Weber River Watershed
Wetland Condition Assessment

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Cover: Predominantly snowmelt-fed wet meadow in the upper Weber River watershed (main photo), aquatic bed fringed by emergent marsh in a managed impoundment near Great Salt Lake (left inset), *Salicornia rubra* (pickleweed) displaying its fall colors in an alkaline depression adjacent to Great Salt Lake (middle inset), and mid-elevation montane shrubland in a small tributary to the Weber River (right inset).

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Executive Summary

The Utah Geological Survey (UGS), with a grant from the U.S. Environmental Protection Agency, conducted an assessment of wetlands in the Weber River watershed in 2014. The assessment project focused on vegetated palustrine wetlands and included all wetlands with at least 30% cover of herbaceous emergent plants, trees, or shrubs and only those aquatic bed wetlands less than 2 meters deep, less than eight hectares in size, and located outside of a channel. Project objectives included providing data for the calibration and validation of assessment methods and using both field and GIS-based landscape data to evaluate wetland condition. A pilot multi-metric index was also developed to more robustly evaluate wetland condition for a subset of the field sites.

The watershed was divided into six strata, including the Wetlands (closest to Great Salt Lake) and Footslopes (in the Wasatch Front area) in the Central Basin and Range ecoregion and the Valleys, Foothills, Montane Zone, and Uintas (arranged from lowest to highest elevation) in predominantly the Wasatch and Uinta Mountains ecoregion. Field surveys were conducted at 12 randomly selected sites per strata using the draft Utah Rapid Assessment Procedure (URAP). This protocol, developed by the UGS, uses a series of metrics to evaluate wetland condition and collects supplementary data on features such as stressors, plant community composition, and water quality parameters. A landscape analysis was conducted in GIS using information on wetland location, wetland type, land ownership, and the results of a recently created wetland landscape stress model to identify potentially rare, unprotected and threatened wetland types.

Altered plant communities were one of the most commonly recorded issues in Weber River watershed wetlands. At 25% of sites, half or more of the total plant cover was composed of non-native species. Wetlands with very little non-native plant cover (<10% relative cover) were common in the Uintas, occasional in the Montane Zone, and very rare in other strata. Plant species of concern in the Central Basin and Range ecoregion include the noxious weeds *Phragmites australis* (common reed) and *Lepidium latifolium* (broadleaved pepperweed), and *Elaeagnus angustifolia* (Russian olive), though only the first of the three species is both widespread and often abundant where found. The non-native species *Bassia hyssopifolia* (fivehorn smootherweed), *Trifolium fragiferum* (strawberry clover), and *Echinochloa crus-galli* (barnyard grass) also have potential for causing ecological and economic damage in the region. In the Wasatch and Uinta Mountains ecoregion, species of concern include the noxious weed *Cirsium arvense* (Canada thistle), *Elymus repens* (quackgrass), and *Phragmites australis* and the non-native *Phalaris arundinacea* (reed canarygrass). This latter species was common and sometimes very abundant in the Valleys and Foothills and is considered a problematic species in the eastern United States. In both ecoregions, some common non-native species are planted for erosion control or livestock forage, so species control is unlikely to occur without a change in management practices.

Livestock grazing was the most frequently recorded stressor within surveyed wetlands and was also very common in wetland buffers. Grazing impacts to hydroperiod and physical substrate, such as stream entrenchment, soil compaction, pugging, and unnatural bare areas, were relatively easy to visibly assess and were rarely severe. Assessing the degree to which livestock grazing may be impacting plant community composition and nutrient dynamics was much more difficult. For example, high non-native species cover could be due to grazing pressure, but could also be the result of factors such as landscape fragmentation from roads. Moderate to severe grazing impacts were most common in the

Footslopes and Foothills, found at 66.7% and 45.5% of wetland area, respectively, and least common in the Wetlands.

High water quality stress is common in the Wetlands, Footslopes, and Valleys and is often related to landscape issues such as impaired water sources or heavy agricultural and urban development, sometimes in combination with intense local grazing pressure. Footslopes sites in particular are subject to high levels of water quality stress based on multiple measures. In contrast, sites in the Foothills, Montane Zone, and Uintas generally have low levels of water quality stress, and most stress is related to local (i.e., livestock grazing) rather than landscape factors. The majority of potential water contaminants are due either to the wetland water source or stressors occurring within sites, so buffers, even though they were generally wide, could not prevent all water quality degradation. Recommendations to improve wetland water quality include (1) improving quality of wetland water sources that are impaired; (2) encourage land managers and private land owners to sustainably manage grazing, off-road vehicle use, and other activities within and adjacent to sites; and (3) obtain more data on the natural range of water quality parameters at different wetland types so that wetland impairment can be better understood. Almost one-third of Utah Division of Water Quality stream assessment units in the Weber River watershed are impaired for one or more uses; most of the common impairments can either be directly filtered (e.g., copper and *E. coli*) or indirectly improved (e.g., dissolved oxygen, temperature) by wetlands. Wetlands are most effective at improving water quality when they are located in watersheds impaired by non-source point pollutants and when they have intact soils and structural components and do not receive pollutants exceeding their assimilative capacity.

Hydropattern alteration is very common in the Wetlands and Footslopes, somewhat common in the Valleys and Foothills, and relatively uncommon in the Montane Zone and Uintas. Sites in the Wetlands typically receive water directly or indirectly as the result of wildlife management activities, whereas sites in the Footslopes usually receive either irrigation return flows or managed water to maintain pastureland. Restoration of hydrology to a natural condition is extremely unlikely, particularly in the Central Basin and Range ecoregion, because hydrologic modifications are permanent fixtures on the landscape. Many wetlands with altered hydrology provide important wildlife and water quality benefits, and some, such as passively managed stock ponds, may mimic the hydrology of natural wetlands.

Wetlands that are minimally altered are relatively rare in the Weber River watershed, particularly wetlands protected from water quality and hydropattern stressors in the Wetlands, Footslopes, and Valleys strata and wetlands with undisturbed, predominantly native (>95% relative native species cover) plant communities in all strata except the Uintas. Least disturbed wetlands across the geographic range are worth protecting to provide baseline expectations for natural wetland condition and function, and because these best-condition wetlands represent a unique piece of biodiversity that cannot easily be replaced. Particular wetland types that are uncommon in the watershed include woody wetlands and emergent saturated wetlands in the Central Basin and Range ecoregion and cattail or bulrush-dominated marshes in the Wasatch and Uinta Mountains ecoregion. Wetlands in the Footslopes and Valleys, where very little wetland area is in a managed wetland class, may benefit most from direct wetland preservation and/or wetland easements. In most other strata, much of the wetland area is owned by public entities or by land owners with large Cooperative Wildlife Management Units, which may make implementing management recommendations easier.

The pilot multi-metric index was very successful at separating least and most disturbed sites and was useful for identifying four important challenges to meet before the method can be more broadly applied. First, subjective site selection must supplement random sampling to make sure that an appropriate sample of least and most disturbed sites are obtained. Second, a statistical method of dividing sites into good, fair, and poor categories should be developed for ease of interpretation of results. Third, a broader range of variables should be considered for index development, such as invertebrate community data and water chemistry parameters. Fourth, we must determine the best method of grouping sites so that groups are inclusive enough to provide an adequate sample size and exclusive enough so that sites within groups are comparable. Ecological System, hydrogeomorphic class, and water regime sometimes, but not always, were useful for determining appropriate groupings. In the Central Basin and Range ecoregion, classifications should be developed based on salinity and both natural and anthropogenic hydrologic classes.

Data from this project and a concurrent U.S. Forest Service funded project on the northwestern slope of the Uinta Mountains were used to verify and calibrate URAP. Some changes to the URAP method were made as a result of this project. Field survey results were also used in the development of a GIS-based landscape stress model for a project funded by the Utah Department of Natural Resources' Endangered Species Mitigation Fund, reported on elsewhere. All URAP category scores and overall URAP scores, analyzed by ecoregion, were at least weakly and usually strongly correlated with at least one of the hypothesized alternative measures of wetland condition. Nonetheless, individual metric scores are more useful then metric summaries because they are more indicative of healthy or stressed condition.

