shown in Figure 3-7. This figure presents both the percentage of wetland area and the number of wetland acres where microcystin is detected, not detected, or unassessed (i.e., no microcystin sample was collected). The NWCA found that, nationally, 12% of wetland area has detectable concentrations of microcystin. Microcystin is not detected at 27% of wetland area, nationally, and 61% of wetland area is unassessed. The large percentage of unassessed wetland area is due to the large number of wetland sites where water depth was not deep enough for a microcystin sample to be collected. At the ecoregional scale, NWCA finds that the Interior Plains has the highest percent of wetland area with detectable

[2] In June 2015, EPA announced health advisory values for microcystin in drinking water. The Agency is using a non-regulatory option of health advisories to address the growing public health threat of cyanotoxins in drinking water. The health advisory values are 0.3 micrograms per liter (µg/L) for children younger than six and 1.6 µg/L for children six and older and adults.

concentrations of microcystin at 34%. This is much larger than the other NWCA Aggregated Ecoregions, which each have ranges closer to the national estimate.

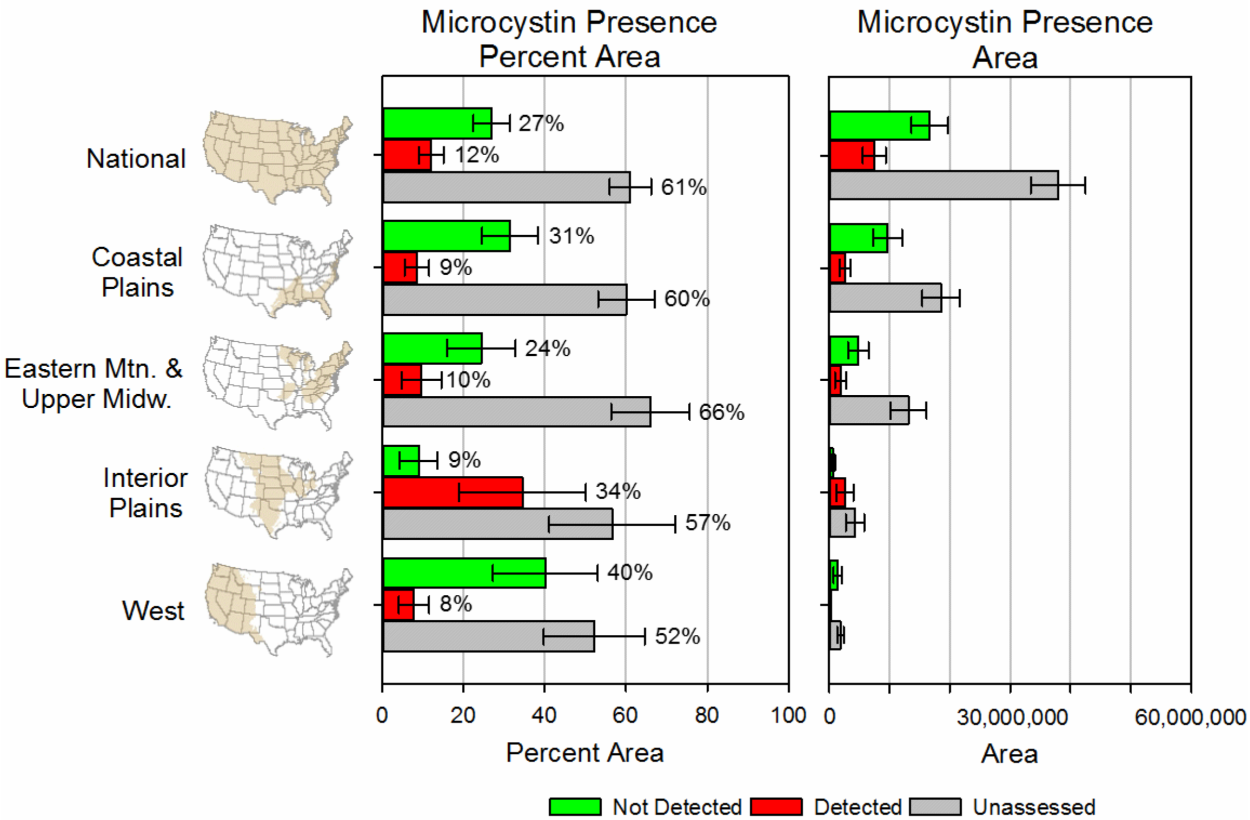


Figure 3-7. Estimated occurrence of microcystin in wetlands. Results are presented nationally and by NWCA Aggregated Ecoregion.

The level of risk associated with recreational exposure to microcystin in wetlands at national and ecoregional scales is shown in Figure 3-8. This figure presents both the percentage of wetland area and number of wetland acres in different risk categories (low, moderate, high) based on the WHO thresholds. Nationally, and across the NWCA Aggregated Ecoregions, NWCA finds very little wetland area (< 1%) at either moderate or high risk levels. Most wetland area is at low risk levels or could not be assessed.

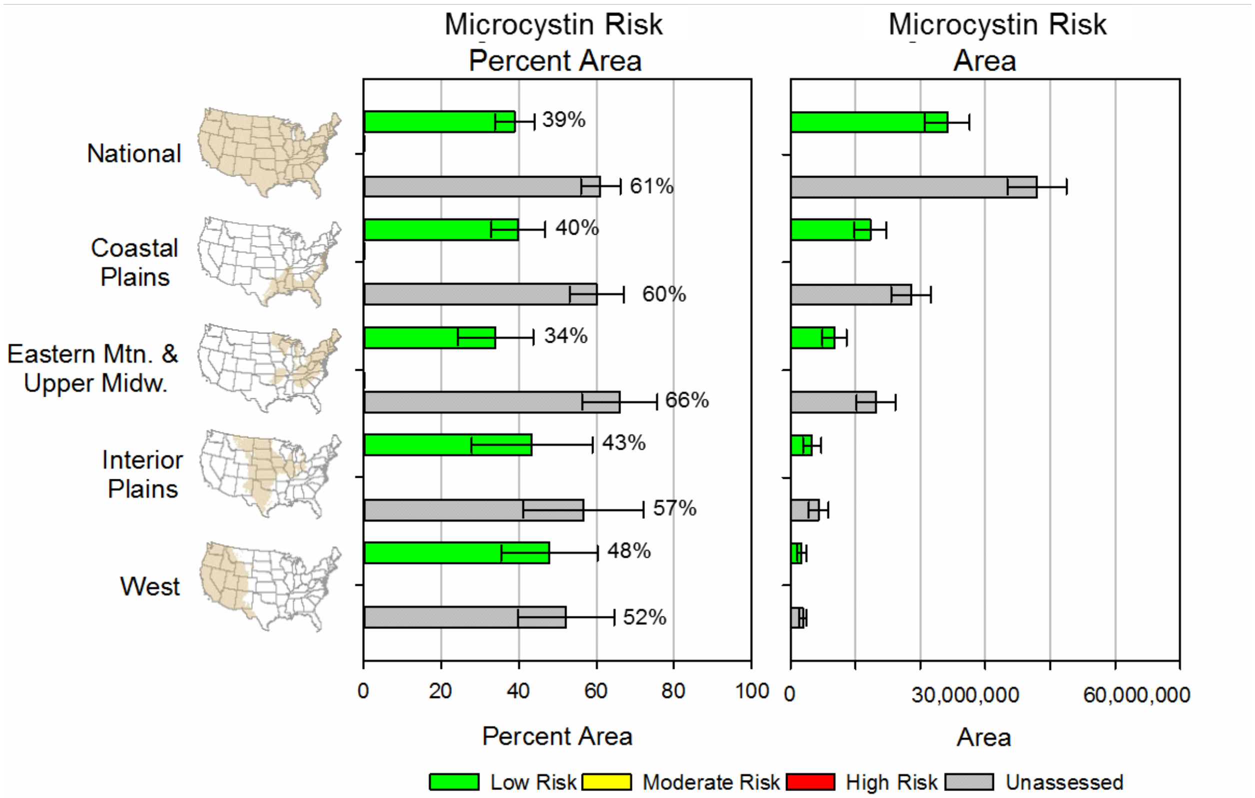


Figure 3-8. Estimated extent of recreational health risk from exposure to microcystin by risk category (low, moderate, and high) based on WHO guidelines. Results are presented nationally and by NWCA Aggregated Ecoregion.

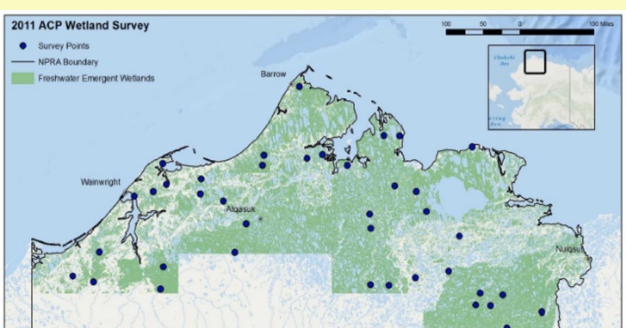
Alaska's Arctic Wetlands Assessment

Terri Lomax, Alaska Department of Environmental Conservation

In 2011, as part of EPA's National Wetland Condition Assessment (NWCA) the Alaska Department of Environmental Conservation (DEC) completed a wetland condition assessment in the Arctic Coastal Plain region of the National Petroleum Reserve-Alaska. Due to Alaska's size and limited infrastructure statewide surveys are not feasible, leaving regional assessments as a more realistic option for sampling in Alaska. DEC partnered with the University of Alaska Anchorage and the North Slope Borough to complete this survey.

Arctic Wetlands. Photo courtesy of Alaska DEC.

Freshwater emergent wetlands are the dominant wetland type in the region, and were selected from the National Wetland Inventory within the sample region. Within this sample frame 57,188 freshwater emergent wetland polygons exist, totaling more than 5 million acres. To relieve community concerns with potential helicopter interference of subsistence hunting activities we created a buffer around high subsistence use areas and excluded sites in the sample frame that fell within the buffer. From the remaining population, 40 random sites were selected according to NWCA protocols. Alaska's limited infrastructure, small population base, and the remote nature of most of the state drives the selection of sites in random surveys, typically only selecting sites with reference or near reference condition. In prior DEC surveys this proved to be problematic as range of disturbance is needed to understand condition and develop metrics based on stress. To overcome this we added 10 targeted sites to our survey, these sites with known or potentially impacted freshwater emergent wetland sites within the sample area. Wetlands in this region differ significantly from wetlands surveyed in the contiguous United States and therefore required modifications to national methods. The Arctic Coastal Plain, the land of the midnight sun and the polar night, is a vast treeless area underlain by continuous permafrost. In cooperation with EPA, DEC modified the national methods to include non-vascular plant identification, modified soil methods to account for permafrost conditions, and excluded analyses requiring short hold times.



Freshwater emergent wetlands in the Arctic Coastal Plain of the National Petroleum Reserve - Alaska, and sites surveyed during the Alaska NWCA survey.

Overall, assessment areas averaged 33 cm of water depth and 16% of the area was covered with surface water. Sites averaged an 89 meter vegetated buffer out of the 100 meters evaluated. The plant community was comprised of short woody and emergent species. 65% of sites were dominated by *Carex aquatilis*, *Eriophorum vaginatum* was the second most common species identified. Other common plants included several species of *Salix*, *Eriophorum russeolum* and *angustifolium*, and *Betula nana*, all typical of arctic emergent wetlands. Permafrost was encountered at all sites, at an average depth of 43 cm.

An ice auger had to be used to collect soil cores during the survey, as ice and permafrost were encountered at every survey site. Photo courtesy of Alaska DEC.

Results were evaluated for patterns across the landscape, overall, and in targeted verses random sites. Differences were observed between random verses targeted sites, but otherwise no significant patterns were observed. The percentage of sites with stressors identified in the buffer and assessment area was greater in targeted sites, additionally plant and diatom richness was greater at targeted sites than random sites. Targeted sites were typically adjacent to previous military installments with one to several meters of fill forming a pad on the tundra. Water chemistry and soil profiles did not demonstrate significant differences.

As expected, stressors were more often observed in targeted sites and typically involved changes in the soil (soil compaction, recent fill, and grading). The next most common stressor identified was off-road vehicle use. Mild to moderately severe stressors were observed in the assessment area of 100% of targeted sites and mild stressors were observed in 37% of random sites. Similar stressors were observed in the buffer of all targeted and none of the random sites. We are continuing to evaluate the data in relation to lake, river, stream and coastal surveys in the same region.

The soil buckles and cracks above the ice wedges that are driven into permafrost, causing polygon patterns to form in the landscape. Photo courtesy of Alaska DEC.

The success of our survey is attributed to our partnerships. Working with local tribal governments, federal and state agencies, and the University was crucial to overcoming numerous challenges. During field work we experienced freezing weather, gale force winds, equipment malfunctions, medical emergencies, and major logistical hurdles. In spite of these challenges, we were able to sample 41 out of the 50 wetlands selected.

To learn more, contact Terri Lomax (terri.lomax@alaska.gov; 907-269-7635), Alaska Department of Environmental Conservation, or visit: https://dec.alaska.gov/water/wqsar/monitoring/AKMAP.htm

Chapter 4: Ecoregion and Wetland Type Results

Ecoregions are geographic areas with similar environmental characteristics, such as climate, vegetation, type of soil, and geology. EPA has defined ecoregions at various scales, from large areas to finer units of the landscape (Omernik 1987, USEPA 2011a). The EPA ecoregions have been widely used in assessing resource status, establishing water quality and biological condition criteria, and setting management goals for resource protection. NARS uses the various levels (scales) of these EPA ecoregions because they were developed to support decision-making for aquatic resources, and it is important to consider aquatic and other natural resources within the context of their ecological setting.

Wetlands in an ecoregion tend to have more similar natural characteristics to each other than with wetlands in other parts of the country. Forested wetlands in the Upper Midwest, for example, share more similar traits with other forested wetlands in this region than they do with forested wetlands in the Coastal Plain. Additionally, different wetland types have distinct characteristics that distinguish them from other wetland types. Wetland types and ecoregions are useful in evaluating and understanding results describing ecological condition and stress because of these patterns.

Previous NARS studies have combined Level III ecoregions into nine major ecoregion groups in order to evaluate the data at ecoregional scales. In the NWCA, to ensure enough sample points within a reporting group to present statistically valid results, it was necessary to combine ecoregions and wetland types for data analysis (see Chapter 2, How are the NWCA results presented?).

The four **NWCA Aggregated Ecoregions** (Figure 4-1) are based on a combination of smaller scale EPA ecoregions:

- Coastal Plains
- Eastern Mountains & Upper Midwest
- Interior Plains
- West

The seven NWCA wetland types were combined into four **NWCA Aggregated Wetland Types**:

- **Estuarine Herbaceous**
- **Estuarine Woody**, which represents both scrub-shrub and forested wetlands.
- **Inland Herbaceous**, which represents emergent, unconsolidated bottom/aquatic bed, and farmed wetlands not in crop production.
- **Inland Woody**, which represents both forested and scrub-shrub wetlands.

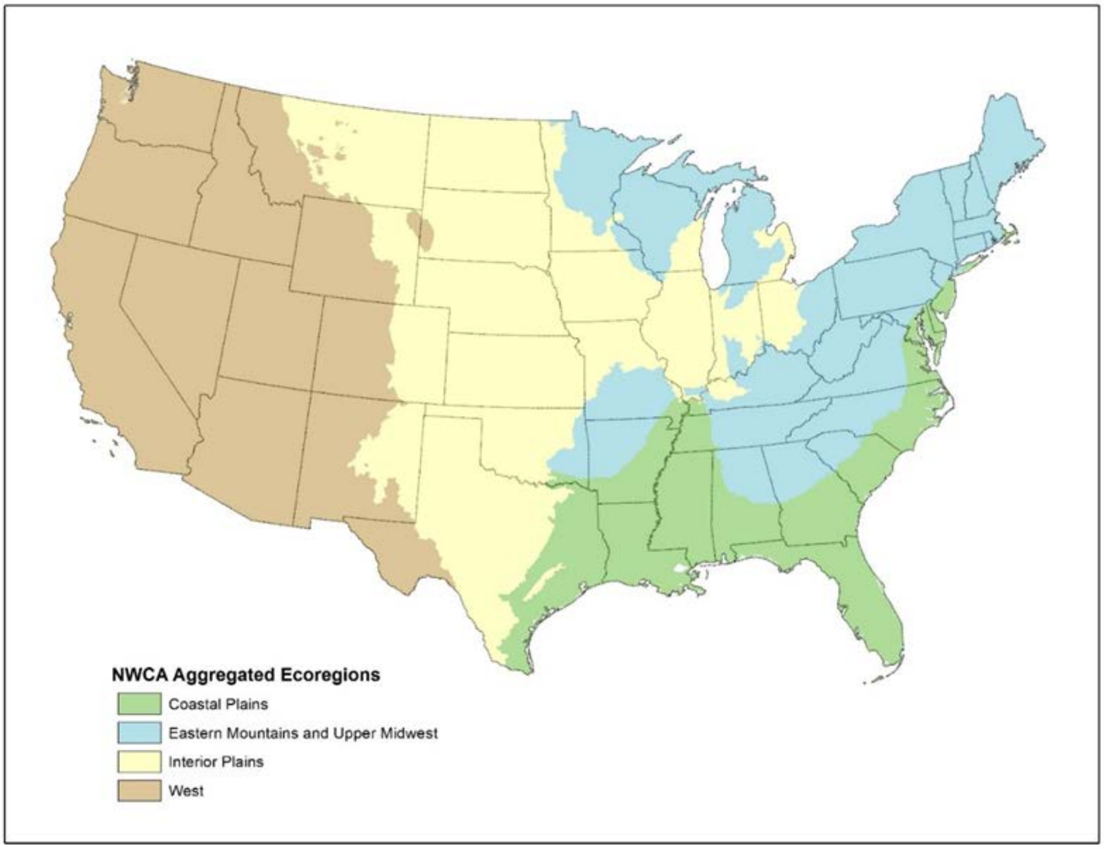


Figure 4-1. The NWCA Aggregated Ecoregions. Chapter 2 of this report and the NWCA 2011 Technical Report (USEPA 2016) detail the compilation of these four ecoregions.