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1.0 Introduction

1.1 Project Background

Wetlands in the Weber River watershed include small ponds and springs in montane areas, riparian meadows and willow stands in mountain valleys, and extensive complexes of marshes, alkaline depressions, mudflats, and playas along the shores of Great Salt Lake. These wetlands have the potential to provide important ecological services including wildlife habitat, water quality improvement, and flood attenuation. The majority of wetland area is concentrated on the edge of Great Salt Lake; these wetlands support millions of migrating and nesting birds, including some of the largest breeding populations of white-faced ibis and American white pelicans in the world (Paul and Manning, 2002). Weber River watershed wetlands support native amphibian species, including a newly reintroduced population of Columbia spotted frog (Bailey and others, 2006). Wetlands can help protect in-stream water quality to support native fish species such as Bonneville cutthroat trout and bluehead sucker and to preserve recreational fishing opportunities, including at the five Blue Ribbon Fisheries located in the Weber River watershed (Weber River Partnership, 2014).

Anthropogenic disturbances have the potential to affect wetland condition and their ability to provide ecological services. About 8% of the Weber River watershed is developed land—most of the population is concentrated in the Wasatch Front between Great Salt Lake and the Wasatch Mountains—and another 8% of the land cover is agriculture (Homer and others, 2015). Livestock grazing is common on the largely privately owned land in the watershed; resource extraction is less common but concentrated in a few areas. Many reservoirs and streams in the watershed are not meeting water quality goals (Utah Division of Water Quality, 2014b and c) and hydrologic modifications such as reservoirs, groundwater withdrawal, and diversions are common. However, little work has been conducted to evaluate the extent to which these anthropogenic disturbances impact wetlands in the region.

The Utah Geological Survey (UGS), with a grant from the U.S. Environmental Protection Agency (EPA), conducted an assessment of wetlands in the Weber River watershed to provide data on the type and condition of wetlands in the study area. This data can provide an important baseline to evaluate future condition as land use in the watershed continues to change; the population is expected to double between 2000 and 2050 (Utah Foundation, 2014), and agriculture land use is projected to decrease by 50% (Utah Division of Water Resources, 2009). Our project had four major objectives including summarizing field-based wetland information to provide an update on current condition and potential concerns, providing data for the calibration and validation of assessment methods, developing a pilot multi-metric index to more robustly evaluate wetland condition, and summarizing mapped wetland data and the results of a landscape stress model to better understand the landscape setting of wetlands in the watershed.

1.2 Overview of Wetland Assessments

1.2.1 EPA's Three-tiered Framework

The work described in this report follows the EPA's three-tiered framework to assess wetland condition at varying spatial scales and levels of intensity (U.S. Environmental Protection Agency, 2006). Level I assessments are conducted at the broadest scale using geographic information systems (GIS) and remotely sensed data to evaluate *expected* wetland condition based on surrounding land use, potential stressors, and other inputs. These assessments are relatively inexpensive and efficient for evaluating wetlands across broad geographic areas, but cannot provide data on *actual* condition and are limited to including only stressors with available spatial data. Level II assessments are field surveys designed to be relatively rapid (approximately four hours of field time per site) and are only moderately detailed, often relying on qualitative rather than quantitative evaluation. These assessments maximize the amount of field sites that can be surveyed and the strength of inference, but methods can be difficult to develop and calibrate. Level III assessments are more detailed quantitative field evaluations that have the highest degree of reliability and can withstand the most scrutiny, but at the expense of requiring the most professional expertise and sampling time. These assessments often use invertebrate, plant community, or water quality parameters to develop indices to distinguish between low and high quality sites and can sometimes be used to evaluate or calibrate Level I and II assessments.

1.2.2 Condition Versus Function Assessments

The assessments conducted for this project are primarily intended to evaluate the condition, rather than the function, of wetlands. Wetlands in good condition exhibit species composition, physical structure, and ecological processing within the bounds of states expected for systems operating under natural disturbance regimes (Lemly and Gilligan, 2013). Direct or indirect anthropogenic alteration may lead to a change in these states and a concomitant lowering of the overall condition of the wetland. For condition-focused assessments, wetlands are evaluated to determine the degree to which they deviate from a reference standard, or anthropogenically unaltered, wetland. Functional assessments, on the other hand, evaluate services provided by wetlands that are deemed important to society, such as the ability to attenuate flood waters or provide wildlife habitat (Fennessy and others, 2007). Many severely altered (i.e., low condition) wetlands still provide functional services; for example, a wetland adjacent to a wastewater treatment plant can improve water quality, and an artificially impounded reservoir can provide amphibian habitat. Wetland processes cannot be easily reduced to a few functional services, and some services provided by naturally functioning wetlands have not yet been recognized or valued by society. Condition assessments serve as a buffer against the subjectivity of societal valuation of services by evaluating wetlands based on a naturally functioning baseline.

1.2.3 Reference Standard

Reference standards are an important component of condition assessments. The reference standard condition is the condition that corresponds with the greatest ecological integrity within the continuum of possible site conditions (Sutula and others, 2006) and is usually specific to a particular class of wetland (e.g., montane meadow, saline depression). The reference standard condition can refer to the expected state prior to any anthropogenic disturbance or at a specified historic point in time, or it can refer to the condition found at the least disturbed sites within the survey area or wetland type (Stoddard and others, 2006). We used both types of reference standards for this project, using pre-European settlement condition as the standard for the Level II rapid assessment and least disturbed condition as the standard for the Level III multi-metric index development.

1.2.4 Wetland Classification

Wetland classification is helpful because appropriate classifications ensure that only similarly situated sites are compared to one another. The only available spatial wetland data for the state, the

National Wetlands Inventory, is classified using the U.S. Fish and Wildlife Service's Cowardin classification scheme, which separates wetlands and deep water habitat into three systems in Utah (riverine, lacustrine, and palustrine) that are further divided based on substrate material, predominant overstory life form, water regime, and other modifiers (Cowardin and others, 1979). Therefore, we only used the Cowardin classification scheme to select wetlands for our survey sample frame and to conduct the Level I landscape analysis.

We classified wetlands using both hydrogeomorphic (HGM) and Ecological Systems classifications to set the context for expected condition of wetlands during field assessments. The anticipated natural state of a wetland depends in large part on its major defining characteristics, such as location (e.g., in an isolated depression or along a river; in arid desert or snowy mountains). The HGM system classifies wetlands as one of seven types based on hydrology and geomorphology, including slope, depressional, and riverine wetlands (Brinson, 1993). HGM classes are useful for setting the expected condition for hydrologic attributes such as water retention time, nutrient cycling capacity, and hydroperiod. The International Terrestrial Ecological Systems Classification (Ecological Systems), developed by NatureServe, classifies terrestrial systems based on vegetation patterns, abiotic factors, and ecological processes (http://explorer.natureserve.org); fifteen wetland and riparian Ecological Systems have been described for the state of Utah. Ecological Systems are useful for setting the expected condition of structural elements of wetlands, such as the relative cover of woody versus non-woody plant species and the amount and type of litter and woody debris.

We also used classification to organize wetlands into groups for analysis and reporting so that differences within groups were more likely to be driven by anthropogenic disturbances rather than natural factors. We almost always conducted separate analyzes for wetlands in the two major Omernik Level III ecoregions in our project area, the Central Basin and Range and the Wasatch and Uinta Mountains. The four hierarchical ecoregion levels divide the landscape into geographical units based on biotic and abiotic properties, including those related to geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Omernik, 1987). We combined the Wyoming Basin Level III ecoregion, which was a very small percent of the study area and only included one surveyed site, with the Wasatch and Uinta Mountains ecoregion for analysis. We also considered the more detailed Level IV ecoregions, the Cowardin water regimes, the HGM classes, and the Ecological Systems when determining how to group sites, trying to minimize natural variability within classes while avoiding the creation of too many classes.