In this chapter, condition and stress results are reported by each major NWCA ecoregion group and for NWCA aggregated wetland types:

- Results for each of the four NWCA ecoregions are presented in two ways based on 1) all NWCA wetland types occurring in a region; and 2) aggregated inland herbaceous and inland woody wetland types within a region.
- Results for estuarine herbaceous and estuarine woody wetland types are presented in the Estuarine Wetlands section of this chapter and include all NWCA ecoregions where estuarine wetlands occur (Coastal Plains, Eastern Mountain and Upper Midwest, and West).

NWCA results should not be extrapolated to an individual state or specific wetland within the ecoregions because the study is not intended or designed to characterize conditions at these finer scales. A number of states worked with EPA to design and implement statistically-based assessments at the state scale in order to characterize the condition of wetland populations within their states. Short highlights discussing these studies appear throughout the report.

Coastal Plains Ecoregion

Landscape setting of the ecoregion

The Coastal Plains ecoregion includes the Mississippi Delta and Gulf Coast, runs north along the Mississippi River to the Ohio River, and includes Florida and eastern Texas, and the Atlantic seaboard from Florida to Cape Cod.

The Coastal Plains is relatively flat and much of the area is less than 500 feet above sea level. Most of the region is composed of sedimentary rocks or unconsolidated sediments of marine origin, with some areas made up of younger alluvial deposits. A large proportion of the natural vegetation is mixed pine and hardwood forests. Along the western edge of the region (coastal Texas and Louisiana), post oak savanna and prairie vegetation is more common. The Mississippi River Valley is dominated by bottomland deciduous forests.

The climate in the Coastal Plains is temperate wet to subtropical, with average annual temperatures ranging from 50 to 80°F. Average annual precipitation ranges from 30 to 79 inches.

Although many areas had been previously cleared for agricultural purposes, much of the region has been reforested or is used for lumber and pulpwood production. Agricultural crops, pasture, and rangeland is found throughout the region, but production of cotton, soybeans, rice, and sugarcane remains a dominant land use in the Mississippi Valley.

The types of wetlands found throughout the region are diverse. Tidal salt and brackish marshes and tidal and non-tidal freshwater marshes are found along the Gulf and Atlantic coasts. In the most southern part of the region (central Florida and southward) mangrove swamps are found in association with coastal marshes. In the interior portions of the Coastal Plains, bottomland hardwood forests and swamps occur along rivers, streams, and their headwaters. Other wetlands found throughout the Coastal Plains region are locally referred to as flatwoods, pineywoods, pine savannas, pine barrens, flatlands, and coastal prairies. These wetlands can be dominated by herbaceous plants, hardwoods, pines, or a mixture of vegetation. Freshwater bogs, called pocosins, are found from southern Virginia to northern Florida.

Swamp in Florida (site NWCA11-1258). Photo courtesy of University of Florida.

In the Coastal Plains, there are several well-known wetland complexes, including the Florida Everglades, the Okefenokee Swamp in southeastern Georgia and northeastern Florida, the Great Dismal Swamp in southeastern Virginia and northeastern North Carolina, and the Louisiana Delta (a complex of forested wetlands, freshwater marshes, salt marshes, and shallow coastal lakes).

Summary of findings

A total of 513 randomly selected sites were sampled in the Coastal Plains ecoregion during the 2011 field season, representing 30,893,305 acres. Of the total number of Coastal Plains sites sampled, 62 are inland herbaceous wetlands, representing 3,750,551 acres, and 163 are inland woody wetlands, representing 21,859,265 acres. Estuarine wetlands in the Coastal Plains include 288 sites, representing 5,283,489 acres. Detailed results for estuarine wetland types are reported in the Estuarine Wetlands section of this chapter.

Biological Condition

For all wetland types assessed in the Coastal Plains (Figure 4-2), 50% of the estimated wetland area is in good condition; 21% is in fair condition and 29% is in poor condition based on the Vegetation Multimetric Index (VMMI) (see Chapter 2 for details on the VMMI). The proportion of wetland area in good (50%), fair (26%), and poor (25%) is similar for inland woody wetlands in this ecoregion. The NWCA found that the proportion of inland herbaceous wetlands in poor condition, however, is much larger, 59%, than the proportion of inland woody wetlands in poor condition (Figures 4-3 and Figure 4-4).

Indicators of Stress

For all wetland types assessed in the Coastal Plains, vegetation removal, ditching, and surface hardening are the indicators with the greatest proportion of wetland area at high stressor levels (Figure 4-2). However, the majority of wetland area throughout the ecoregion has low levels for each of the stressors. Key findings include:

- Vegetation removal is high for 25% of the wetland area compared to moderate for 21% and low for 54% of wetland area.
- Hardening levels are high in 23% of wetland area, while 9% and 69% of wetland area have moderate or low stressor levels, respectively.
- Ditching is high in 21% of the wetland area, moderate in 5%, and low in 74%.

For inland wetland types assessed within the Coastal Plains ecoregion (Figures 4-3 and 4-4), data show:

- More than half of the area assessed for inland herbaceous wetlands has high stressor levels associated with vegetation removal (61%), hardening (57%), and ditching (52%).
- The most prevalent stressors at high levels for inland woody wetlands are also vegetation removal (24% of wetland area), hardening (20%), and ditching (16%), but these high stressor levels are a smaller proportion of wetland area compared to the herbaceous wetlands.
- The extent of high levels of vegetation removal, damming, ditching, hardening, and filling/erosion stressors are greater in inland herbaceous wetlands than in inland woody wetlands. Very high and high levels for the nonnative plant stressor indicator are also greater in herbaceous wetlands.

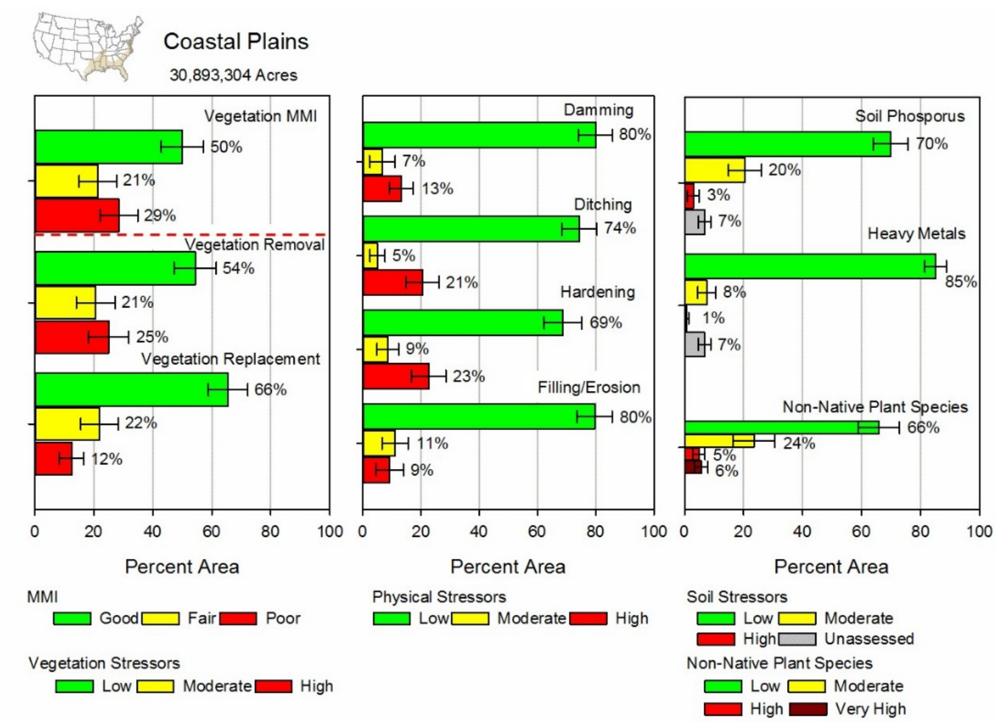


Figure 4-2. NWCA 2011 survey results for the wetlands (i.e., all target wetland types) across the Coastal Plains. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

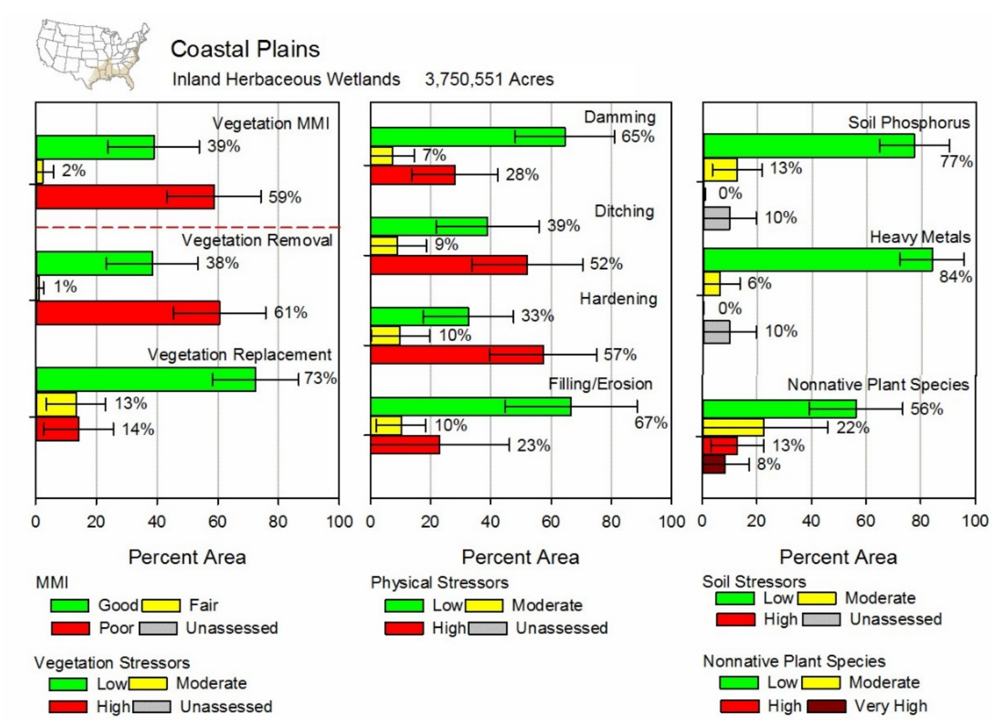


Figure 4-3. NWCA survey results for the inland herbaceous wetland type across the Coastal Plains. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

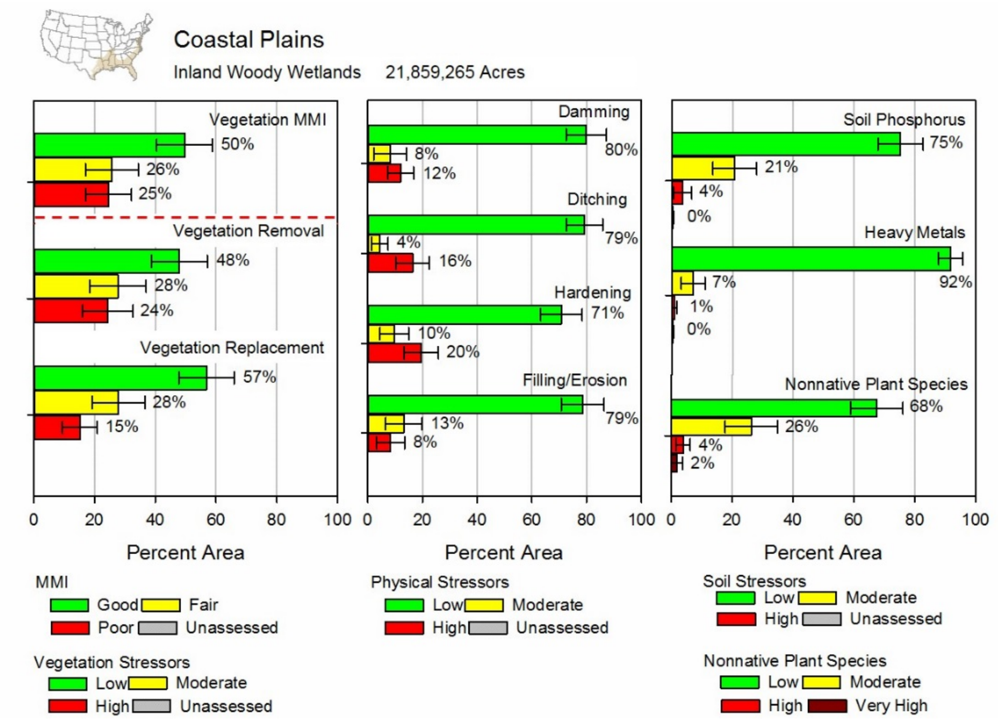


Figure 4-4. NWCA 2011 survey results for the inland woody wetland type across the Coastal Plains. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

Southeast Wetlands Monitoring and Assessment Intensification Study: North Carolina, South Carolina, Alabama, and Georgia

Rick Savage and Kristie Gianopulos, N.C. Department of Environment and Natural Resources

Overview: Recognizing that natural ecosystems are not confined within state boundaries, four neighboring states embarked on an unprecedented collaboration to study the condition of forested wetlands in the Southeastern United States. North Carolina, South Carolina, Georgia, and Alabama performed a regional analysis of forested wetlands within the Piedmont and Coastal Plain ecoregions, using both NWCA survey methodologies and additional indicators of wetland health (i.e., amphibian, macroinvertebrates, and overall landscape measures). The regional intensification project included 110 forested wetlands across the four states involved in the study. Data reveal differences in condition between the ecoregions, as well as areas of possible concern for amphibian populations.

Sampling and Protocols: There were 45 wetland sites sampled in the Piedmont Region and 65 wetland sites sampled in the Coastal Plain Region. At each of these sites, NWCA data were collected as well as additional indicators, including for amphibians and macroinvertebrates. This intensification study developed a composite scoring system from several data indicators gathered at each location in order to determine the overall wetland condition at each site. The wetland condition index integrated several important measurements into one total, including the following individual biotic and abiotic measures: the vegetation mean C; vegetation invasive species cover, the Amphibian Quality Assessment Index (AQAI), macroinvertebrate diversity, the buffer Landscape Development Intensity Index (LDI), the Ohio Rapid Assessment Method score, water quality nutrients, and soil metals information. Mean C is a commonly used metric based on Coefficient of Conservatism values of the plant species. Species are rated from 0 to 10 based on their fidelity to natural habitat; a high C value indicates nearly all species occurrences are in pristine habitat and low C values are assigned to weedy species which are

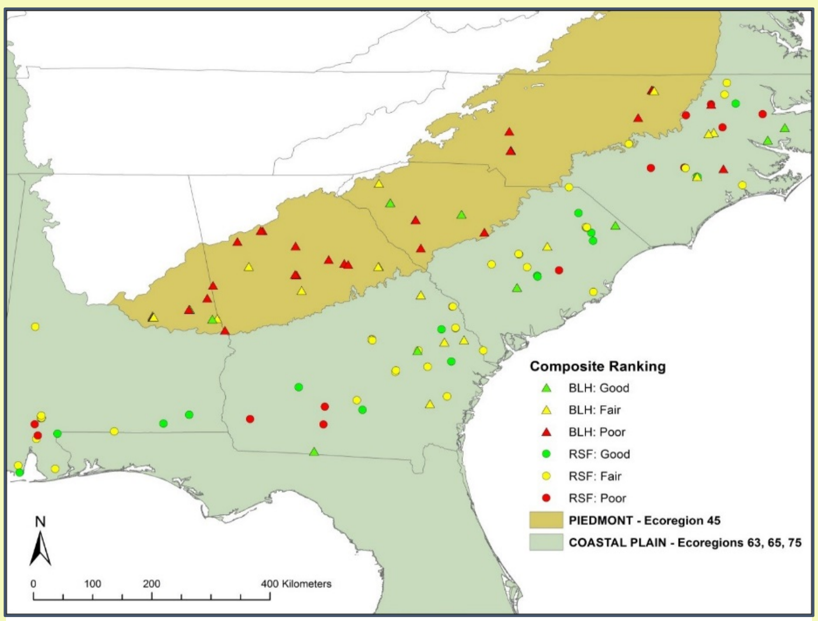


Figure 1. Composite rankings for forested wetland sites; good rankings indicate best quality and poor rankings indicate lowest quality, based on a variety of factors.