1.3 Project Objectives

1.3.1 Objective 1: Condition Summarization

Our first objective was to provide information on the status of wetlands in the Weber River watershed to create a baseline and to provide potentially useful information for water quality specialists, wildlife managers, conservation and restoration specialists, and others with an interest in wetlands and watersheds. We used the draft Utah Rapid Assessment Procedure (URAP) to collect field data on wetland condition in the Weber River watershed. URAP was developed by the UGS in early 2014 after field surveys were undertaken to compare three different rapid assessment protocols, including the Utah Wetlands Ambient Assessment Method (Hoven and Paul, 2010), a protocol used by the EPA as part of the 2011 National Wetland Condition Assessment (www.epa.gov/wetlands/survey), and a protocol used by the Colorado Natural Heritage Program (Lemly and Gilligan, 2013) based on the Ecological Integrity Assessment developed by NatureServe (Faber-Langendoen and others, 2008). The core of URAP is a Level II assessment composed of a series of metrics designed to allow surveyors to quickly evaluate important and visibly apparent aspects of wetland condition. The protocol also includes a substantial amount of supplementary data collection, including a soil profile, observations of stressors observed at and surrounding the survey site, detailed plant community composition data, and cover of structural (e.g., woody debris, boulders, seeps, etc.) and ground cover (e.g., litter, bare ground, algae) features. This additional data can be used to evaluate the relationship between metric scores and site measures and to better characterize wetland states.

The reference standard condition for the URAP metrics is adopted from Colorado Natural Heritage Program's Ecological Integrity Assessment, which sets a standard based on "deviation from the natural range of variability expressed in wetlands over the past ~200–300 years (prior to European settlement)" (Lemly and Gilligan, 2013). Reference standard condition is ideally determined from field observations of undisturbed or minimally disturbed wetlands (i.e., reference standard sites), but there can be too few undisturbed sites in some highly altered landscape to determine the natural range of variability. Because of this, reference standards for URAP were developed based on a combination of field observations from minimally disturbed wetlands, review of relevant literature, and evaluation of conditions described in rapid assessment protocols from other states. For some URAP metrics, surveyors are required to evaluate wetland condition in relation to expectations for either the HGM class (for hydrologic metrics) or Ecological System (for metrics related to litter).

Survey results were analyzed to provide information on the status of wetlands in the study area, including evaluation of the types and commonness of stressors in the landscape, summarization of rapid assessment survey results, and characterization of wetland vegetation. URAP condition metrics are presented on their own, summarized within categories, and summarized together to provide an overall condition score. Numeric metric scores were converted to ranks, letter grades A through D, to denote wetland condition ranging from pristine or reference condition to severely altered wetlands that may have little conservation value and may be extremely difficult to restore (table 1). Categories and descriptions of metrics used in URAP are shown in table 2. Plant community composition data was used to calculate Floristic Quality Assessment (FQA) metrics. These metrics aggregate composition data into indices based on number of species, species' nativity, species' relative tolerance for disturbance and species cover (Rocchio and Crawford, 2013; Rocchio, 2007).

1.3.2 Objective 2: Method Verification and Calibration

Our second objective was to produce data that could be used to refine wetland assessment tools and evaluate their effectiveness. Data from this project and a concurrent U.S. Forest Service funded project on the northwestern slope of the Uinta Mountains were used to verify and calibrate URAP. Verification is a general assessment of whether metrics are measuring wetland condition as intended, and calibration is the determination of the scientific validity of metrics through correlation with more intensive measures of condition (Sutula and others, 2006). We verified individual URAP metrics by analyzing relationships between metric values and other similar measures whenever possible and through discussion with field surveyors regarding how well metric states captured observed field conditions. We also verified the robustness of plant community composition data by comparing FQA

Table 1. Definition of assessment ranks and associated point values used for scoring Utah Rapid Assessment Procedure. Definitions are taken from Lemly and Gilligan (2013).

Rank	Score	Definition
A	5	Reference Condition (No or Minimal Human Impact): Wetland functions within the bounds of natural disturbance regimes. The surrounding landscape contains natural habitats that are essentially unfragmented with little to no stressors; vegetation structure and composition are within the natural range of variation, nonnative species are essentially absent, and a comprehensive set of key species are present; soil properties and hydrological functions are intact. Management should focus on preservation and protection.
B	4	Slight Deviation from Reference: Wetland predominantly functions within the bounds of natural disturbance regimes. The surrounding landscape contains largely natural habitats that are minimally fragmented with few stressors; vegetation structure and composition deviate slightly from the natural range of variation, nonnative species and noxious weeds are present in minor amounts, and most key species are present; soils properties and hydrology are only slightly altered. Management should focus on the prevention of further alteration.
C	3	Moderate Deviation from Reference: Wetland has a number of unfavorable characteristics. The surrounding landscape is moderately fragmented with several stressors; the vegetation structure and composition is somewhat outside the natural range of variation, nonnative species and noxious weeds may have a sizeable presence or moderately negative impacts, and many key species are absent; soil properties and hydrology are altered. Management would be needed to maintain or restore certain ecological attributes.
D	1	Significant Deviation from Reference: Wetland has severely altered characteristics. The surrounding landscape contains little natural habitat and is very fragmented; the vegetation structure and composition are well beyond their natural range of variation, nonnative species and noxious weeds exert a strong negative impact, and most key species are absent; soil properties and hydrology are severely altered. There may be little long term conservation value without restoration, and such restoration may be difficult or uncertain.

metric values with and without low-cover plant species and metric values collected at different spatial scales. Some changes were made to the draft URAP protocol based on input from field surveyors, including modified descriptions of metric states. We developed methods to combine individual metrics into categorical and overall scores based on calibration with stressor and plant community composition data. Results presented in this report use the final scoring methods developed through the calibration process. Details of method verification and calibration are presented in appendix A.

Once a final scoring method was developed, URAP results were used in the development of a GIS-based landscape stress model for a project funded by the Utah Department of Natural Resources' Endangered Species Mitigation Fund (Menuz, 2015b). The landscape stress model is a 30-m resolution raster file depicting the potential degree of wetland stress across the landscape based on geospatial predictors hypothesized to be associated with wetland disturbance, such as urban land cover and hydrologic modification. Each predictor was assigned a weight based on its probable severity and a decay function based on the distance at which the predictor was assumed to no longer impact a site. Selection of predictor weights and decay functions and of a final method to combine predictors into an overall stress score were calibrated with URAP scores and plant community composition data from the Weber River watershed project. Details of model development and calibration are presented in the model report (Menuz, 2015b).

In this report, we analyze the strength of relationships between all three levels of data, including landscape stress model values, field-based stressor data, rapid assessment scores, and intensive plant

Table 2. Metrics evaluated by the Utah Rapid Assessment Procedure, listed under metric categories. Some metrics are evaluated directly within the assessment area (AA), some in areas surrounding the AA, and some take into consideration both local and landscape factors.

Metric	Description
Landscape Context	
Percent Intact Landscape	Percent of 500 m buffer surrounding AA that is directly connected to AA and composed of natural or semi-natural (buffer) land cover
Percent Buffer[1]	Percent of AA edge composed of buffer land cover
Buffer Width[1]	Mean width of buffer land cover (evaluated up to 100 m in width)
Buffer Condition- Soil and Substrate[1]	Soil and substrate condition within buffer (e.g., presence of unnatural bare patches, ruts, etc.)
Buffer Condition-Vegetation[1]	Vegetation condition within buffer (e.g., nativity of species in buffer)
Connectivity- Whole Wetland Edge	Hydrologic connection between wetland edge and surrounding landscape
Hydrologic Condition	
Hydroperiod[2]	Naturalness of wetland inundation frequency and duration
Timing of Inundation[2]	Naturalness of timing of inundation to wetlands
Turbidity and Pollutants[3]	Visual evidence of degraded water quality, based on evidence of turbidity or pollutants
Algae Growth[3]	Evidence of potentially problematic algal blooms within AA (evaluated both in water and in areas with large patches of dried algae)
Water Quality	Evidence of water quality stressors reaching AA or within AA
Connectivity- AA Edge	Hydrologic connection between AA edge and surrounding landscape
Physical Structure	
Substrate and Soil Disturbance	Soil disturbance within AA
Vegetation Structure	
Horizontal Interspersion[4]	Number and degree of interspersion of distinctive vegetation patches within AA
Litter Accumulation[5]	Naturalness of herbaceous litter accumulation within AA
Woody Debris[5, 6]	Naturalness of woody debris within AA
Woody Species Regeneration[5, 6]	Naturalness of woody species regeneration within AA
Plant Species Composition	
Relative Cover Native Species	Relative cover of native species (native species cover / total cover)
Absolute Cover Noxious Species	Absolute cover of noxious weeds

[1]Buffer metrics are combined into one overall buffer score
[2]Evaluated with respect to similar wetlands within hydrogeomorphic class
[3]Only evaluated when water is present at sites or when large patches dry algae were present at sites
[4]Only included in scoring for some Ecological Systems
[5]Evaluted with respect to similar wetlands within Ecological System
[6]Only evaluated when woody debris and woody species are expected at sites

composition metrics. This analysis is not an independent assessment of methods because data from each method was used in the development of other methods. Nonetheless, comparison between levels of data is helpful to better understand the strengths and weakness of each method and to identify potential areas of future method improvement.