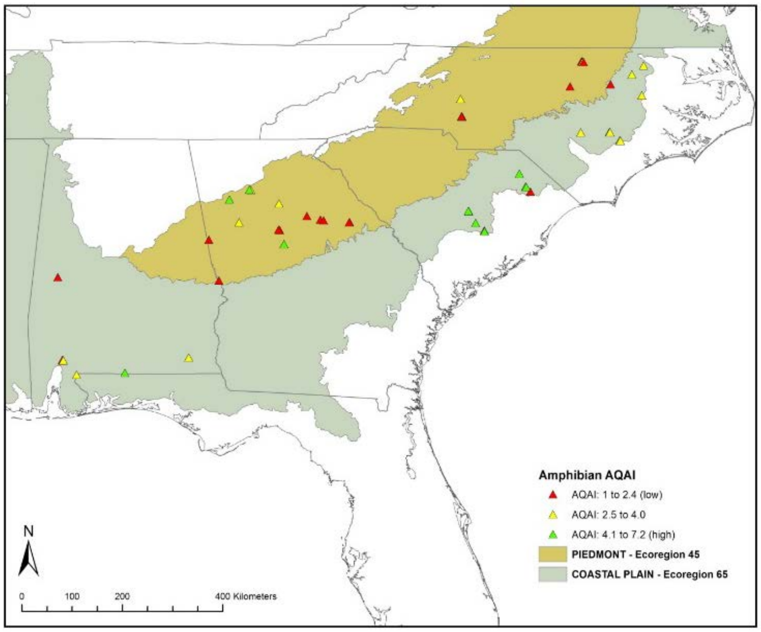


Figure 2. Wetland condition based on Amphibian AQAI indicator; low numbers indicate low species quality.

tolerant of human-caused disturbance. The LDI scores were developed using GIS analysis of land uses and their aerial extent surrounding sampled wetland points. The AQAI values were calculated using Coefficient of Conservatism ratings developed for amphibian species and an equation identical to that used commonly for floristic quality assessments (FQA). Low AQAI values indicate low species diversity at a given site, while higher numbers correspond with increasing quality.

What They Have Learned: Data analysis reveal differences between the ecoregions and have identified areas of possible concern for amphibian populations. Composite rankings (Figure 1) for forested wetland sites within the region indicate that forested wetlands in the Southeastern Coastal Plain (riverine swamp forests) are in better condition than those in the Piedmont ecoregion (bottomland hardwood forests). This may not be surprising since the Piedmont has been heavily farmed and is more densely populated.

In addition to the overall composite score, specific measures like the AQAI provide insight into the condition of wetlands and management implications for amphibian habitat. Amphibians are considered sentinel indicators because of their sensitivity to environmental stress, making them ideal for regional biomonitoring. While all of these results are preliminary, the AQAI scores derived from sampling site data are largely consistent with the overall composite indicator of wetland condition.

Marbled Salamander (*Ambystoma opacum*).

Generally, greater numbers of amphibian species were found in Coastal Plain sites, where unique species counts ranged from 3 to 12 (mean = 4.9). In the Piedmont ecoregion, the number of amphibian species found at each site ranged from 1 to 7 species (mean = 3.8). These numbers correspond to AQAI values in the good score (green), fair (yellow), and poor score (red) categories as seen in Figure 2. Similar to the findings of the overall composite scoring, AQAI values in the Piedmont Region were relatively low or poor compared to AQAI scores for the Coastal Plain wetlands. The marbled salamander is a species particularly sensitive to anthropogenic disturbances, and is found mainly in the highest quality wetland sites. Marbled salamander were found in twice as many Coastal Plain sites (12) as Piedmont sites (6).

Overall, this type of wetland condition information can aid state and regional management decisions about wetland services such as flood control, water quality filtering, or the identification of restoration needs and opportunities. When the full analysis is complete, the improved knowledge of wetland condition in the Southeast region will help state agencies and conservation organizations to target scarce resources toward improving wetland condition in an efficacious way.

To learn more, contact Rick Savage (rick.savage@carolinawetlands.org; 919-412-9754), Carolina Wetlands Association or Kristie Gianopulos (kristie.gianopulos@ncdenr.gov; 919-707-8796), N.C. Department of Environment and Natural Resources.

Eastern Mountains and Upper Midwest

Landscape setting of the ecoregion

The NWCA Eastern Mountains and Upper Midwest ecoregion combines the Northern Appalachians, Southern Appalachians, and the Upper Midwest NARS ecoregions. The region includes portions of Minnesota, Wisconsin, Michigan, northeastern Ohio, and virtually all of the New England states. It also includes New York, Pennsylvania, West Virginia, most of Kentucky, a significant part of Tennessee, as well as portions of East Coast states interior to the Coastal Plains ecoregion. The southern part of the ecoregion extends into northeastern Alabama and the Ouachita Mountains in Arkansas, Missouri, and Oklahoma.

Dominant landscape features of the Eastern Mountains and Upper Midwest ecoregion include the Appalachian Mountains and the Great Lakes Basin. Retreating ice during the last glacial period and karst topography were important in shaping the region's landscape. The northern portion is composed of glaciated terrain, with expansive plains and hills in the area surrounding the Great Lakes. In some areas (particularly northern Minnesota), extensive peatlands have formed on glacial lake plains. Most of the Northern Appalachians was also glaciated, resulting in mountainous or hilly terrain with intermixed plains. The Southern Appalachian region is also hilly, with wide valleys, plateaus, and irregular plains. Northern boreal and broadleaf deciduous forests transition to broadleaf and needleleaf forest communities toward the south.

The climate of the Eastern Mountains and Upper Midwest is characterized by a range of temperatures and precipitation. Cold winters and relatively short summers with a mean of 20 to 47 inches of precipitation characterize the areas surrounding the Great Lakes. Moving eastward, the climate is slightly warmer with increased annual precipitation totals ranging from 35 to 60 inches. Average annual temperatures range from 39 to 49^{o}F. The southern portion of the ecoregion is both warmer and wetter, with annual precipitation of about 40 to 80 inches and average annual temperatures ranging from 52 to 59^{o}F.

Forests in the Eastern Mountains and Upper Midwest were extensively cleared in the 18th and 19th centuries for agricultural and industrial production. Today, much of the area within this ecoregion is highly populated and major manufacturing, including chemical, steel and power production may be found in metropolitan areas throughout the ecoregion. However, much of the northern part of the region remains forested and relatively undeveloped.

Wetlands are relatively abundant in the northern portion of the ecoregion, owing to the climate and glaciated terrain. In contrast, wetlands are not as dominant a landscape feature in the southern portion. Forested wetlands are the most common type found throughout the ecoregion, and include forested swamps, bottomland hardwoods, wet flatwoods in the plains of the Great Lakes, and boreal coniferous forested bogs. Depressional wetlands, such as small ponds, kettle depressions, and vernal pools, form in low-lying areas left from retreating glaciers, areas with karst topography, and other landscape characteristics. Freshwater marshes are common around the Great Lakes and other water bodies throughout the ecoregion, while salt marshes may be found along the New England coastline.

Forested wetland in New Hampshire (site NWCA11-2163). Photo courtesy of New Hampshire Department of Environmental Services.

Well known wetland complexes in the Eastern Mountains and Upper Midwest include the Boundary Waters area of Northern Minnesota, Horicon Marsh in Wisconsin, and Montezuma Swamp in the Finger Lakes region of New York.

Summary of findings

A total of 152 randomly selected sites were sampled in the Eastern Mountains and Upper Midwest ecoregion during the 2011 field season, representing 19,956,668 acres. Of the total number of Eastern Mountains and Upper Midwest sites sampled, 55 are inland herbaceous wetlands, representing 3,762,089 acres, and 83 are inland woody wetlands, representing 16,165,406 acres. Estuarine wetlands in the Eastern Mountains and Upper Midwest included 14 sites, representing 29,173 acres. Detailed results for estuarine wetland types are reported in the Estuarine Wetlands section of this chapter.

Biological Condition

For all wetland types assessed in the Eastern Mountains and Upper Midwest (Figure 4-5), 52% of the estimated wetland area is in good condition; 11% is in fair condition, and 37% is in poor condition based on the VMMI. Inland herbaceous wetlands have 62% of assessed wetland area in good condition, 17% in fair condition, and 22% in poor condition (Figure 4-6). Compared to the inland herbaceous wetlands, a slightly lower proportion of inland woody wetlands are in good and fair condition, 50% and 9%, respectively, while a greater proportion of inland woody wetlands are in poor condition, 41% (Figure 4-7).

Indicators of Stress

For all wetland types assessed in the Eastern Mountains and Upper Midwest, surface hardening, vegetation removal, ditching, and soil phosphorus concentration are the indicators with the greatest proportion of wetland area at high stressor levels (Figure 4-5). However, the majority of wetland area throughout the ecoregion had low levels for each of the stressors. Key findings include:

- Hardening has high stressor levels for 22% of wetland area, while 23% and 55% have moderate or low levels, respectively.
- Vegetation removal stressor levels are high in 17% of wetland area, moderate in 15% of wetland area, and low in 68% of wetland area.

- Ditching is high in 15% of the wetland area, moderate in 8%, and low in 77%.
- Soil phosphorus concentrations in this ecoregion are at high stressor levels for 13% of wetland area, moderate for 22% and low for 63% of wetland area. Soil phosphorus could not be assessed for 1% of the wetland area due to difficulties collecting soil samples at some sites.

For inland wetland types assessed within the Eastern Mountain and Upper Midwest ecoregion (Figures 4-6 and 4-7), data show:

- The most prevalent stressors at high levels for inland herbaceous wetlands are soil phosphorus (35% of wetland area), vegetation removal (18%), ditching (14%), hardening (12%), and damming (12%).
- The most prevalent stressors at high levels for inland woody wetlands are hardening (25% of wetland area), vegetation removal (17%), and ditching (15%).
- High stressor levels for soil phosphorus are found at a greater proportion of wetland area for inland herbaceous wetlands (35%) than inland woody wetlands (8%). It should be noted that 8% of the herbaceous wetlands could not be assessed for soil phosphorus due to difficulties collecting soil samples at some sites. Less than 1% of woody wetlands were not assessed.
- Hardening is a more prevalent stressor for inland woody wetlands, with 25% of wetland area having high-stressor levels compared to 12% for inland herbaceous wetlands.

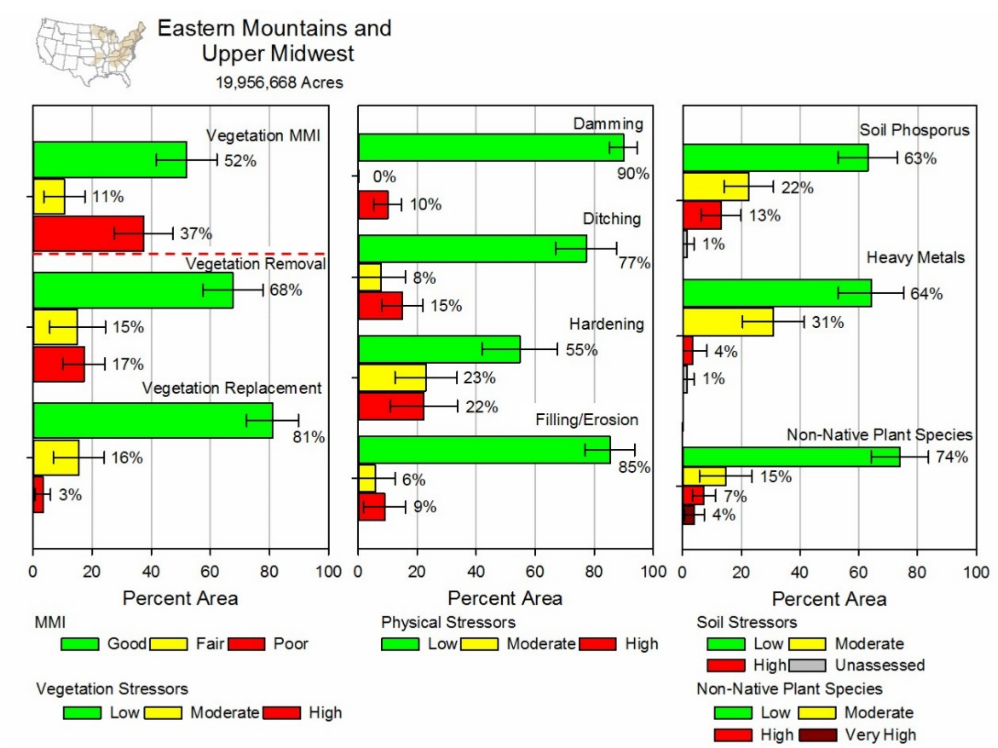


Figure 4-5. NWCA 2011 survey results for the wetlands (i.e., all target wetland types) across the Eastern Mountains and Upper Midwest. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

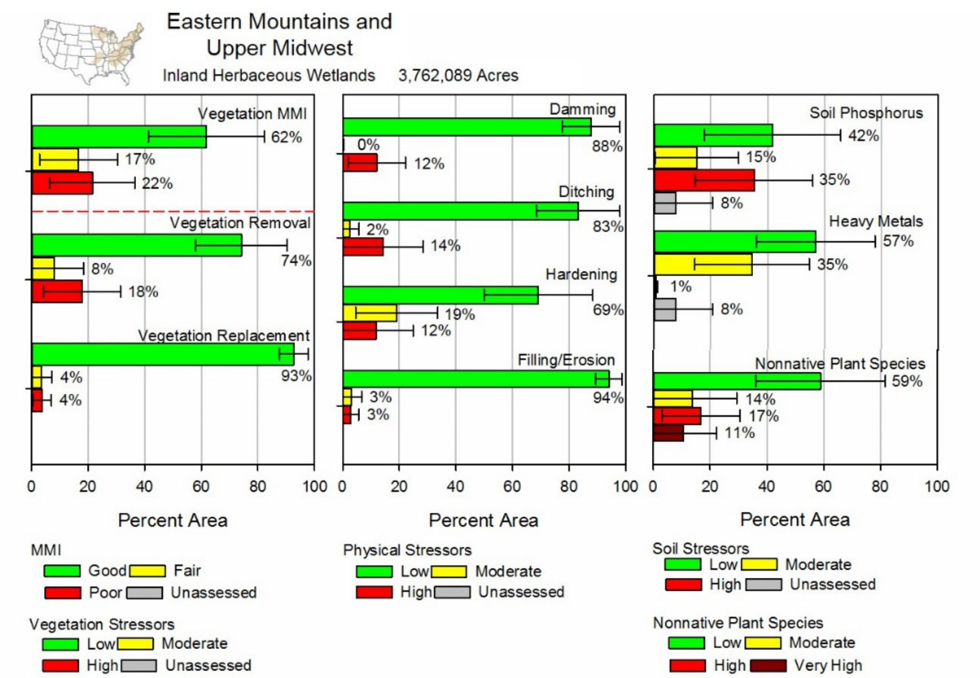


Figure 4-6. NWCA 2011 survey results for the inland herbaceous wetland type across the Eastern Mountains and Upper Midwest. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

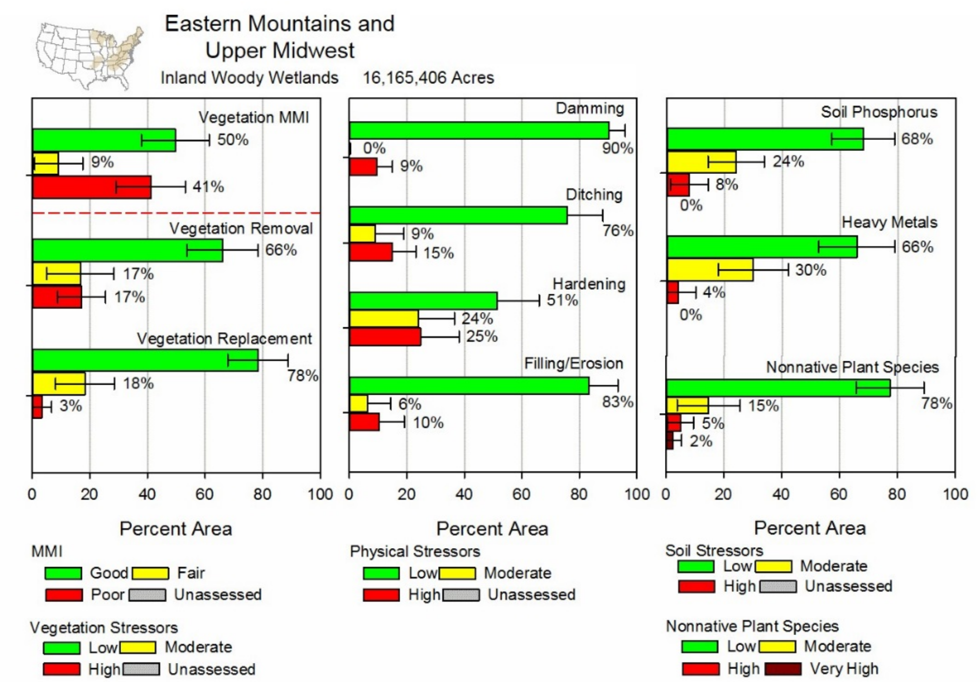


Figure 4-7. NWCA 2011 survey results for the inland woody wetland type across the Eastern Mountains and Upper Midwest. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

Establishing a Baseline for Ohio's Valuable Wetland Resources: A National Wetland Condition Assessment Intensification

Brian Gara, Ohio EPA

Objectives: According to previous estimates, Ohio has lost approximately 90% of its original, pre-settlement wetland habitat (Dahl 1990). The main goal of this intensification project was to perform a statewide survey to determine the current ecological condition of wetlands in Ohio that will serve as a baseline for future studies of this valuable and diminishing resource. A randomly-selected sample of 50 wetlands were studied between 2011 and 2014 to generate the data necessary to determine condition and to:

(1) Compare and contrast the results NWCA 2011 with results generated from Ohio's Level 1, 2, and 3 wetland assessment methodologies.

(2) Identify differences in how NWCA and Ohio field methods assess wetland conditions that will help inform monitoring protocols for future state and national wetland condition assessments.

(3) Develop a plan to consistently repeat this statewide analysis on a regular schedule to illustrate long-term trends in both wetland quantity and quality in Ohio.

Protocols and Methods Used: Eleven wetland sites were sampled in Ohio for the NWCA 2011 survey, following the national NWCA protocols. An additional 39 wetland sites were sampled over the course of four field seasons (2011-2014) using the national protocols and other wetland methodologies previously developed by Ohio EPA. Because the sample design is area-weighted, a large proportion of the sites included in Ohio's intensification study are located in the northeastern part of the state, where a majority of the remaining wetland area is contained (Figure 1). The other assessment methodologies included the Ohio Rapid Assessment Method for Wetlands (ORAM), a simplified soil sampling protocol, and expanded identification and collection of all unique bryophyte species found within NWCA vegetation plots to calculate metrics for bryophytes. From these data, an ORAM score, a

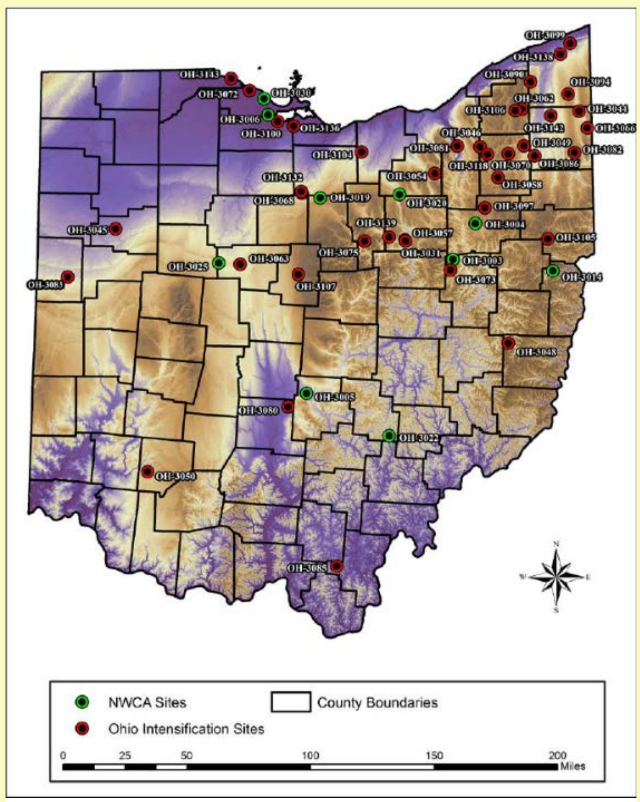


Figure 1. All Ohio NWCA and intensification sites included in the study.

Vegetation Index of Biotic Integrity (VIBI), and a recently developed vegetation analysis called the VIBI-Floristic Quality (VIBI-FQ), were calculated for each site. The VIBI-FQ is a simplified analysis of vegetation based on two equally-weighted metrics calculated for diversity and dominance (Gara 2013). Ohio utilized proposed bryophyte metrics in order to explore the utility of bryophyte taxonomic group systems as a potential measure of ecological condition. The metrics include (1) the proposed Moss Quality Assessment Index (Moss QAI); (2) the number of bryophyte species; and (3) the number of bryophyte genera.

What They Found: The 2011-2014 intensification project provided a unique opportunity to survey a random sample of wetlands in Ohio. Using the data collected, Ohio has completed ORAM, VIBI and VIBI-FQ assessments, which all suggest that Ohio wetland resources are in generally good ecological condition. Both VIBI and VIBI-FQ assessments resulted in approximately half of the wetlands within the "Excellent" or "Good" ecological condition ranges, while the ORAM assessment resulted in over half of wetlands within that upper range (Table 1). This is higher than expected, given the amount of wetland loss experienced historically.

Wetland Condition	ORAM	VIBI	VIBI-FQ
"Poor"	7 (14%)	11 (22%)	8 (16%)
"Fair"	15 (30%)	14 (28%)	16 (32%)
"Good"	17 (34%)	7 (14%)	16 (32%)
"Excellent"	11 (27%)	18 (36%)	8 (16%)

Table 1. ORAM, VIBI, and VIBI-FQ score for all Ohio NWCA intensification wetlands, based upon unweighted data and by approximate ecological condition ranges which correspond to Ohio's wetland anti-degradation categories.

This study further allowed for the comparison of VIBI-FQ with results from both ORAM and VIBI for all 50 sites. VIBI-FQ is shown to be highly correlated to both the level 2 (ORAM) and level 3 (VIBI) assessments that have been part of the Ohio EPA wetland regulatory program for more than 10 years (Figure 2, Figure 3). Ohio EPA is considering making this new tool a preferred assessment technique for monitoring certain wetland restoration projects.

The bryophyte metrics have been calculated for all 50 surveyed sites, and preliminary results have shown a strong statistical correlation between the overall diversity of bryophytes present and the ecological condition of the wetland vascular plant community. Developing a bryophyte index of biotic integrity could be extremely beneficial to the state wetland regulatory program because most bryophytes are present year-round, unlike most other indicators for detailed biological

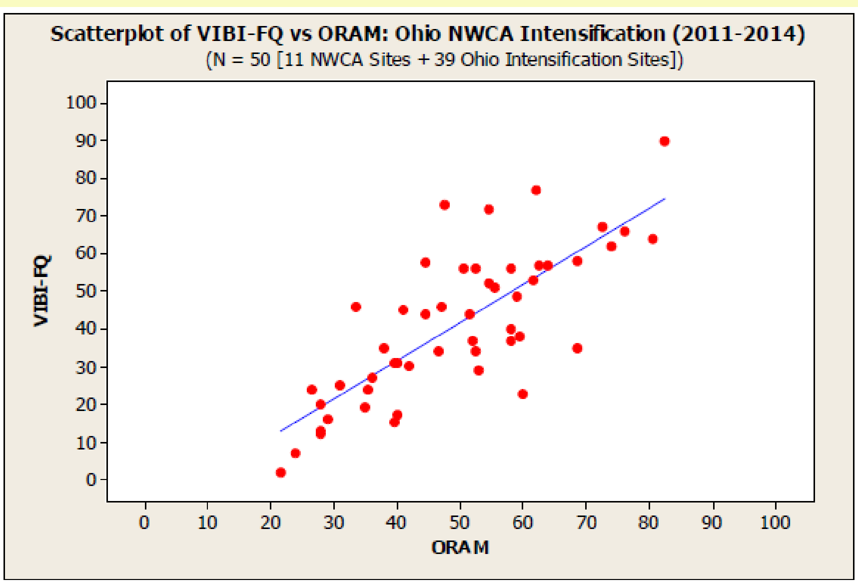


Figure 2. VIBI-FQ vs. ORAM.

assessments. Ohio is still analyzing the soils data, with plans to compare results to those from the NWCA; additionally, state-specific protocol results will be compared with those generated from NWCA's USA-RAM, VMMI, buffer stressors, etc.

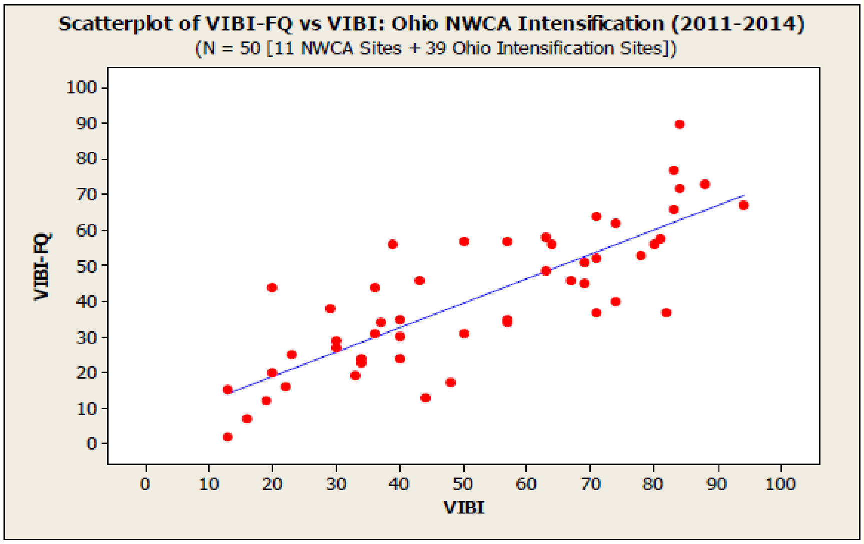


Figure 3. VIBI-FQ vs. VIBI.

The Ohio intensification of the NWCA has proven to be a valuable first step toward characterizing the state's remaining wetland resources. Several "lessons learned" will allow Ohio to streamline field protocols when conducting future state surveys, and they have been considered in the context of future NWCA protocol revisions. Ohio hopes to replicate this probabilistic wetland survey on a regular basis in order to track temporal trends in both wetland quality and quantity, preferably in conjunction with future cycles of NWCA.

To learn more, contact Brian Gara (brian.gara@epa.ohio.gov; 614-836-8787), Ohio EPA, Division of Surface Water, Wetland Ecology Group.

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Minnesota's Intensification Project: NWCA Intensification Survey Helps Reveal Important Regional Variation in Minnesota

Michael Bourdaghs, Minnesota Pollution Control Agency

Minnesota is known as the "land of 10,000 lakes," but wetlands also cover 10.62 million acres of the state (Kloiber and Norris 2013). By any measure it is a water rich state, however, surface water resources (and the pressures they face) do not occur evenly throughout.

As with many other states, a variety of landscapes occur in Minnesota, with three widely recognized ecoregions present. As described by Omernik level II ecoregions they are (Figure 1):

- ***Mixed Wood Shield:*** Covering the northeast and north-central areas of the state, the Mixed Wood Shield is characterized by a mix of conifer and hardwood forests. Wetlands are extensive and agricultural and urban development is very low compared to the rest of the state, with forestry and mining as top industries.
- ***Mixed Wood Plains:*** This ecoregion occupies a central transitional zone between the drier/warmer former prairies to the south and west and the wetter/cooler northern forests. Historically, much of the ecoregion was covered by hardwood forests. Currently, agricultural development is widespread and the majority of Minnesota's population is concentrated here.
- ***Temperate Prairies:*** Once covered by tallgrass prairie, oak savanna, and aspen parkland, the Temperate Prairies ecoregion is now predominantly used for agricultural production.

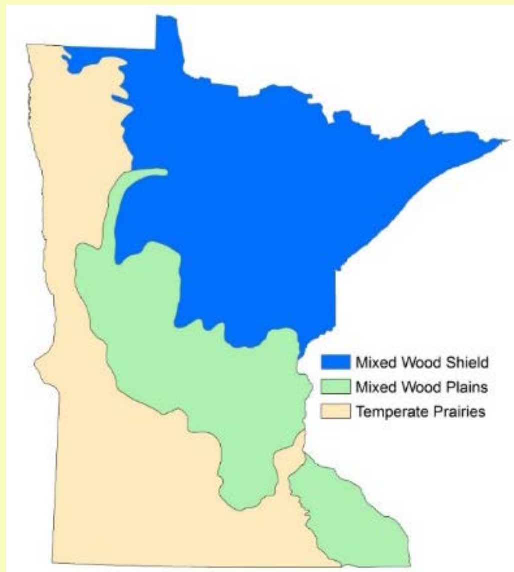

Figure 1. Omernik Level II ecoregions in Minnesota.

Across the state, approximately 50% of pre-settlement wetlands remain. However, development and wetland drainage history vary by ecoregion. Most of the pre-settlement wetlands remain in the Mixed Wood Shield, with counties in the ecoregion retaining 92% of wetland acreage on average (Anderson and Craig 1984). Remaining wetland acreage is much lower in the Mixed Wood Plains, with counties averaging 40%. Wetland losses are even greater in the Temperate Prairies, where on average only 5% of each county's pre-settlement wetlands remain.

The Minnesota Pollution Control Agency took the opportunity to conduct an intensification survey in conjunction with the NWCA. Considering the known variation in development, drainage history, and wetland quantity between ecoregions, Minnesota chose a sampling approach that reduced field sampling

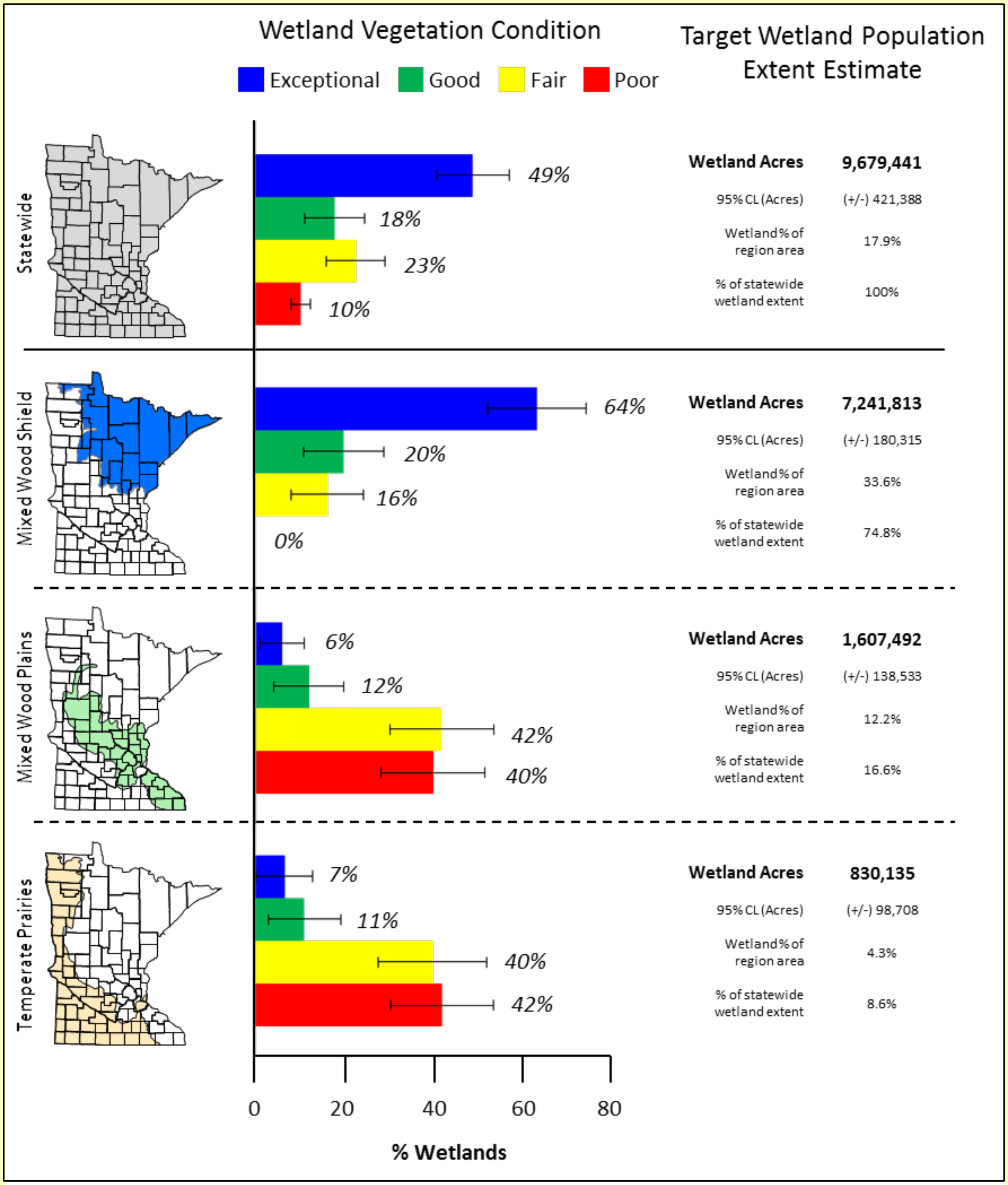

Figure 2. Wetland vegetation condition in Minnesota (statewide and by ecoregion).

at individual sites and focused on vegetation condition. This allowed them to increase the number of sites sampled and achieve a representative sample for each of the ecoregions.