1.3.3 Objective 3: Multi-Metric Index Development

Our third objective was to develop a pilot multi-metric index to more intensely assess wetland condition. A multi-metric index is a Level III tool for assessing wetland condition that combines several quantitative metrics together to form a single unitless measure. The component metrics are each individually responsive to anthropogenic alterations, often capturing different aspects of a site that may respond to different types of impacts; the use of multiple metrics increases the reliability and often the strength of the index compared to use of a single metric (Furse and others, 2006). Multi-metric indices are developed by testing metrics and metric combinations that maximize the distinction between reference standard and highly disturbed sites. A multi-metric index can identify wetlands that are in good condition in spite of unnatural alterations, due perhaps to system resilience or effective management, because those wetlands have index values similar to reference standard sites. URAP would likely assign lower scores on some metrics to such wetlands based solely on the altered state of the wetland. Multi-metric indices are more reliable and scientifically defensible for characterizing individual sites. Multi-metric indices can also help determine the critical values at which stressors such as nutrient loading or livestock grazing alter a site from good to poor condition.

We developed a multi-metric index on a subset of sites to experiment with different development strategies and determine the scope of data needs before applying development to a larger group of sites. The reference standard condition was the least disturbed condition, the condition of those wetlands within the study group that were subject to the least amount of stress, rather than the pre-European settlement state used as the standard for URAP. Least disturbed condition is easier to characterize than pre-European states because extant examples are on the landscape, and least disturbed condition is a more realistic restoration or conservation goal. The index was developed using plant composition metrics because plant composition data represents an integration of information about recent and on-going disturbances, even those that are not readily apparent during field surveys (e.g., water quality disturbances, late season grazing). We developed the index using the broadest possible group of sites where differences in vegetation composition between sites did not depend on natural site attributes. We wanted to ensure that multi-metric index thresholds were appropriate and potentially obtainable for all wetlands within the group; it is not useful to apply thresholds developed in the Uinta Mountains to wetlands in mid-montane agricultural valleys. We loosely followed the multi-metric index development procedure used the EPA's National Wetland Condition Assessment (U.S. Environmental Protection Agency, *in review*), though we had a much smaller sample size of sites and had to modify many aspects of the procedure. This exploratory multi-metric index development will be expanded and refined with additional data from sites surveyed using URAP or similar protocols.

1.3.4 Objective 4: Landscape Analysis

Our fourth objective was to apply a Level I landscape analysis to all wetlands in the Weber River watershed to help identify potentially rare, unprotected and threatened wetland types. Some important wetland attributes can be evaluated directly for the entire wetland population using geospatial data rather than inference from the relatively small number of sites with field surveys. We looked at three important wetland attributes: wetland type, wetland ownership, and wetland stress level. Wetland types were identified based on Cowardin systems (emergent, shrub/scrub, and aquatic bed), Cowardin water regimes, and location relative to stream and lakes. These attributes help separate different wetlands based on the potential to provide wildlife habitat and potential to contribute to water quality improvement or degradation. Analysis of the abundance of wetland types per Level IV ecoregions can help identify rare wetland types and areas that may be lacking suitable habitat for some wildlife species. Wetland ownership was categorized based on the major ownership types within the study area, including state wildlife areas, other state lands, national forest lands, and private land. Data on wetland ownership provides insight into how wetlands are likely to be managed and can be used to prioritize conservation through identification of areas with very little formal wetland protection. Wetland stress levels were estimated using values from the landscape stress model developed by Menuz (2015b), described above. Wetland stress data were analyzed in conjunction with wetland type and wetland ownership data to determine the most threatened wetland types and potential management or conservation opportunities.

2.0 Study Area

2.1 Geographic and Ecoregional Setting

The study area for this project was the Weber watershed, as defined by the U.S. Geological Survey's [USGS] 6-digit Hydrologic Unit Code [HUC6] 160202 (http://nhd.usgs.gov/wbd.html, figure 1). The watershed has an area of approximately 6432 km^2 and about 99.7% of that area is located in Utah. The remaining area, located in Wyoming, was not included in this study. The watershed is bordered by the Wasatch Range to the east, the Uinta Mountains to the southeast, the Bear and Monte Cristo Ranges to the north, and Great Salt Lake to the west. Streams and rivers originate in montane headwaters and flow through mountain valleys and canyons to reach the Wasatch Front. The Wasatch Front is a flat, fertile plane formed by alluvial deposits from Lake Bonneville (Woods and others, 2001), an ancient lake that covered roughly 51,800 km^2 of the Great Basin until approximately 14,500 years ago (Oviatt, 1997). The watershed terminates at Great Salt Lake, a high-salinity terminal lake on the eastern edge of the Great Basin that is a remnant of Lake Bonneville.

The Weber River watershed is composed of three Omernik Level III ecoregions, the Wasatch and Uinta Mountains (82.2% of area), the Central Basin and Range (16.7%), and the Wyoming Basin (2.1%), and eleven Level IV ecoregions ([Omernik, 1987], table 3). The Wasatch and Uinta Mountains and Wyoming Basin ecoregions are collectively referred to as the montane ecoregion in this report and the Central Basin and Range ecoregion is referred to as the basin and range ecoregion.

The Wasatch and Uinta Mountains are composed of high, glaciated and partially glaciated mountains, dissected plateaus, foothills, and high elevation valleys (Woods and others, 2011). Plant communities range from alpine meadows above timberline, subalpine and mid-elevation forests composed of firs (*Abies* spp.), Engelmann spruce (*Picea engelmannii)*, lodgepole pine (*Pinus contorta)*, ponderosa pine (*Pinus ponderosa)*, and aspen (*Populus tremuloides)*, and semiarid foothills with a mix of pinyon-juniper woodland, sagebrush (*Artemisia* spp.), and Gambel oak (*Quercus gambelii*). The most land cover change in the ecoregion has occurred in mountain valleys, where sagebrush and other shrub species have been converted to irrigated cropland and pastureland. Wetlands within the ecoregion include headwater meadows and shrublands formed from groundwater and snowmelt, lower-elevation riparian areas, springs and seeps, and small often excavated depressions frequently used for watering livestock.