Statewide, wetland vegetation condition was high overall (Figure 2), with an estimated 49% of wetlands assessed as Exceptional and another 18% in Good condition. Correspondingly, degraded vegetation conditions were low with 23% assessed as Fair and only 10% in Poor condition. These are encouraging results. The clear majority of Minnesota's wetlands have either no detectable or only minor impacts to their vegetation.

The ecoregion results, however, reveal a disparity of vegetation conditions (Figure 2) that correspond with the broad patterns of human development. Wetland vegetation condition in the largely intact Mixed Wood Shield was very high, with an estimated 64% in Excellent condition. Conversely, in the heavily developed Mixed Wood Plains and Temperate Prairies, vegetation was predominately degraded–about 80% of wetlands were assessed as Fair or Poor.

The predominant stress indicator in these two ecoregions was non-native invasive plant species that can tolerate higher degrees of human impacts, out-compete native species, and produce persistent litter thereby altering native plant communities and driving out native species (Galatowitsch 2012). The most widespread non-native invasives were Reed canary grass (*Phalaris arundinacea*) and the invasive Cattails (*Typha angustifolia* and *Typha x glauca*). High non-native cover was strongly associated with all types of stressors estimated in the survey. For example, non-native cover was high at approximately 95% of wetlands that had at one time been plowed and left to revert back to natural wetland (about 14-16% of the wetland area in the Mixed Wood Plains and Temperate Prairie ecoregions). However, 9%-12% of the wetland area had moderate to high non-native species cover when all other stressor categories were low or absent, suggesting that non-native invasives may also be acting independent of other types of human impacts.

Approximately 75% of Minnesota's wetlands occur in the Mixed Wood Shield and the high level of condition found there drives the statewide results, largely masking the degraded conditions in the Mixed Wood Plains and Temperate Prairies. While estimating overall wetland condition on a statewide basis is a fundamental scale for monitoring the long term status and trends of wetlands, in Minnesota, the regional scale provides a much more complete story.

To learn more, contact Michael Bourdaghs (Michael.Bourdaghs@state.mn.us; 651-757-2239), Minnesota Pollution Control Agency, Surface Water Monitoring Division.

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Interior Plains

Landscape setting of the ecoregion

The NWCA Interior Plains ecoregion combines the Northern Plains, Temperate Plains, and Southern Plains NARS ecoregions. The region extends from northern Montana to southern Texas and from the Rocky Mountains east to western Ohio.

The terrain consists of smooth and irregular plains interspersed with tablelands and low hills. The northern portion has also been shaped by glacial deposits from the last Ice Age. Great prairie grasslands were once a dominant feature of this region, but have been replaced by other vegetation as land was developed for other uses. Mixed prairie and forest communities occur along the eastern edge of the region.

The climate is generally dry and temperate. Annual precipitation ranges from 10 to 43 inches, with the eastern Temperate Plains being wetter than the Northern and Southern Plains. Temperatures vary more widely with average annual temperatures between 45°F and 79°F in the Southern Plains and 36°F and 45°F in the Northern Plains.

Farming and livestock production is an important and dominant economic activity throughout the region. Mining, petroleum and natural gas production have a long history in the southern portion of the region and are increasingly prevalent in the north.

Terrain, climate, and land use have influenced the types of wetlands commonly found in the region today. In the north and central parts of the region, depressional wetlands called prairie potholes are a prevalent feature of the landscape. Prairie potholes typically have a mix of wetland vegetation, varying from submerged and floating plants found in areas with deeper water near the center of the pothole, to bulrush, cattails, and other marsh plants occurring along the edge. In the southern parts of the region, a type of depressional wetland called a playa wetland (also commonly known as a playa lake) is prevalent. Prairie potholes and playa wetlands provide important habitat for migrating waterfowl and other wildlife by, among other things, providing a source of water and food in these drier parts of the country. Prairie potholes and playa wetlands also are important sources of groundwater recharge. Wet meadows, marshes, and forested wetlands associated with major river systems like the Missouri River are also commonly found within this region.

Prairie pothole sampled in North Dakota (site NWCA11-ND-5032). Photo courtesy of NDSU.

Well known wetland complexes in the Interior Plains include the Prairie Pothole Region, the Sandhills and

Rainwater Basin in Nebraska, the Cheyenne Bottoms in Kansas, as well as a well-defined region of playas that includes parts of Nebraska, Colorado, Kansas, Oklahoma, Texas, and New Mexico.

Summary of findings

A total of 156 randomly selected sites were sampled in the Interior Plains during the NWCA 2011 field season, representing 7,659,166 acres. Of the total number of Interior Plains sites sampled, 115 are inland herbaceous wetlands, representing 4,598,831 acres, and 41 are inland woody wetlands, representing 3,060,335 acres.

Biological Condition

For all wetland types assessed in the Interior Plains (Figure 4-8), 44% of the estimated wetland area is in good condition; 36% is in fair condition, and 19% is in poor condition based on the VMMI. The proportion of wetland area in good condition for inland herbaceous wetlands is much larger, 60%, than it is for inland woody wetlands, where only 20% are in good condition (Figures 4-9 and 4-10). The proportion of woody wetlands in fair condition, however, is much larger, 59%, than it is for herbaceous wetlands, 21%. The proportion of area in poor condition is similar for both herbaceous (18%) and woody (21%) wetlands.

Indicators of Stress

For all wetland types assessed in the Interior Plains, vegetation removal, surface hardening, ditching, and nonnative plants are the indicators with the greatest wetland area at high stressor levels (Figure 4-8). While the majority of stressors in this ecoregion are at low levels, both vegetation removal and nonnative plant stressors have a greater proportion of wetland area at high and very high levels than low. Key findings include:

- Vegetation removal is at high stressor levels in 44% of the wetland area, moderate levels in 14%, and low levels in 42%.
- Hardening is high in 35% of wetland area, compared to 15% and 49% of wetland area at moderate or low stressor levels, respectively.
- Ditching stressor levels are high in 28% of the wetland area, moderate in 10%, and low in 62%.
- Damming is at high stressor levels in 26% of the wetland area, at moderate levels in 4%, and at low levels in 70%.
- The nonnative plant stressor has very high and high stressor levels in 21% and 25% of the wetland area, respectively, moderate levels in 26% of wetland area, and low levels in 27%.
- Soil phosphorus concentration is at low stressor levels, for most of the wetland area in the region, 71%. However, it is not assessed for 23% of the area due to difficulties in collecting soil samples or because some soil samples for this ecoregion were not analyzed using NWCA lab protocols. Similarly, heavy metal concentrations are at low stressor levels for 61% of wetland area, but is not assessed for 23% of the area.

For inland wetland types assessed within the Interior Plains ecoregions (Figure 4-9 and 4-10), data show:

- Inland herbaceous wetlands have several indicators at high stressor levels for large proportions of assessed wetland area. These include hardening (56% of wetland area), vegetation removal (55%), ditching (41%), and vegetation replacement (30%). In addition, 63% of inland herbaceous wetlands have high or very high levels for the nonnative plant stressor.

- The indicators of stress with the largest proportion of wetland area at high stressor levels for inland woody wetlands are damming (37%) and vegetation removal (28%). Wetland area for woody wetlands at high or very high levels for the nonnative plant stressor is 20%.
- For most of the stressors measured, a greater proportion of herbaceous wetland area has high stressor levels relative to the woody wetlands. The exception is the damming stressor, which is at high levels in 37% of woody wetlands compared to 18% of herbaceous wetlands.
- While the majority of herbaceous wetlands have low stressor levels for soil phosphorus (55% of wetland area) and heavy metals (60%), it should be noted that 38% of the wetland area was not assessed due to difficulties in collecting soil samples or because some soil samples for this ecoregion were not analyzed using NWCA lab protocols.

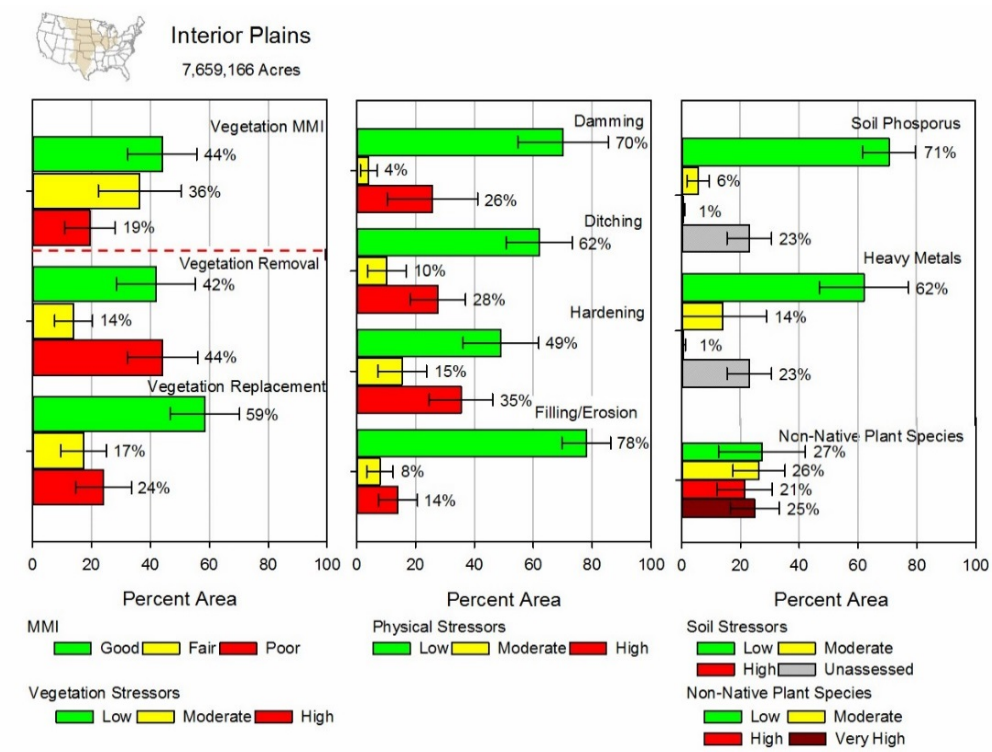

Figure 4-8. NWCA 2011 survey results for the wetlands (i.e., all target wetland types) across the Interior Plains. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

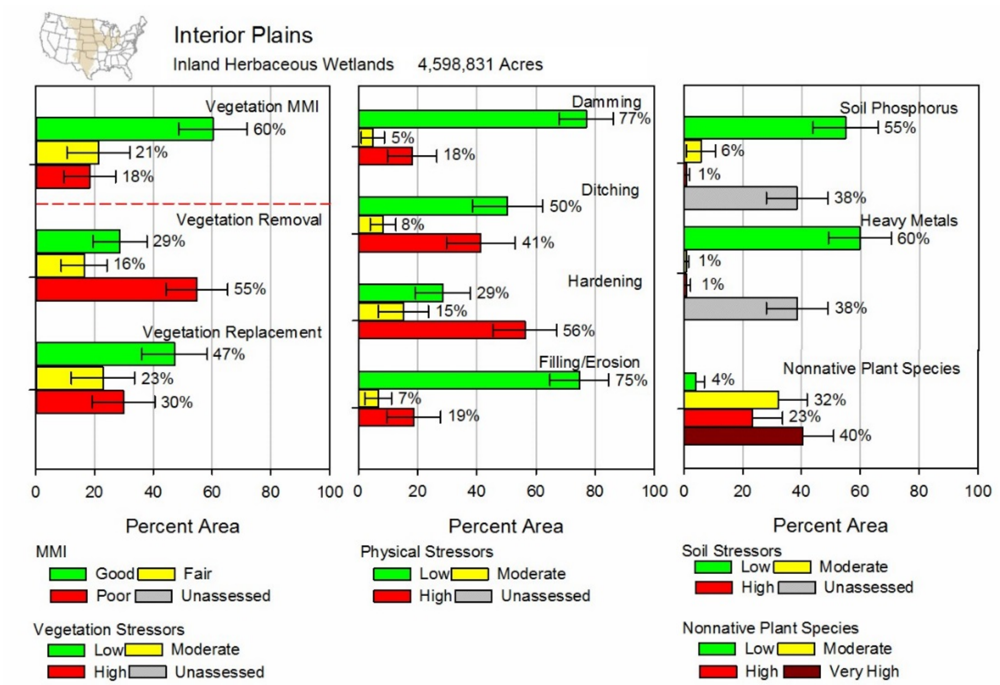

Figure 4-9. NWCA 2011 survey results for the inland herbaceous wetland type across the Interior Plains. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

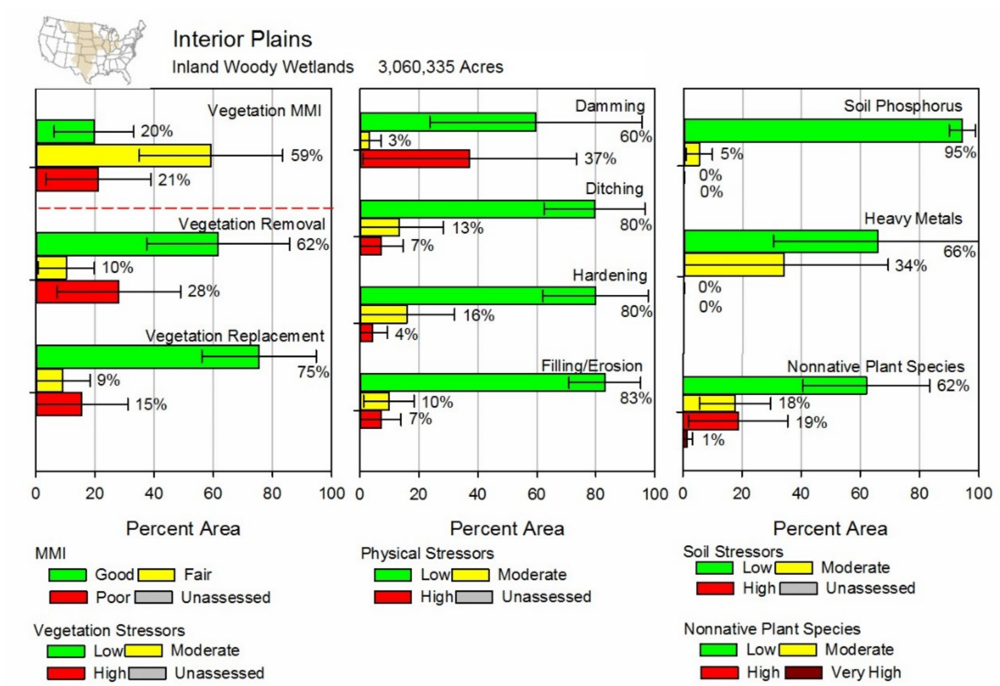

Figure 4-10. NWCA 2011 survey results for the inland woody wetland type across the Interior Plains. Bars show the percentage of wetland area within a condition or stressor classes. Error bars represent 95% confidence intervals.

West Ecoregion

Landscape setting of the ecoregion

The NWCA West ecoregion combines the Western Mountain and Xeric NARS ecoregions. The region includes the western parts of Texas, New Mexico, Colorado, Wyoming, and Montana to the Pacific Coast.

The West ecoregion is topographically diverse, including large extensive mountain ranges, plateaus and high-relief tablelands, lowland plains with hills and low mountains, isolated mountains, and intermountain basins and valleys. Coastal mountains are bordered by coastal plains and include important estuaries along the margins of the Pacific Ocean. The topographic and climatic diversity of the West ecoregion results in diverse plant communities. In the drier parts of the region, native vegetation is dominated by grasses and shrubs, with relatively few large trees. Desert and shrub-steppe ecosystems are found in the rain shadow of large mountain ranges, but within the mountain ranges, vegetation communities include alpine tundra, mountain meadows, valley grasslands, shrublands, and hardwood riparian systems. Foothills and mountain ranges are often dominated by expansive forests.

The climate varies widely across the West ecoregion. In the Xeric region, conditions tend to be hot and dry with a long summer dry season. Average annual temperatures range from 32 to 75°F. Average annual precipitation throughout the region ranges from 2 to 40 inches but varies widely both spatially and temporally. The Western Mountain region tends to be cooler and more humid than the Xeric region, with average annual temperatures ranging from 32 to 55°F and average annual precipitation ranging from 16 to 240 inches. At higher elevations, most precipitation falls as snow.

Much of the region is federally-owned land, some of which is used for recreation purposes. Grazing is widespread and timber production is a leading industry in forested areas. Agricultural production varies widely across the region with climate—ranging from citrus, subtropical, and tropical fruits to vegetables and horticultural crops, to irrigated and dry-farmed grain and forage crops.