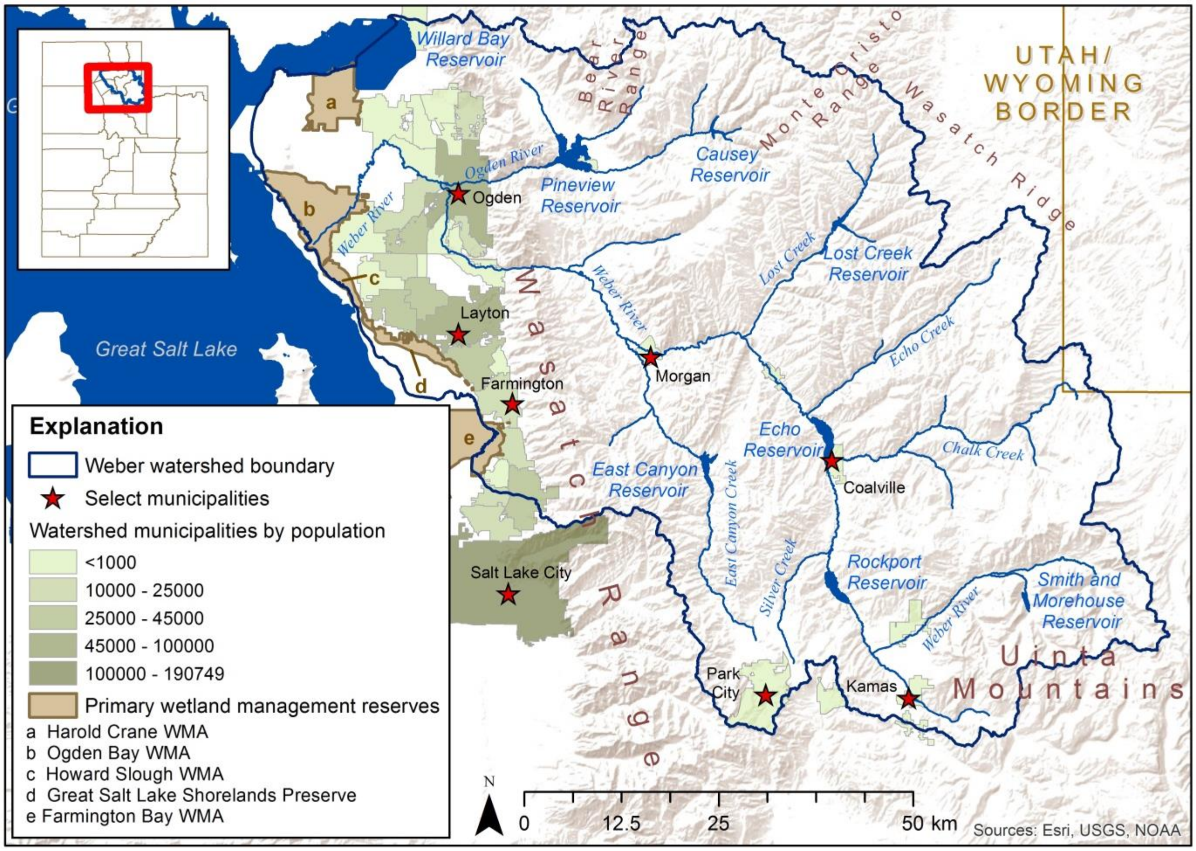

Figure 1. Overview map of the Weber watershed, including municipalities, major streams and reservoirs, and primary wetland management reserves.

Though less than one-fifth of the watershed, the Central Basin and Range ecoregion contains the majority of wetlands in the study area. Most wetlands occur on the eastern shore of Great Salt Lake and many are highly managed for waterfowl production by the Utah Division of Wildlife Resources through systems of canals, control structures, and impoundments. Plant communities vary depending on water management and the availability and duration of freshwater. Bulrush (*Schoenoplectus* spp.), cattails (*Typha* spp.), common reed (*Phragmites* spp.), and submerged aquatic vegetation (primarily *Stuckenia* spp.) are common in emergent marshes and artificial impoundments. Mountain rush (*Juncus arcticus* ssp. *littoralis),* and spikerushes (*Eleocharis* spp.) are commonly in seasonally flooded areas. Barren and sparsely vegetated playas, salt flats, and mudflats also occur throughout the area and have salt-tolerant plant species including pickleweed (*Salicornia* spp.) and saltgrass (*Distichlis* spp.). Land between the Great Salt Lake wetlands and the Wasatch Mountains is predominantly urban with some remnant wetlands and irrigated pastureland and cropland.

2.2 Climate and Hydrology

The Weber River watershed receives more precipitation than any other major basin in Utah and has the second highest ratio of water yield to land area (Utah Division of Water Resources, 2009). The

Table 3. Summary of ecoregional characteristics in the Weber watershed for Level III and IV Omernik ecoregions, with the amount of area occupied by each Level IV ecoregion within the study area. Information adapted from Woods and others (2001). Strata groupings indicate how each ecoregion was combined to form final strata (see text).

Level III Ecoregion	**Level IV Ecoregion**	**Area (km^2)**	**Geography**	**Plant Communities**	**Stratum**
Wasatch and Uinta Mountains	Alpine zone	22	Glaciated areas above timberline (~3300 m) in the Uinta and Wasatch Mountains	Meadows and rockland	Uintas
	Uinta subalpine forests	104	High elevation (~3000 to timberline) regions with glaciated basins, deep canyons, and lakes in the Uinta Mountains	Engelmann spruce (*Picea engelmannii)*, lodgepole pine (*Pinus contorta*), subalpine fir (*Abies lasiocarpa*)	Uintas
	Mid-elevation Uinta Mountains	605	Middle elevation (~2400-3000) regions with glacial features and deep canyons with perennial streams in the Uinta Mountains	Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), aspen (*Populus tremuloides)*, lodgepole pine (*P. contorta)*	Uintas
	Wasatch montane zone	864	Forested mountains and plateau in the Wasatch Mountains	Douglas-fir (*P. menziesii*), aspen (*P. tremuloides)*, Engelmann spruce (*P. engelmannii)*, subalpine fir (A. *lasiocarpa*)	Montane Zone
	Mountain valleys	457	Unforested terraces, flood plans, alluvial fans, and hills	Sagebrush (*Artemisia tridentata*); now mostly rangeland and irrigated cropland and pastureland	Valleys
	Semiarid foothills	3223	Drier woodlands and shrublands between ~1500 and 2400 m in elevation	Juniper trees (*Juniperus*) mixed with the shrubs sagebrush (*A. tridentata*), Gambel oak (*Quercus gambelii*) and mountain mahogany (*Cercocarpus* spp.), some ponderosa pine (*P. ponderosa*) at higher elevations	Foothills
Wyoming Basin	Foothill Shrublands and Low Mountains	68	Hilly area in the rain shadow of high mountains	Bunchgrasses and sagebrush (*Artemisia tridentata*)	Foothills
Central Basin and Range	Moist Wasatch Front footslopes	670	Gently sloping area fed by perennial streams and aqueducts	Urban areas with irrigated crops including vegetables, alfalfa, and small grains	Footslopes
	Shadscale-dominated saline basins	1	Internally-drained, gently sloping to flat arid region with highly salty and alkaline soils	Shadscale (*Atriplex confertifolia*), greasewood (*Sarcobatus vermiculatus*)	Wetlands
	Salt deserts	178	Nearly level, internally-drained, mostly barren, arid playas, salt flats, mud flats, and saline lakes with poorly drained clay soils	Barren or sparsely vegetated with salt-tolerant plants such as Salicornia (*Salicornia* spp.) and saltgrass (*Distichlis spicata*)	Wetlands
	Wetlands	225	Poorly drained often salty soils inundated with freshwater to create important habitat for migratory birds	Bulrush (*Schoenoplectus* spp.), cattails (*Typha* spp.), common reed (*Phragmites* spp.), and submerged aquatic vegetation (primarily *Stuckenia* spp.) with areas of open water	Wetlands

majority of precipitation occurs in the higher elevation foothills, mountain valleys, and mountains, which receive between 55 and 91 cm of precipitation per year; most as snowfall (Daly and others, 2008). Areas along the Wasatch Front and on the edge of Great Salt Lake receive between 44 and 47 cm of precipitation. Mean annual temperatures in the study area range from 3.3°C in the Uinta Mountains to between 5 and 7°C in the mid-elevation mountains and mountain valleys and around 11°C along the Wasatch Front and Great Salt Lake.

The majority of the watershed drains to Great Salt Lake via the Weber River, except for the southwest section (approximately 9% of the total area) which drains directly from the Wasatch Mountains to Great Salt Lake. The Weber River starts in the southeast of the watershed in the Uinta Mountains at an elevation of 3579 m and flows northwest through the valleys of Henefer and Morgan, and then through Weber Canyon to the city of Ogden. The Ogden River, flowing from its headwaters in the Monte Cristo, Wasatch and Bear River Ranges, joins the Weber River in Ogden. The natural path of the Weber River then continues west to wetlands on the shore of Great Salt Lake at approximately 1260 m. The east shore of Great Salt Lake was historically a river delta, though now depending on water needs and time of year, water is sometimes diverted to Willard Bay reservoir or pumped through canals to other areas (Weber River Partnership, 2014) and large amounts of the flow has been channelized or impounded. The Weber River accounts for approximately 20% of the surface flow and 13% of the overall inflow to Great Salt Lake (Arnow and Stephens, 1990).

The Weber River watershed has been modified to help provide 21% of Utah's drinking and irrigation water (Weber River Partnership, 2014). Two major dams were built in the watershed in the 1920s and 1930s including Echo Dam on the Weber River and Pineview Dam on the Ogden River (Weber River Partnership, 2014). The U.S. Bureau of Reclamation enlarged Pineview Dam and constructed five dams and reservoirs, three diversion dams, two aqueducts, one tunnel, four canal systems, and two power plants between 1953 and 1969 as part of the Weber Basin Project (McCune, 2001). There are now two major reservoirs on the Weber River, Echo and Rockport, and six main tributary impoundments—Smith and Morehouse, Lost Creek, East Canyon, Willard Bay, Causey, and Pineview—as well as many minor impoundments (Weber River Partnership, 2014). Water storage volume in the watershed is just below 600,000 acre-feet (Utah Division of Water Resources, 2009).

2.3 Wildlife

The most well-known and extensive aquatic habitat in the Weber River watershed is in the Great Salt Lake wetlands, which extend along the western edge of the watershed and outside the watershed to the north and south. Millions of birds, including two-thirds of all Wilson's phalaropes (*Phalaropus tricolor*) and half of all eared grebes (*Podiceps nigricollis*), use Great Salt Lake's wetlands for migration habitat between northern breeding grounds and winter locations. These wetlands also support large populations of breeding birds (Jehl Jr., 1988, Paul and Manning, 2002). Two species' that utilize Great Salt Lake wetlands, white pelicans (*Pelecanus erythrorhynchos*) and long-billed curlew (*Numenius americanus*), have been designated as wildlife species of concern by the state of Utah due to declining nesting populations caused by habitat alteration, increased disturbance, and increased predation (Utah Division of Wildlife Resources, 2011).

Higher in the watershed, rivers, streams, and reservoirs provide habitat for native fish species, though non-native fish species are also abundant and often dominate larger streams and most of the lakes (McKell and Schaugaard, 2009). Two fish species that receive special management in Utah under a state Conservation Agreement, bluehead sucker (*Catostomus discobolus*) and Bonneville cutthroat trout (*Oncorhynchus clarkia utah*), are also in the watershed (McKell and Schaugaard, 2009). A third Conservation Agreement species, the least chub (*Iotichthys phlegethontis*), has been extirpated (Bailey and others 2005).

Wetland habitat is also important for amphibian species in the Weber River watershed, including non-native American bullfrog (*Rana catesbeiana*) and native chorus frog (*Pseudacris maculate*), northern leopard frog (*Lithobates pipiens*), and tiger salamander (*Ambystoma tigrinum*). Historically, both the Columbia spotted frog (*Rana luteiventris*), a Conservation Agreement species, and Western toad (*Bufo boreas*), a Utah Species of Concern, occurred in the watershed. The only currently confirmed population of either species is a single Columbia spotted frog population that was introduced to Swaner Nature Center in Park City in 2004 (Bailey and others, 2006).

2.4 Land Ownership and Land Use

Land ownership within the Weber River watershed is 78.2% private, 15.7% federal, and 6.0% state, based on GIS calculations using data from the Automated Geographic Reference Center (http://gis.utah.gov/data/sgid-cadastre/land-ownership). Within the basin and range ecoregion, 51% of the land near Great Salt Lake is state-owned. Slightly over half of the remaining area is privately owned, including privately owned duck clubs and conservation preserves. The Wasatch Front region is almost 95% privately owned. In the montane ecoregion, as elevation increases, private ownership decreases: mountain valleys (97% private), semiarid foothills (86% private), Wasatch (75% private), and Uinta mountains (49% private). The state owns about 3% of the land in the montane ecoregion. Much of the private land is enlisted as Cooperative Wildlife Management Units (CWMUs). The CWMU program incentivizes landowners to preserve and manage land for wildlife and to create public hunting opportunities in exchange for the right to privately sell hunting permits. CWMU landowners must write a management plan with the assistance of a state wildlife biologist and must have a minimum of 5000 contiguous acres to enroll in the program.

As of 2010, approximately 92% of the population in the Weber River watershed was concentrated along the Wasatch Front (Utah Division of Water Resources, 2009), municipalities stretch from Bountiful in the south to Willard in the north. Ogden is the largest city with 77,226 people, and two of the fastest growing cities in Utah, West Haven and Hooper, are located in the watershed. In the montane ecoregion, Park City has the largest population, at 7371. None of the other towns in the mountain valleys have populations over 2700 (Utah Division of Water Resources, 2009). Development accounts for 7.7% of the land cover overall in the watershed, including 58% of the Wasatch Front footslopes and 10% of the mountain valleys (Homer and others, 2015). These two areas also each had about one-third agricultural land cover. As of 2007, approximately 7.8% of the watershed was used for agriculture on 367 km^2 of irrigated land and 135 km^2 of non-irrigated land (Utah Division of Water Resources, 2009). Pasture is the most common agricultural use, followed by alfalfa and hay production. The remaining land cover in the watershed is predominantly open water, wetlands, barren and scrub-shrub in the basin and range ecoregion and forest and scrub-shrub in the montane ecoregion. Much of the non-agricultural, non-developed land is used as rangeland.

Major resource extraction is limited to a few areas of the watershed. Past and current oil and gas development is largely restricted to the Chalk Creek drainage and some development near tributaries to Echo Creek (http://gis.utah.gov/data/energy/oil-gas/). The largest concentration of historic mineral mining operations recorded in Utah Division of Oil, Gas, and Mining's database of abandoned mines are found near Park City, and a smaller cluster of abandoned mines is near Echo Reservoir (R. Williams, Utah Division of Oil, Gas, and Mining, unpublished information, 2015). Mineral mining is now uncommon in the watershed, though major clay, rock, and limestone quarries are located in the northern Wasatch Front along several montane sections of the Weber River and near Rockport Reservoir. Large evaporation ponds have been built on the lakebed of Great Salt Lake in the watershed for the production of magnesium chloride, salt, and potash.

Recreation is another important land use in the watershed. The mainstem Weber River is the second most visited stream fishery in Utah, and the Weber River watershed supports five Blue Ribbon Fisheries, meaning that these waterbodies have met criteria for high quality fishing, outdoor experience, fish habitat, and economic benefits (Weber River Partnership, 2014). Waterfowl hunting and bird watching are popular along Great Salt Lake. Other recreation opportunities include big game hunting, boating in lakes and reservoirs, skiing, and hiking.

2.5 Water Quantity and Water Quality

The combined population of the four counties that make up the majority of Weber River watershed—Weber, Davis, Morgan, and Summit—grew 23% between 2000 and 2010 and is projected to double between 2000 and 2050 (Utah Foundation, 2014; http://gomb.utah.gov/budget-policy/demographic-economic-analysis). Even with incremental water conservation leading to 25% water savings by 2050, the Weber River watershed is projected to face a deficit of public community water supplies of 37,331 acre-feet by 2060, though agricultural water use is projected to decline in that same time period by 147,600 acre-feet (Utah Division of Water Resources, 2009). Surface water in the watershed is fully appropriated and new groundwater appropriations are very restricted; wells along the Wasatch Front show a declining trend in groundwater levels (Utah Division of Water Resources, 2009). Even with transfers of existing agricultural water rights to municipal rights, the growing population is likely to have an impact on water availability in aquatic and wetland systems. Water may be moved from the Weber River or East Canyon Reservoir to Park City, resulting in less in-stream flow (Utah Division of Water Resources, 2009), and diminished irrigation return flows may affect wetlands on the shore of Great Salt Lake. Furthermore, continuing trends in decreasing groundwater levels could impact groundwater-dependent wetlands.