Wetlands comprise a relatively small, but important, proportion of land area in the West, and vary widely with geography and climate. They support a variety of habitats, including the salmon fishery, and are key contributors to water supplies, especially in the drier regions. In relatively dry basins and valleys, wetlands are concentrated along rivers, streams, and in abandoned river channels. Additionally, wet meadows and emergent marsh complexes are found in large basins and valleys. Snowmelt- and groundwater-fed wetlands such as wet meadows, fens, seeps, and forested wetlands are found in mountain ranges. Tidal salt and freshwater marshes, wet meadows and forests are found along the coast.

Wet meadow along riparian corridor in Yellowstone National Park, WY (site NWCA11-2790). Photo courtesy of Colorado Natural Heritage Program.

Large estuaries, such as the San Francisco Bay and Puget Sound, are familiar to many people, but extensive wetland complexes are also associated with major rivers and lakes throughout the region (e.g., the Colorado, Columbia, Sacramento, and Snake Rivers, the Great Salt Lake).

Summary of findings

A total of 146 randomly selected sites were sampled in the West ecoregion during the NWCA 2011 to characterize the condition of 3,647,060 acres. Of the total number of West sites sampled, 70 are inland herbaceous wetlands, representing 1,488,139 acres, and 51 are inland woody wetlands, representing 1,985,936 acres. Estuarine wetlands in the West total 25 sites, representing 172,985 acres. Detailed results for estuarine wetland types are reported in the Estuarine Wetlands section of this chapter.

Biological Condition

For all wetland types assessed in the West (Figure 4-11), 21% of the estimated wetland area is in good condition; 18% in fair condition, and 61% in poor condition based on the VMMI (see Chapter 2 for details on the VMMI). Inland herbaceous wetlands have an estimated 25% of wetland area in good condition, 32% in fair condition, and in 43% poor condition (Figure 4-12). Inland woody wetlands have an estimated 21% of wetland area in good condition, 8% in fair condition, and 71% in poor condition (Figure 4-13).

Indicators of Stress

For all wetland types assessed in the West, ditching, nonnative plants, surface hardening, and vegetation removal are the indicators with the greatest wetland area at high stressor levels (Figure 4-11). Each of these stressors have a greater proportion of wetland area at high levels than low. Key findings include:

- Ditching is at high stressor levels for 76% of wetland area, moderate for 1% and low for 22%.
- The nonnative plant stressor is at very high or high stressor levels for 72% of the wetland area, and at moderate and low levels for 15% and 14%, respectively.
- Hardening stressor levels are high for 70% of wetland area, moderate for 7%, and low for 23%.
- Vegetation removal stressor levels are high for 61% of the wetland area, moderate for 6%, and low for 33%.
- Damming is at high stressor levels for 32% of wetland area, moderate for 1%, and low for 67%.

For inland wetland types assessed within the West ecoregion (Figures 4-12 and 4-13), data show:

- The indicators of stress with the greatest percent wetland area at high levels for inland herbaceous wetlands are ditching (78% of wetland area), hardening (70%), damming (61%), and vegetation removal (47%). High or very high levels for the nonnative plant stressor total 73% of wetland area.
- The indicators of stress with the greatest percent wetland area at high levels for inland woody wetlands are vegetation removal (76% of wetland area), ditching (75%), and hardening (75%). High or very high levels for the nonnative plant stressor total 74% of wetland area.
- Inland herbaceous and woody wetland area have similar percentages of wetland area at high stressor levels for ditching, hardening, and nonnative plant indicators. Both wetland types also have large percentages of wetland area at low stressor levels for vegetation replacement, filling/erosion, and soil phosphorus indicators.

- Inland woody wetlands have a greater proportion of wetland area at high stressor levels for vegetation removal, 78%, than inland herbaceous wetlands, which have 47%.
- High stressor levels for damming are found in 61% of inland herbaceous wetland area, but only 10% of inland woody wetland area.
- The majority of inland herbaceous wetlands have low stressor levels for heavy metals (80% of wetland area), which is greater than the percentage for inland woody wetlands. Among woody wetlands, only 20% of wetland area have low stressor levels, while 69% have moderate and 4% have high stressor levels for the heavy metals indicator.

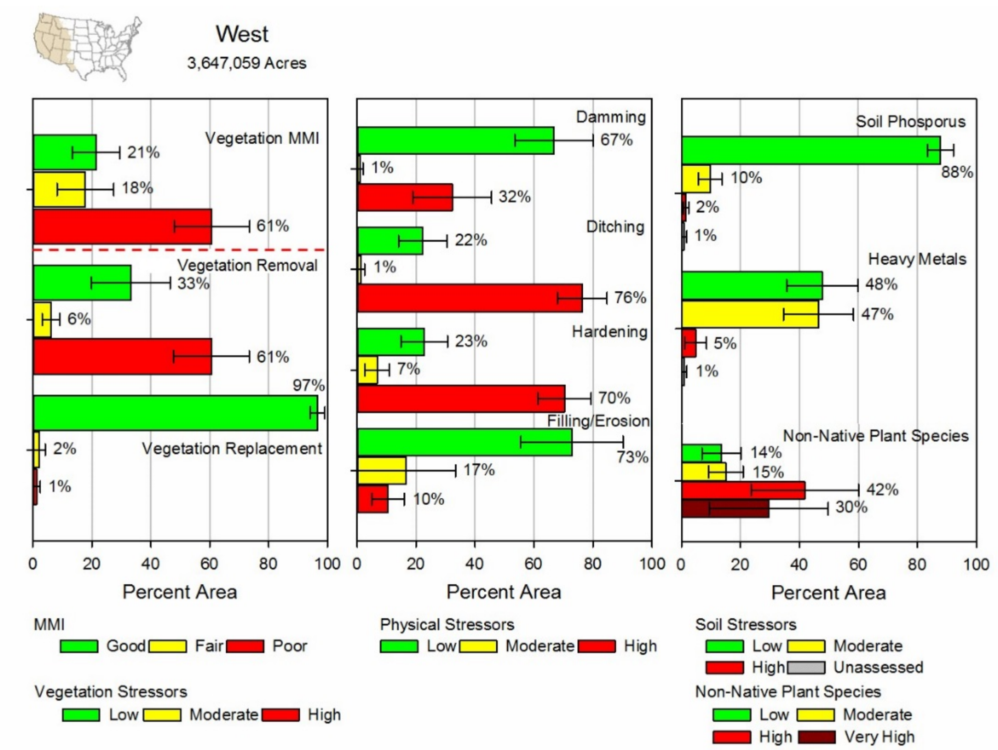

Figure 4-11. NWCA 2011 survey results for the wetlands (i.e., all target wetland types) across the West. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

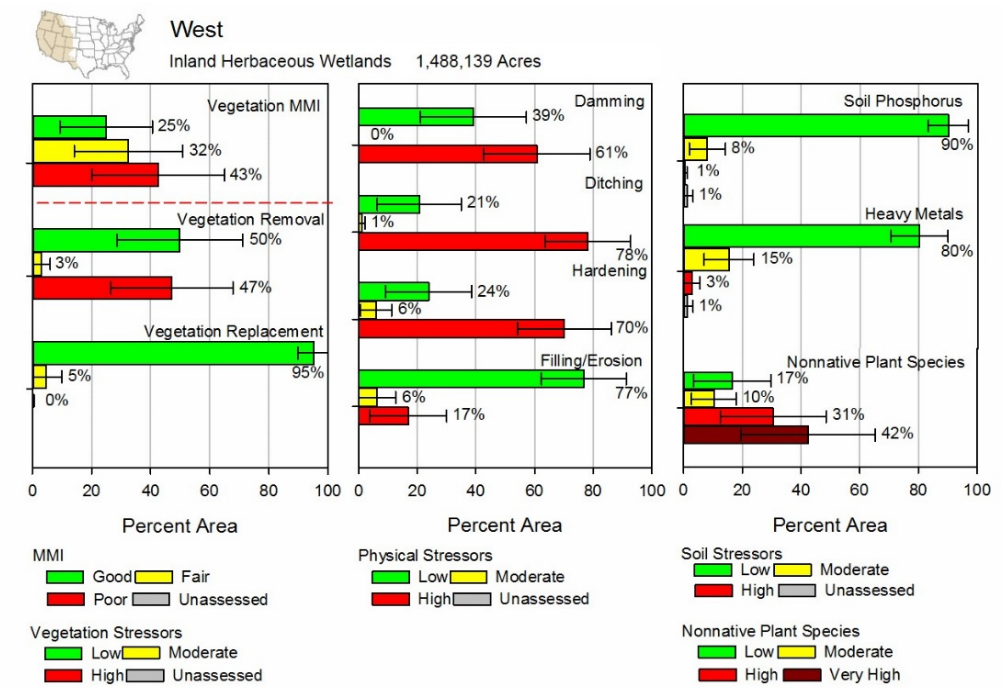

Figure 4-12. NWCA 2011 survey results for the inland herbaceous wetland type across the West. Bars show the percentage of wetland area within a condition or stressor class (good, fair, and poor. Error bars represent 95% confidence intervals.

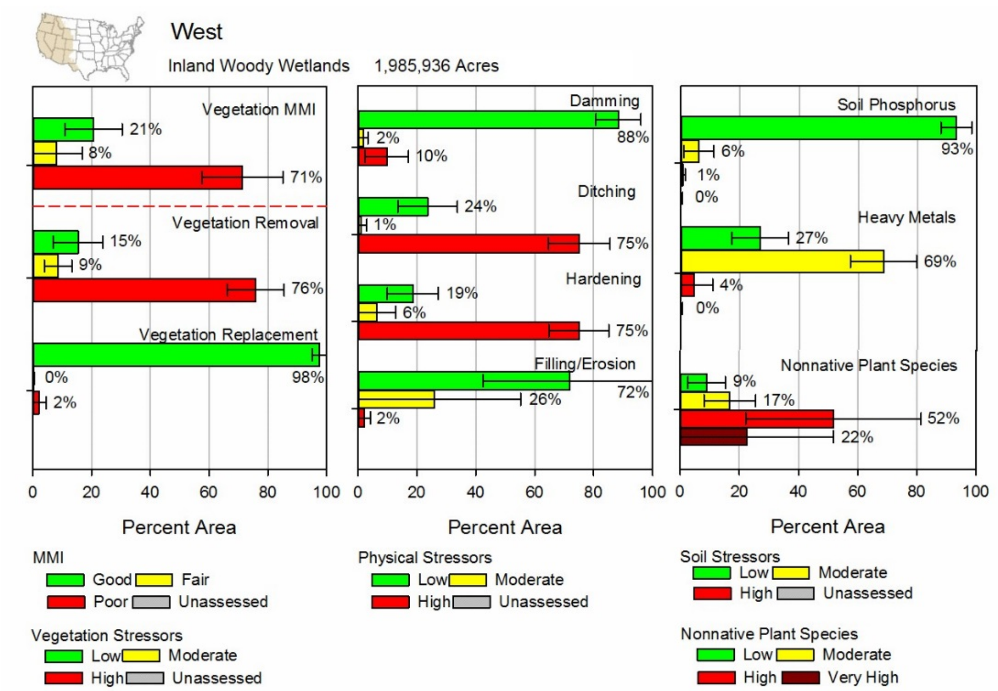

Figure 4-13. NWCA 2011 survey results for the inland woody wetland type across the West. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

Estuarine Wetlands

Landscape setting for estuarine wetlands

Estuarine wetlands occur along the coastal areas of the conterminous U.S. They can be found in three of the NWCA Ecoregions: Coastal Plains, Eastern Mountains and Upper Midwest, and the West.

Estuarine wetlands—tidal systems that are saline or brackish—may be dominated by herbaceous emergent vegetation or by shrubs or trees. Estuarine wetlands occur predominantly along coastal areas of the Coastal Plains Ecoregion, while fewer estuarine wetlands occur along the west and northeastern coasts of the U.S. Because few NWCA 2011 sites occurred in western and northeastern estuarine wetlands, results for estuarine wetlands are presented only by wetland type—estuarine herbaceous and estuarine woody.

Tidal salt and brackish marshes are found along the nation's coasts. Shrub/tree dominated wetlands are often located in high intertidal zones along coasts where they are exposed to less saltwater and there are greater influxes of freshwater from the surrounding landscape. In the most southern part of the Eastern coast, mangrove swamps are found in association with coastal marshes.

Salt marsh in Florida (site NWCA11-3069). Photo courtesy of University of Florida.

Summary of findings

The 327 randomly selected estuarine wetland sites that were sampled in the NWCA represent an estimated 5,485,646 acres. Estuarine wetlands are reported separately for herbaceous and woody types. Estuarine herbaceous wetlands (salt marshes) are evaluated based on 258 randomly selected sites, which represented an estimated 4,987,824 acres. Estuarine woody wetlands (deciduous or evergreen woody dominated wetlands, mangrove swamps) represent a smaller proportion of the wetland area, 497,821 acres, based on evaluation of 69 sites.

Biological Condition

Estuarine herbaceous wetlands have an estimated 58% of wetland area in good condition, 17% in fair condition, and 26% in poor condition (Figure 4-14) based on the VMMI (see Chapter 2 for details). Estuarine woody wetlands have an estimated 59% of wetland area in good condition, 20% in fair condition, and 22% in poor condition (Figure 4-15).

Indicators of Stress

Stressor level is generally low for all indicators of stress for both estuarine herbaceous and estuarine woody wetlands. For the estuarine herbaceous wetlands (Figure 4-14) the indicators of stress with the greatest estimated wetland area at high stressor levels are ditching (18%), surface hardening (11%), and damming (10%). In addition, high or very high levels for the nonnative plant stressor total 24% of estuarine herbaceous wetland area. Soil phosphorus stressor levels are low for 37% of herbaceous wetland area, moderate for 28%, and high for 2%. Soil phosphorus and soil heavy metal stressors are not assessed for 33% of the wetland area, due to difficulties collecting soil samples at some sites.

In the estuarine woody wetlands (Figure 4-15), the indicators of stress with the greatest estimated wetland area at high stressor levels are ditching (18% of wetland area) and hardening (13%). The heavy metals stressor is at low levels for 44% of wetland area, but at moderate levels for 55%. Less than 1% of estuarine woody wetland area is at high stressor levels for heavy metals.

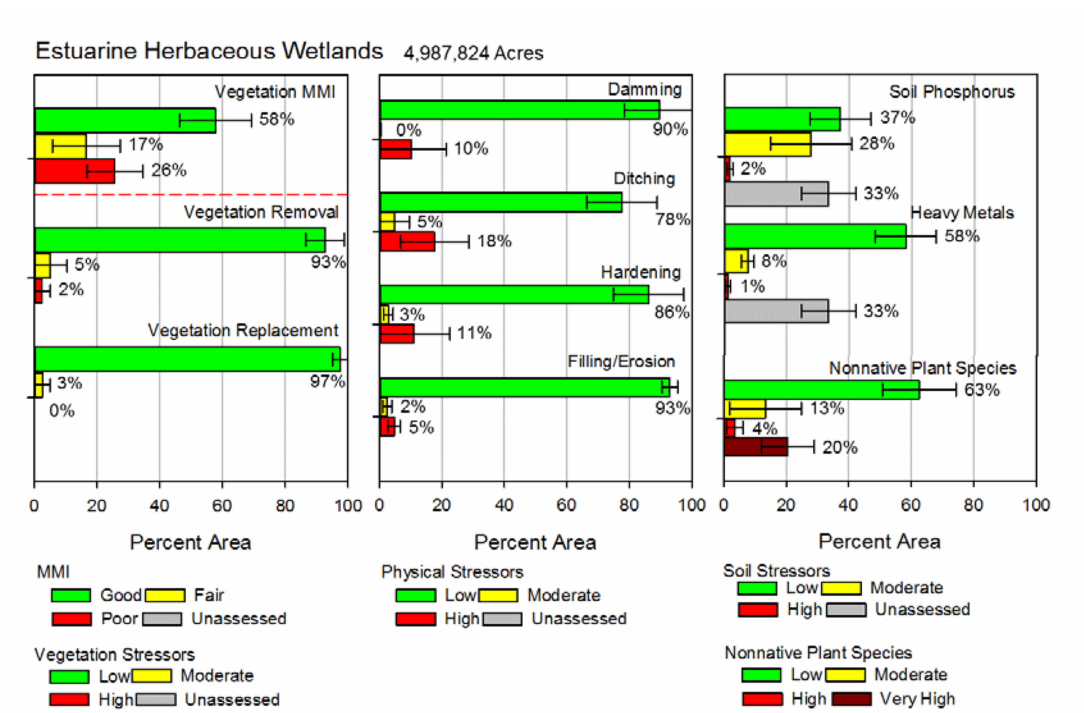

Figure 4-14. NWCA 2011 survey results for estuarine herbaceous wetland types across all coastal areas of the conterminous U.S. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

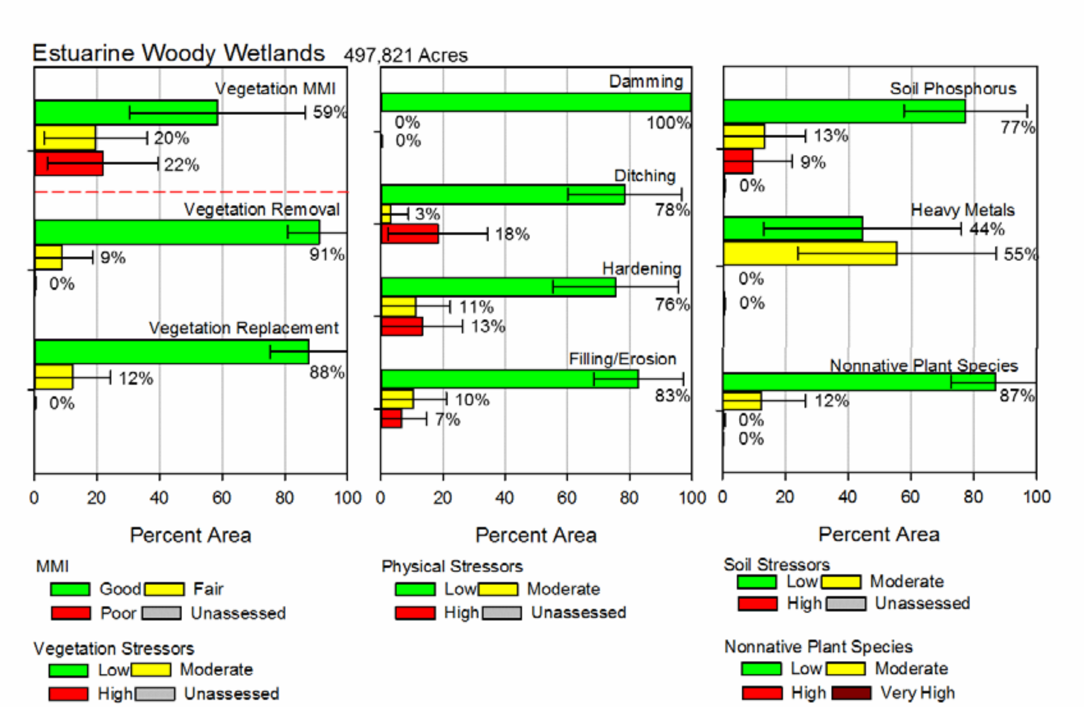

Figure 4-15. NWCA 2011 survey results for estuarine woody wetland types across all coastal areas of the conterminous U.S. Bars show the percentage of wetland area within a condition or stressor class. Error bars represent 95% confidence intervals.

Chapter 5: Summary and Next Steps

Summary of Major Findings and Implications

The NWCA 2011 is the first national assessment of wetland ecological condition. This accomplishment required an extraordinary amount of effort and cooperation between state, tribal, and federal partners throughout its design and implementation. During the 2011 field season, more than 50 field crews sampled 1,179 wetland sites across the country, using standardized protocols to collect information to characterize wetland condition. Previous wetland monitoring and assessment studies have been conducted at local and regional scales, or have focused on specific wetland types or ecological properties, but none have evaluated wetland condition for a full range of wetland types across the entire country. Thanks to the efforts of the field crews and many other partners, the NWCA collected the most comprehensive set of biological, physical, and chemical data on wetlands across the U.S. This national data set will provide valuable and previously unavailable information on the ecological condition of a broad range of wetlands to policy makers, land managers, and scientists. This includes important insight on wide-spread stressors impacting wetland biological condition, and the potential improvement that could be seen nationally by reducing these stressors.

The NWCA 2011 found 48% of wetland area is in good condition, based on the national Vegetation Multimetric Index (VMMI) developed for NWCA, while 32% of wetland area is in poor condition. Of the four major ecoregions reported on by NWCA, the West had the lowest percentage of wetland area in good condition at 21%. The Coastal Plains (50%), Eastern Mountains and Upper Midwest (52%), and Interior Plains (44%) have similar percentages of area in good condition as the national estimates.

Nationally, vegetation removal, surface hardening (e.g., pavement, soil compaction), and ditching are the most widespread of the indicators of stress evaluated in NWCA. Vegetation removal and surface hardening stressor indicators are high for 27% of wetland area, while the ditching stressor is high for 23% of wetland area. NWCA 2011 further found that wetlands with high stressor levels from vegetation removal and surface hardening are about twice as likely to have poor biological condition as those with low or moderate levels. Additional analysis that looks at how condition might improve if these two stressors are reduced, called attributable risk, suggests a possible 20% reduction in wetland area with poor biological condition if the stressor level was reduced from high to moderate or low.

Stressor levels for both of the soil indicators of chemical stress are low for the majority of wetland area nationally. However, moderate stressor levels for heavy metals are found in 47% of wetland area in the West and 31% of wetland area in the Eastern Mountains and Upper Midwest. Soil phosphorous stressor levels are also moderate or high for 22% and 13% of wetland area, respectively, in the Eastern Mountains and Upper Midwest.

NWCA conducted the first national study of algal toxins in wetlands. Microcystin, a toxin that can harm people, pets, and wildlife, was detected in 12% of wetland area nationally. However, based on recreational exposure risk levels established by the World Health Organization, very little wetland area is found at either moderate or high risk levels.

Nationally, 61% of wetland area has low stressor levels from the nonnative plant indicator, but stressor levels varied by ecoregion. In the West, the majority of wetland area, 71%, has high or very high stressor levels from the nonnative plant indicator. In the Interior Plains, nearly half of the wetland area (46%) has high or very high stressor levels.

Advancing Wetland Science

The contributions of the NWCA go beyond the development of the first national assessment of wetland condition. EPA, states, tribes, and other federal agency efforts to implement the NWCA resulted in a robust national program and contributed to the development and enhancement of state and tribal wetland monitoring programs. For example, Minnesota used vegetation data from a larger sample set within the state to identify regional variations in wetland condition and potential stressors (see state highlight, "Minnesota's Intensification Project: NWCA Intensification Survey Helps Reveal Important Regional Variation in Minnesota").

The NWCA 2011 survey led to the first national vegetation multimetric index developed for wetlands. This index provided an assessment of the biological condition of wetlands nationally, and the methods and assessment tools can also be used at a regional level. In addition, several indicators of stress based on readily collected field data were developed and used to evaluate the relationship between common stressors and biological condition. Research into a number of other potential indicators of wetland condition was conducted, and while not part of this report, will help inform future scientific studies.

NWCA scientists, for example, attempted to develop indicators of wetland condition based on the presence, abundance, and diversity of algal species, recognizing their role in wetland ecology. The difficulty in collecting uniform samples and identifying species presence limited the development of such an indicator. However, the data collected provides valuable information to scientists to further study relationships between algal communities and wetland ecosystem health.

Water chemistry has been widely used in monitoring and assessment programs in aquatic habitats. While the NWCA collected water chemistry data from 631 sites, its use was somewhat limited in the NWCA 2011 because of the variability in surface water presence, both within a wetland and among wetland types. Future efforts will focus on protocol improvements that would allow for better and more complete sampling of wetland surface and/or subsurface water. Additionally, analysis of data collected in 2011 may reveal relationships between water quality and other measures of wetland condition and ecosystem function that can be further developed in future studies.

Rapid assessment methods (RAMs) are widely used at state and regional levels to evaluate wetlands and play a key role in the implementation of many state wetland monitoring and assessment programs. As part of the NWCA, EPA developed and tested a national rapid assessment method named USA-RAM. This was an integral component of the methods used in the 2011 survey. Initial analysis of the data indicates that USA-RAM provided measures of wetland stress and condition that correlated with several individual metrics from the more intensive assessment methods used in the NWCA. Further research into the data is needed to fully understand how the rapid assessment methods work across regions and wetland types and to verify and refine USA-RAM. Many states are conducting their own field assessments of the USA-RAM protocols, and adapting these protocols to meet state-specific wetland assessment and management needs.

Microbes play an essential role in the breakdown of organic carbon compounds in soils. Their activity is of particular interest in wetland soils, which have the capacity to store (or sequester) large amounts of carbon. Carbon storage or release occurs through microbial respiration and is affected by a number of factors including hydrology, climatic conditions, and the microbial community. Amid growing concerns regarding greenhouse gases and climate change, scientists are interested in better understanding the factors that affect carbon cycling in wetlands and their role in the global carbon cycle. As part of the NWCA 2011, soil samples from 936 wetland sites across the U.S. were analyzed for microbial enzyme activity and respiration. By analyzing the specific types of enzymes present and their relative proportions in the soil, researchers hope to identify nutrient imbalances in the wetland that may limit microbial growth. These data will also be used to assess the impact of other factors, such as water and soil chemistry, land use and related anthropogenic stressors, and atmospheric deposition of nutrients, on microbial growth. Scientists also hope to use this information to estimate rates of carbon decomposition and how changes in environmental factors might change microbial communities and decomposition rates.

As part of NWCA 2011, analysts measured carbon concentrations in the soil, which provides important information on the amount of carbon that is stored in wetland soils. This is helpful as scientists work to understand carbon cycling in various wetland types and regions. For instance, scientists will be using soil data collected for NWCA 2011 to inform the development of baseline estimates of carbon storage in coastal wetlands as they work to include coastal wetlands into the U.S. Greenhouse Gas Emissions and Sinks Inventory under the Intergovernmental Panel on Climate Change. This report is prepared annually by the EPA and cooperating agencies to track greenhouse gas emissions and sinks associated with anthropogenic activities and land uses. Coastal wetlands (i.e., tidal marshes, mangroves, and sea grasses) have an important role in greenhouse gas cycling, however they have not yet been included in the inventory.

NWCA is an initial step in our endeavors to assess wetland condition. As the first survey of its kind, the 2011 study identified biological, chemical, and physical indicators of condition and stress for wetlands and developed appropriate metrics to assess ecological condition at national and regional scales. The indicators measured provide new information regarding the health of wetlands nationally, and on relationships between indicators of ecosystem stress or disturbance and wetland condition. Subsequent studies and research by EPA, states, and other partners will continue to build upon the knowledge resulting from the NWCA and allow us to further explore and evaluate the condition of wetlands at multiple scales. We will be better able to answer important policy and management questions about the overall health of this critical resource, and design effective strategies to fulfill the objectives of the CWA.

Next Steps: Preparing for the 2016 Assessment

NWCA scientists used the findings of the 2011 survey to guide preparations for the next round of the national assessment. For NWCA 2016, the survey design was adjusted to incorporate digitized National Wetland Inventory maps into the sample frame from which sites are selected. Using these maps increases the number of wetlands in the NWCA sample frame and allows for greater spatial distribution of sites across the country. This should improve the ability to report results for certain ecoregions in future NWCA studies. NWCA methods were further refined and developed with the goal of increasingly effective and efficient assessment of national wetland condition.

As an example, a number of different physical, chemical, and biological measures indicative of soil quality were collected as part of the 2011 survey and were used to indicate potential stressors. Soils are an important component of wetland ecosystems and the NWCA is interested in further exploring how these indicators could be used to make assessments about soil health in wetlands. Using both the data collected and the insights of research scientists and 2011 field crews, the NWCA developed new methods and further refined existing protocols to assess the condition of wetland soils and link soil properties to other measures of wetland health.

The NWCA would not have been possible without the assistance and collaboration of hundreds of dedicated scientists working for state, federal, and tribal agencies and universities across the country.

These scientists helped plan and design the survey, select indicators, develop and pilot assessment protocols, train field crews, conduct sampling, track samples, review data for quality control, analyze data, and review and write up the findings. Future wetland surveys will continue to rely on this close collaboration between EPA and its partners, as we further develop our abilities to study and assess wetlands at multiple scales. We will also continue to build upon the considerable baseline of information on wetland condition and work to ensure its use in evaluating our progress in protecting and restoring the quality of our nation's wetlands.

The U.S. Fish and Wildlife Service's Wetlands Status and Trends Program

Mitch Bergeson, U.S. Fish and Wildlife Service

The U. S. Fish and Wildlife Service (FWS) is the principal Federal agency that provides information to the public on the extent and status (quantity and type) of the Nation's wetlands. The Wetlands Status and Trends (S&T) component has had a history of success in providing scientific information to resource managers and decision makers about wetlands resource trends. The scientific integrity of the Wetlands S&T study is unchallenged as it represents the most comprehensive and contemporary effort to track wetlands acreage on a national scale. The information in the National Wetlands S&T Report and the NWCA Report will complement each other providing the most comprehensive nation-wide picture of wetland resources.

In 1986, the Emergency Wetlands Resources Act (Public Law 99-645) was enacted to promote the conservation of our Nation's wetlands. Congress recognized that wetlands are nationally significant resources and that these resources have been affected by human activities. Under the provisions of this Act, Section 401 requires the FWS to conduct wetland S&T studies of the Nation's wetlands at periodic intervals. Reports on the S&T of wetland area were produced by the FWS in 1983/84, 1990, 1991, 2000, 2006, 2008, 2011 and 2013.

> ***The goal of Wetlands Status and Trends is to provide the Nation with current scientifically valid information on the status and extent of wetland, riparian and related aquatic resources and monitor trends of these resources over time*.**

The S&T studies have provided the nation with information on wetland quantity. The FWS worked closely with the EPA in preparation for the NWCA study which was designed to address the quality of wetlands across the nation. This partnership arose because the FWS's Wetlands S&T data set offered one of the best starting points for a probabilistic national wetlands sampling design. This sample design included a population of stratified random sample plots across the nation that contained wetlands defined with Cowardin *et al*. (1979) wetland classes. These two studies will prove to be invaluable tools by providing resource managers, agencies and the public with information on both quantity and quality of wetlands of the Nation.

Wetland Definition and Classification: The FWS uses the Cowardin *et al*. (1979) definition of wetland. This definition is the standard for the agency and is the national standard for wetland mapping, monitoring, and data reporting as determined by the Federal Geographic Data Committee and is separate from the definition of a wetland found in Section 404 of the CWA regulatory program. The Cowardin *et al*. definition of wetlands is described below:

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.
>
> For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.

As noted in this definition, plant community composition, soil morphology, and site wetness (hydrology) are the principal indicators of whether a site is a wetland for ecological purposes. Site wetness (i.e., the presence of water) while central to the concept of wetland, is often the most difficult indicator to assess accurately because it is more dynamic (temporally variable) than plant community composition or soil properties. Plants and soil tend to reflect the prevailing degree of wetness at a site over time. For this reason, they frequently are excellent indicators of relative wetness, and this is why they are listed first as indicators of wetlands.

Ephemeral waters, which are not recognized as a wetland type, and certain types of "farmed wetlands" as defined by the Food Security Act and that do not coincide with the Cowardin *et al.* definition were not included in this study. The definition and classification of wetland types are consistent between every S&T study conducted by the FWS and the focus of reporting is on the Nation's wetlands regardless of ownership. Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in the Wetland S&T studies.

Wetland Classification Applications: The FWS has made adaptations to the Cowardin classification system to accommodate the use of remotely sensed imagery as the primary data source. For example, water chemistry, water depth, substrate size and type and even some differences in vegetative species cannot always be reliably ascertained from imagery. Image analysts must rely primarily on physical or spectral characteristics evident on high altitude imagery, in conjunction with collateral data, to make decisions regarding wetland classification and deepwater determinations[3].

The delineation of wetlands and deepwater habitat features through image analysis forms the foundation for deriving all subsequent products and data results. The wetlands are interpreted from the image by photo interpreters using key concepts of tone, size, shape, texture, pattern, shadow, location and association. The FWS makes no attempt to adapt or apply the products of these techniques to regulatory or legal authorities regarding wetland boundary determinations, jurisdiction or land ownership, but rather uses the information to assist in making trends estimates characterizing wetland habitats.

Study Design: The S&T studies were designed to be a quantitative measure of the areal extent of all wetlands in the conterminous U.S. The approach used is a stratified random sampling of plots. These are examined, with the use of remotely sensed data in combination with field work, to determine wetland change.

To monitor changes in wetland area, the 48 conterminous U.S. are stratified or divided by state boundaries and 37 physiographical subdivisions described by Hammond (1970) and shown in Figure 1. Zone 36 was added by the FWS to include coastal wetlands and nearshore features. In 2008, Zone 37 was added to intensify the coastal wetlands along the Pacific coast of conterminous U.S.

To permit even spatial coverage of the sample and to allow results to be computed easily by sets of states, the 37 physiographic regions formed by the Hammond subdivisions and the coastal zone stratum are intersected with state boundaries to form 220 subdivisions or strata. An example of this stratification approach and the way it relates to sampling frequency is shown for Georgia (Figure 2).

Within the physiographic strata described above, weighted, stratified sample plots are randomly allocated in proportion to the amount of wetland acreage expected to occur within each stratum. Each sample area is a plot 2 miles (3.218 km) on a side or 4 square miles of area equaling 2,560 acres (1,036 ha). The study includes all wetlands regardless of land ownership.

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[3]Analysis of imagery is often supplemented with limited field work and ground observations.