Water quality in the Weber River watershed has been affected by agriculture, resource extraction, hydrologic modification, habitat modification, and, to a lesser degree, construction, point source dischargers, and urban runoff (Toole, 2011). Only 14 of the 87 water quality stream assessment units in the watershed were designated as fully meeting water quality standards, whereas 27 were designated as impaired and 38 had insufficient data with at least some record of exceedances (Utah Division of Water Quality, 2014b). The most common impairments were copper and impaired macroinvertebrate communities, followed by dissolved oxygen, *E. coli*, temperature, total dissolved solids, and pH. Pineview, East Canyon, Rockport, and Echo Reservoirs are all listed as impaired for temperature; Echo and Rockport also impaired for dissolved oxygen and/or phosphorus (Utah Division of Water Quality, 2014c).

3.0 Study Design and Survey Methods

3.1 Site Selection

3.1.1 Target Population and Sample Frame

The target population for this study was vegetated palustrine wetlands within the Weber River watershed that were at least 0.1 ha in size. Wetlands are areas that receive periodic substrate saturation or inundation, which often results in distinctive plant communities and distinctive soils due to the physiological constraints imposed by anoxic soil conditions (Federal Geographic Data Committee, 2013). The characteristics typically required to identify wetlands are indicators of wetland hydrology, hydric soil indicators, and a predominance of hydrophytic plant species (Cowardin and others, 1979; U.S. Army Corps of Engineers, 2008). For this study, sites were considered a wetland if at least one of the three indicators were present and the site had characteristics of historical wetland hydrology.

The U.S. Fish and Wildlife Service's National Wetlands Inventory program maps wetlands and deep water habitat throughout the United States using Cowardin classification. We obtained digital National Wetland Inventory data for the state of Utah in February 2014 from the Utah Automated Geographic Reference Center (AGRC) using the file "Wetlands NWI Archive" (http://gis.utah.gov/data/water-data-services/wetlands). Imagery from the early 1980s was used to map a majority of the watershed, except for the southwest corner of the study area near Farmington and Bountiful which was mapped using 1997 and 1998 imagery. Wetland data from Great Salt Lake to the Wasatch Mountains north of Farmington was partially updated in 2005 through use of ground delineations.

To obtain a sample frame for our target population (vegetated palustrine wetlands) we selected only those features assigned to the palustrine Cowardin system and emergent, scrub-shrub, forested, or aquatic bed Cowardin classes. The final sample frame of wetlands included all wetlands with at least 30% cover of persistent emergents, trees, shrubs, or emergent mosses and only those aquatic bed wetlands not located in a channel, not over two meters deep, and not greater than eight hectares in size. Features that crossed the Weber HUC6 boundary were kept in the sample frame only if the majority of the feature was within the boundary.

3.1.2 Strata

To ensure that we surveyed sites across the watershed, we stratified wetland polygons using a simplified version of the Level IV ecoregions (figure 2). Ecoregions that were rare in our study area were combined with ecologically similar ecoregions to create a single stratum (table 3). The basin and range ecoregion had two strata, Wetlands, located closest to Great Salt Lake, and Footslopes, the remaining Wasatch Front area. The montane ecoregion had four strata, including, in order from lowest elevation to highest elevation, Valleys, Foothills, Montane Zone, and Uintas. Wetland polygons that crossed ecoregion boundaries were generally assigned to the ecoregion where the majority of that wetland was located. Characteristics of each stratum can be found in table 4. Strata names will be capitalized throughout this report to refer to all sites and/or all wetland area within each strata (e.g., Wetlands' sites) and to the geographic area represented by the strata (e.g., in the Wetlands).

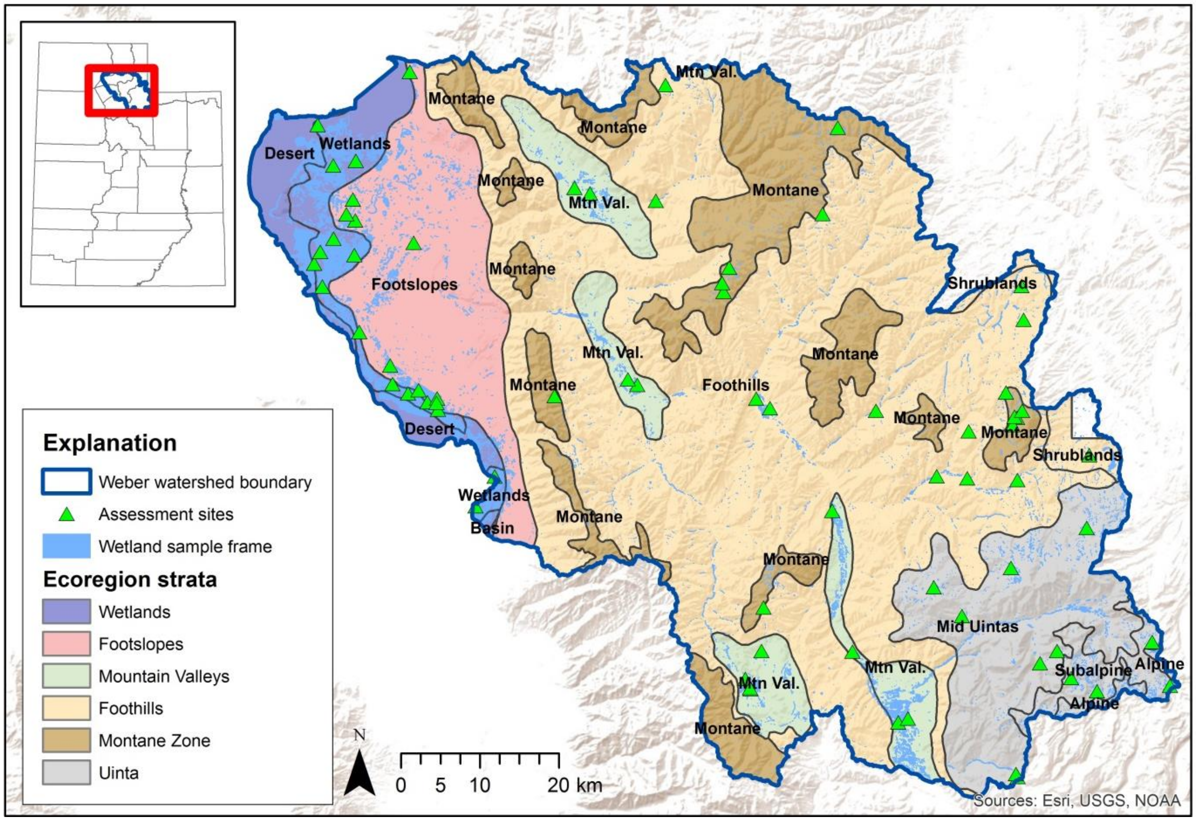

Figure 2. Map of strata used in surveys and surveyed wetland sites. Ecoregion polygons are labeled with their Level IV Omernik ecoregion, but colored according to the final strata. The desert, wetlands and basin Level IV ecoregions are part of the Central Basin and Range Level III ecoregion, the shrublands Level IV ecoregion is part of the Wyoming Basin Level III ecoregion, and all remaining Level IV ecoregions are part of the Uinta and Wasatch Mountains Level III ecoregion.

3.1.3 Selection of Study Sites

We used the spsurvey package (Tom and others, 2012) in R 3.0 statistical software (R Core Development Team, 2013) to select survey sites using a Generalized Random Tessellation Stratified (GRTS) survey design. A GRTS design is a statistical method to select random sample locations that are spatially balanced and ordered so that any consecutive sets of samples points are themselves spatially balanced (Stevens and Olsen, 2004). We selected survey points instead of wetland polygons because URAP evaluates fixed area plots rather than whole wetlands and due to limitations in the accuracy of the National Wetland Inventory data. We selected an equal number of survey points per stratum rather than weighting strata by total strata area, total wetland area, number of wetland polygons within the strata. The Wetlands had over 50% of all wetlands by area, but less than 8% of both the total watershed area and number of wetlands (table 4). Conversely, the Foothills had the highest percent of the total watershed area and number of wetlands, but had amongst the least amount of wetland area. Selecting an equal number of points ensured that data would be collected across a breadth of ecological conditions. We selected 12 sample and 50 oversample points per stratum using a stratified GRTS design.