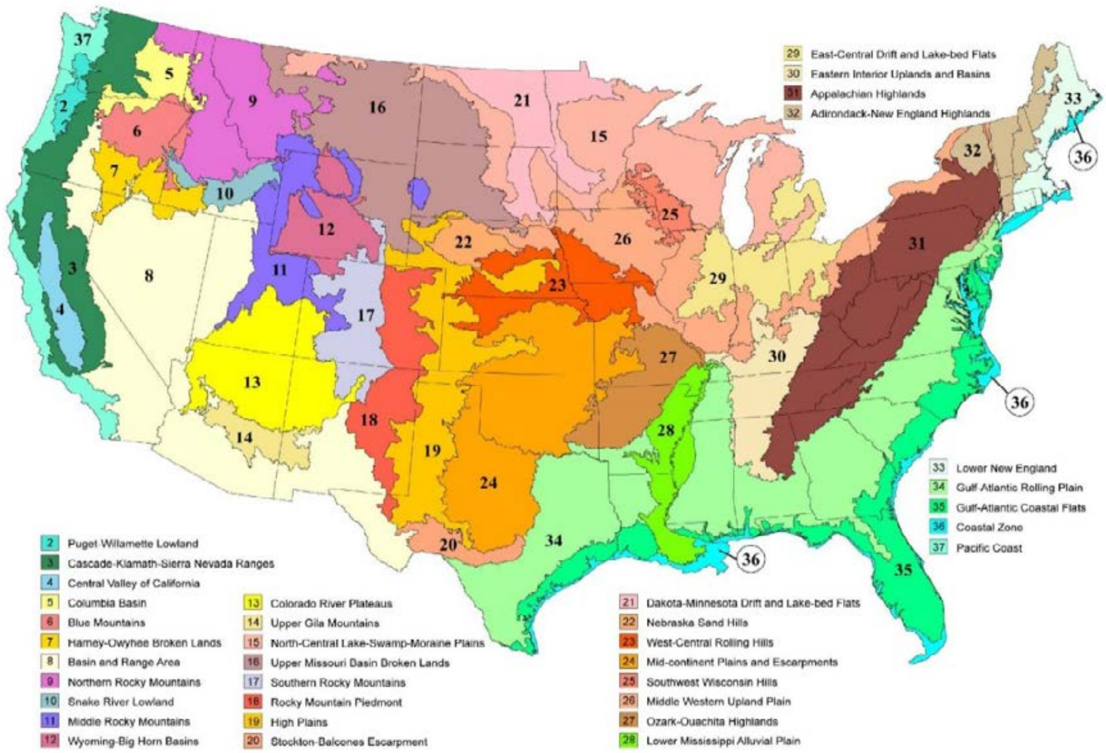

Figure 1. Physiographic regions of the conterminous U.S. as used for stratification in the Wetlands S&T study (adapted from Hammond 1970).

The advantages to this design are that it was developed by an interagency group of spatial sampling experts specifically to monitor wetland changes. It can be used to monitor conversions between ecologically different wetland types, as well as, measure wetland gains and losses.

All habitats, including wetlands, uplands and deepwater, were mapped in each plot using imagery at two different dates. The dates of imagery were selected based on availability of imagery closest to the start and end dates of the sample period for each study. All wetland change was also recorded whether it was considered the result of either natural change, such as the natural succession of emergent wetlands to shrub wetlands, or human induced change. The analysis of this data provides accurate estimates of wetland acreage or status at the start and end of the sample period and also provides estimates of observed changes over time by wetland type.

Data from S&T studies provide important long-term trend information about specific changes and the overall status of wetland quantity in the U.S. The FWS has documented this information by producing six national reports. With the release of the EPA's NWCA report the nation will have documented information on the quality and condition of these same wetlands. These reports, used in conjunction, will provide Federal and State agencies, the scientific community and conservation groups information on both quantity and quality of the Nation's wetlands to assist in planning, decision making and wetland policy formulation and assessment.

To learn more, contact Mitch Bergeson (mitch_bergeson@fws.gov, 608-238-9333 ext 112), U.S. Fish and Wildlife Service

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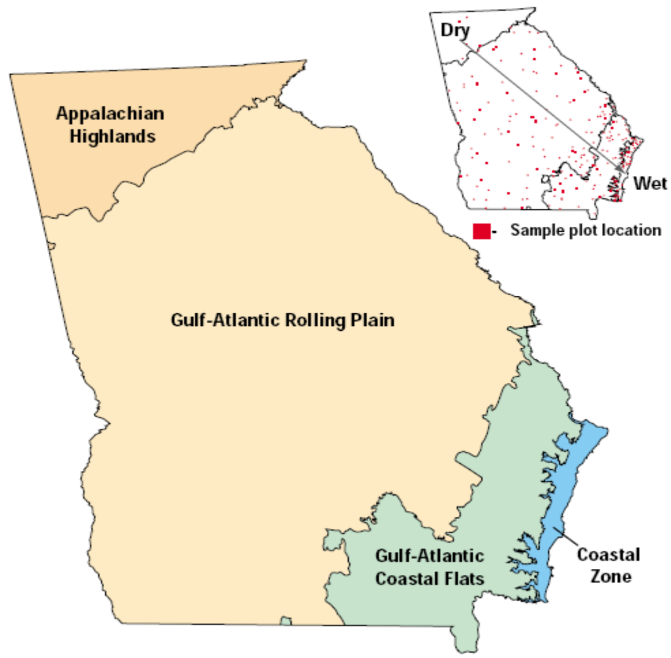

Figure 2. Physiographic strata in Georgia.

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Glossary of Terms

Anthropogenic: Made by people or resulting from human activities. Usually used in the context of environmental impacts that are a result of human activities.

Assessment Area: A 0.5 hectare area that represents the wetland sampling point where data were collected for the NWCA.

Attributable Risk: An estimate of the proportion of the population in poor biological condition that could be reduced if the effects of a particular stressor were eliminated.

Buffer: A defined area immediately adjacent to and surrounding the NWCA Assessment Area, extending 100 meters from the Assessment Area.

Coefficient of Conservatism (C-value): An assigned value describing the tendency of an individual plant species to occur in disturbed versus pristine conditions. Values are state or regionally specific and scaled from 0 (widespread, generalist species that thrive under disturbed conditions) to 10 (occur in specific habitats that are minimally disturbed*).*

Condition: The ecological state of a wetland. The NWCA used indicators of condition, such as the Vegetation Multimetric Index, to describe ecological condition.

Conterminous United States: The United States exclusive of Alaska and Hawaii.

Cowardin Classification System: A national wetland classification system developed by the U.S. Fish and Wildlife Service (FWS) to describe ecological units with similar natural attributes and provide uniform concepts and terminology for describing and mapping wetlands and deepwater habitats. The units are arranged in a hierarchal system to aid resource management decisions.

Cowardin Definition of a Wetland: Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands categorized using the Cowardin System must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes (i.e., plants that have adapted to living in saturated conditions); (2) the substrate is predominantly undrained hydric soils; and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year. This biologically-based definition is used by the NWCA to define the target population or group of wetlands of the survey.

Damming Stressors: Indicators of stressors that cause hydrologic alterations in a wetland by impounding or impeding water flow from or within the wetland. Stress was measured based on observations of features or activities that could restrict water flow from a site, such as dikes, dams, berms, or railroad beds.

Ditching Stressors: Indicators of stressors that cause hydrologic alterations in a wetland by draining water within the wetland. Stress was measured based on observations of features or activities that potentially drain water from a site, such as ditches, corrugated pipe, excavation, or dredging.

Ecoregion: Geographical areas that are similar in climate, vegetation, soil type, and geology. Water resources within a particular ecoregion have similar natural characteristics and similar responses to stressors.

Ecosystem services: The direct and indirect benefits that people, society, and the economy receive through the goods and services provided by nature.

Estuarine Ecosystem: As defined by the Cowardin system, deep water tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed, or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land.

Eutrophication: The enrichment of water bodies by inorganic plant nutrients (e.g., nitrogen, phosphorus). It may occur naturally but can also be the result of human activity (e.g., fertilizer runoff, sewage discharge).

Filling/Erosion Stressors: Indicators of stressors that cause hydrologic alterations in a wetland by removing or depositing soil or sediment. Stress was measured based on observations of features caused by erosion or deposition, such as soil loss, root exposure, fill/spoil banks, or freshly deposited sediment.

Floristic Quality Assessment Index (FQAI): A two metric calculation that captures information about plant community composition based upon the total number of unique plant species at a given site, known as species richness (diversity), and the tolerance of each species to human-mediated disturbance. One of four metrics included in the Vegetation Multimetric Index.

Geomorphology: The science and study of landforms on the Earth's surface, their evolution over time, and the interpretation of landforms as a record of geologic history.

Hardening Stressors: Indicators of stressors that cause hydrologic alterations in a wetland by prohibiting or restricting the movement of water or air into or through the soil. Stress was measured based on observations of activities that result in surface hardening or compaction, such as parking lots, suburban residential development, or roads.

Heavy Metal Index: Indicator of stressors that can cause elevated heavy metal concentrations in wetland soils. The index evaluated concentrations of 12 heavy metals associated with anthropogenic activities relative to their natural background concentrations in soils.

Hydrogeomorphic (HGM) Classification System: A wetland classification system developed by the U.S. Army Corps of Engineers that describes and categorizes wetlands based on geomorphic setting (landscape location), water source(s), and hydrodynamics.

Hydrodynamics: The movement of groundwater and surface water.

Hydrology: The movement, distribution, and physical and chemical characteristics of surface and subsurface water.

Hydrophytes: Plants that have adapted to living in saturated conditions.

Indicators of Condition: Physical, chemical, and biological factors that describe the ecological condition of a wetland. The NWCA uses a Vegetation Multimetric Index as a biological indicator of condition.

Index: A combination of metrics used to generate a single score evaluating the condition or prevalence of stressors at a site.

Indicators of Stress (Stressors): Physical, chemical, and biological factors that can result from, and therefore, can be used to identify stressors or anthropogenic activities that have impacted wetland condition.

Least-disturbed: A disturbance class used to describe sites that represent the best available physical, chemical, and biological habitat conditions in the current state of the landscape within an NWCA Reporting Group; represents approximately 15-25% of the sites within a Reporting Group and used as Reference Condition for the purposes of the NWCA Survey.

Metric: An individual measure of a particular property used to evaluate condition or stressors at an individual site.

Microcystin: A potentially toxic substance produced by cyanobacteria (a group of microbes also called blue-green algae).

Monocot: One of two groups of flowering plants characterized by seedlings that have one seed-leaf (e.g., grasses, sedges, rushes, lilies, irises, and orchids).

Most-disturbed: A disturbance class used to describe sites that have the worst physical, chemical, and biological habitat condition in the current state of the landscape within an NWCA Reporting Group; represents approximately 20-30% of the sites within a Reporting Group.

Native Plant Species: Plant taxa that are indigenous to the state in which they occur.

Nonnative Plant Species: For purposes of the NWCA, nonnative plant species include introduced taxa (nonindigenous to the conterminous United States (US)), adventive taxa (native to some areas of the US, but introduced in the location of occurrence), and cryptogenic taxa (taxa that include both native and introduced genotypes, varieties, or subspecies).

Nonnative Plant Stressor Indicator (NPSI): Indicator of stress caused by the presence of nonnative plants in a wetland. The Index is comprised of three metrics: Relative Cover of Nonnative Species, Richness of Nonnative Species, and Relative Frequency of Occurrence of Nonnative Species.

Number of Plant Species Tolerant to Disturbance: The number of plant species at the sampling location with a Coefficient of Conservatism (C-value) indicating a relatively high tolerance for disturbance. One of four metrics included in the Vegetation Multimetric Index.

Nutrients: Mineral substances that are absorbed by the roots of plants for nourishment. These substances (e.g., nitrogen, phosphorus) are essential to life, but in excess concentrations can over-stimulate the growth of algae and other plants in water. Excess nutrients in aquatic resources can come from agricultural and urban runoff, leaking septic systems, sewage discharges, and similar sources.

NWCA Aggregated Ecoregions: Refers to the four ecoregions (Coastal Plains, Eastern Mountain and Upper Midwest, Interior Plains, and West) used for NWCA analysis and reporting. The Aggregated Ecoregions are combinations of nine aggregated ecoregions used in other NARS studies.

NWCA Aggregated Wetland Types: Refers to the four general wetland types (Estuarine Herbaceous; Estuarine Woody; Inland Herbaceous; and Inland Woody) used for NWCA analysis and reporting. The Aggregated Wetland Types are combinations of Cowardin Wetland Types that were part of the NWCA target population.

Palustrine Ecosystem: As defined by the Cowardin system, includes all nontidal wetlands dominated by trees, shrubs, persistent emergent, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.05%. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 8 hectares (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2 meters at low water; and (4) salinity due to ocean-derived salts less than 0.05%.

Population Estimates: An approximation (reported as a percent of the total area or number of acres) of the entire group of wetlands in the conterminous U.S. that were the target of the study. The NWCA focus is on wetlands as groups or populations, rather than individual wetlands.

Probability Based Design: A type of random sampling technique in which every element of the population has a known probability of being selected for sampling.

Reference Condition: The least-disturbed condition available in an ecological region; determined based on specific criteria and used as a benchmark for comparison with other sample sites in the region.

Relative Cover of Native Monocot Species: The proportion of the sampling location covered by native monocot species in relation to all plant species present. One of four metrics included in the Vegetation Multimetric Index.

Relative Cover of Nonnative Species: The proportion of the sampling location covered by nonnative plants relative to all plant species present. One of three metrics included in the Nonnative Plant Stressor Index (NPSI).

Relative Extent (Stressor 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 Frequency of Occurrence of Nonnative Species: The occurrence of nonnative plant species at a site compared to the total number of species. One of three metrics included in the Nonnative Plant Stressor Index (NPSI).

Relative Importance of Native Plant Species: A measurement of the proportion of the sampling location covered by native plants relative to all plants present (i.e., relative cover) and the occurrence of native plant species at a site compared to the total number of species (i.e., relative frequency). One of four metrics included in the Vegetation Multimetric Index.

Relative Risk: The probability or likelihood of having poor ecological condition when the magnitude of a stress indicator is high relative to when it is low. This is often presented as a relative risk ratio.

Richness of Nonnative Species: The number of nonnative plant species at the sampling location. One of three metrics included in the Nonnative Plant Stressor Index (NPSI).

Soil Phosphorus: An essential plant nutrient. However, high concentrations, due to runoff from agricultural and urban runoff, sewage discharges, leaking sewer systems, and other sources, can lead to eutrophication in wetlands and other water bodies. For the NWCA, the concentration of total phosphorus in the soil was used as an indicator of stressors that cause elevated soil phosphorus concentrations. Soil phosphorus concentrations were assessed relative to a threshold set using the reference site distribution approach.

Stressors: Factors, activities, or land uses that adversely affect, and therefore degrade, aquatic ecosystems. The NWCA measures stress using chemical, physical, and biological indicators (e.g., high soil phosphorus concentrations, ditches, relative cover of nonnative plants).

Vegetation Multimetric Index (VMMI): A national indicator of biological condition developed for the NWCA based on plant species composition (presence and abundance) at sampling locations and plant species traits. It combines four metrics: a Floristic Quality Assessment Index (FQAI), Relative Importance of Native Plant Species, Number of Plant Species Tolerant to Disturbance, and Relative Cover of Native Monocot Species.

Vegetation Removal Stressors: Indicators of stressors that result in losses, removals, or damage of the vegetation community in a wetland. Stress was measured based on observations of activities that result in vegetation removal, such as mowing, shrub cutting, herbicide use, intensive grazing, and recently burned forest.

Vegetation Replacement Stressors: Indicators of stressors that result in changes to the plant species present in a wetland. Stress was measured based on observations of activities or land uses that would alter the composition of the plant community, such as tree plantations, nursery, golf courses, lawns, parks, row crops, pasture, hay fields, or rangeland.

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List of Abbreviations and Acronyms

Ag	Silver
Cd	Cadmium
cm	Centimeter
Co	Cobalt
Cr	Chromium
Cu	Copper
C-value	Coefficient of Conservatism
CWA	Clean Water Act
EPA	U.S. Environmental Protection Agency
˚F	degree Fahrenheit
FQAI	Floristic Quality Assessment Index
FWS	U. S. Fish and Wildlife Service
GRTS	Generalized Random Tessellation Stratified
GIS	Geographic Information System
ha	Hectare
HAB	Harmful Algal Bloom
HGM	Hydrogeomorphic Class
kg	Kilogram
L	Liter
m	Meter
mg	Milligram
MMI	Multimetric Index
NARS	National Aquatic Resource Survey
Ni	Nickel
NPSI	Nonnative Plant Stressor Indicator
NRCS	Natural Resources Conservation Service
NWCA	National Wetland Condition Assessment
ORD	Office of Research and Development
ORISE	Oak Ridge Institute for Science and Education
OW	Office of Water
P	Phosphorus
Pb	Lead
RAM	Rapid Assessment Method
Sb	Antimony
S&T	Status and Trends
Sn	Tin
spp	Multiple species
µg	Microgram
USA-RAM	U.S.A. Rapid Assessment Method
USDA	U.S. Department of Agriculture
V	Vanadium
VMMI	Vegetation Multimetric Index
W	Tungsten
WHO	World Health Organization

Zn	Zinc