Table 4. Characteristics of strata including extent and abundance of wetlands, climatic and elevational means (Daly and others, 2008), land ownership (http://gis.utah.gov/data/sgid-cadastre/land-ownership), and land cover (Homer and others, 2015).

Stratum		Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uinta
Area (km^2) (% of total)		404 (6.3%)	669 (10.4%)	457 (7.1%)	3288 (51.3%)	864 (13.5%)	730 (11.4%)
# of wetlands (% of total)		978 (7.9%)	1550 (12.5%)	1467 (11.8%)	3942 (31.8%)	1393 (11.2%)	3057 (24.7%)
Wetland area (ha) (% of total)		10,807 (56.2%)	2902 (15.1%)	2646 (13.8%)	1578 (8.2%)	211 (1.1%)	1090 (5.7%)
Mean 30 year monthly climate data	Mean Temp (°C)	11.1	10.7	7	6.5	5.3	3.3
	Max Temp (°C)	33.5	33.1	29.9	28	25.1	23.2
	Min Temp (°C)	-7.7	-7.9	-12	-11.1	-10.7	-13.2
	Annual Precip (mm)	438	475	548	621	876	913
Mean elevation (m) (elevation range)		1284 (1279-1425)	1341 (1281-1797)	1800 (1483-2317)	2038 (1351-2753)	2416 (1758-3226)	2728 (2050-3644)
Ownership, by Percent	Federal	21.1	4.1	0.5	10	22.3	51.1
	Private	27.7	94.9	96.8	86.1	74.5	48.6
	State	51.3	1.1	2.6	3.9	3.1	0.3
Land Cover, by Percent	Developed	2.2	57.8	10	1.3	0.5	0.4
	Agriculture	11.1	32.1	33.2	1.4	0	0
	Forest	0	0.7	9.7	53.3	81.4	87.5
	Wetland and open water	66.1	5.1	4.5	0.8	0	0.3
	Scrub-shrub	7.5	3.6	42.5	42.9	17.4	8.2
	Other (barren, grass)	13.1	0.5	0.2	0.4	0.6	3.5

Oversample points were used to replace any of the primary sample points that could not be surveyed due to lack of permission from landowners or absence of target wetland.

3.2 Site Office Evaluation and Landowner Permission

Selected sample sites were evaluated in the office using the process outlined in the draft *Utah Rapid Assessment Procedure Method for Evaluating Ecological Integrity in Utah Wetlands—Office Evaluation Method* (appendix B). Survey points were screened, using true color and infrared aerial imagery, digital elevation models (DEM), data on water-related land use, and National Wetland Inventory polygons to determine whether they were located near wetland. We allowed the survey points to be moved up to 100 m from the original point to account for inaccuracies in the National Wetland Inventory mapping. Survey points were assigned to one of four classes depending on their likelihood of containing sampleable wetland: 1: Probably/definitely wetland, (2) Possibly wetland or unclear, (3) Probably not wetland, and (4) Not wetland. Only class 1 and 2 wetlands were visited in the field due to the need for greater field efficiency.

For sample points not removed during the screening process, we determined land ownership based on county parcel data and put forth a diligent effort to contact land owners to seek permission to access sites. We obtained phone numbers for land owners through a combination of internet searches, information from state watershed coordinators, and inquiring with nearby landowners. We called land owners several times and left at least one message in an effort to obtain permission to survey sites. If we could not obtain a contact phone number for a landowner, we stopped by the mailing address associated with the property at least once if it was convenient with routes driven in the field. We rejected all sample points where access was denied or where we were unable to obtain permission.

We compiled data for each survey site in GIS to provide more information to field surveyors. We used either the Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) or the USA Soil Survey layer in ArcGIS online to determine the map unit name, slope, hydric rating, and drainage class of soils at the site. We examined elevation, water-related land use, and hydrography data, including watershed boundaries and flowlines, to assess likely sources of site hydrology as well as visible stressors to hydrology such as dams, water control structures, and irrigation return flows. We evaluated stressors that had a potential to degrade water quality including development, agriculture, rangeland, point source dischargers, oil and gas wells, and mines. We also determined whether contributing streams or lakes were listed in the most recent list of impaired waterbodies, the draft 2014 integrated report (Utah Division of Water Quality, 2014b and 2014c). Whenever possible, information from the landscape analysis was verified by observations in the field. Due to time constraints, we did not conduct a landscape analysis for some sites before surveys. A full description of the landscape analysis process can be found in appendix B.

3.3 Field Methods

3.3.1 Training

Five surveyors were employed for this project three had substantial experience with wetland condition assessments and URAP and two were trainees. The experienced surveyors worked for UGS year-round, had developed URAP, and completed wetland delineation training. The experienced surveyors trained the new surveyors in June of 2014 by working through the field protocol as a group at several sites and talking through difficult metrics. Trainees were also shown photographs of sites that had received A, B, C, and D ratings in some metrics, such as algae growth, litter accumulation, and substrate and soil disturbance, so they could better understand the range of conditions they could encounter. One surveyor per team was responsible for collecting plant community composition data. These individuals were given additional training on plant identification resources, proper plant collection techniques, and plant cover estimation. A second surveyor on each team was responsible for collecting soil profile data and individuals were given additional training on collecting data. For most of the field season, surveyors worked in a set team with one experienced and one less experienced surveyor. Less experience surveyors visited at least 30 sites before they were paired with another less experienced surveyor. At thirteen sites throughout the field season, three or more surveyors worked together at a site, helping ensure calibration between surveyors.

3.3.2 Establishment of Assessment Area

The first step in field surveys was to determine whether a target wetland was within 60 m of the original sample point. We used a combination of best professional judgement and easily observable hydrologic, soil, and vegetation indicators to determine whether sites were wetlands, loosely following standards from the U.S. Army Corps of Engineers (Army Corps) wetland delineation guides (U.S. Army Corps of Engineers, 2008; U.S. Army Corps of Engineers, 2010). Wetland determination was conducted in a relatively rapid manner using traits such as redoximorphic features or gleying in augured soil samples rather than full soil profiles, as well as readily apparent hydrology indicators. If the plant species was known, we assessed sites for the presence of hydrophytic vegetation. Otherwise, we only attempted to determine dominant species when site status was unclear. We only required the presence of one indicator to consider a site as target wetland, though sites with marginal hydrophytic vegetation that lacked any clear indicator of wetland hydrology were frequently rejected. Wetland determinations done for this project should not be considered U.S. Army Corps delineations due to the limited time spent on each determination and the looser standards applied to wetlands.

If a wetland was present at the site, we set up an assessment area. Data for URAP are collected within an assessment area (AA) rather than across an entire wetland to increase comparability between individual sites. Whenever possible, AAs are 40-m radius circular survey plots centered on a randomly selected sample point. To avoid inclusion of non-target areas, AAs can also be 40-m radius plots with shifted centers or rectangular or free form units as long as they are between 0.1 and 0.5 ha and more than 10 m wide. For this project, we shifted or reshaped AAs to ensure that they contained at least 90% target wetland and no more than 10% water over one meter deep. We also always placed AAs in a single wetland not broken by major changes in hydrology, such as dikes, above-grade roads, and bermed ditches. Each AA was generally placed within a single Ecological System.

3.3.3 Rapid Assessment Metrics and Stressor Data

We collected wetland condition data using the metrics described in *Utah Rapid Assessment Procedure Method for Evaluating Ecological Integrity in Utah Wetlands—User's Manual, Version 1.0-Draft* (appendix C). Metrics are divided into five categories: landscape context, hydrologic condition, physical structure, vegetation structure, and plant species composition (table 2). Plant species composition metrics were calculated in the office using plant community data collected in the field. For the other metrics, observers used maps and information obtained from walking around AAs and AA buffers to score each metric according to the observed condition. Photos and notes were frequently taken in order to better capture condition, especially when sites were difficult to evaluate.

Data on stressors observed in the field were also collected. Stressor data included information about features within 200 meters of each AA as well as features within the AA. For each stressor present, we recorded the extent of the evaluated area where the stressor was present and the degree of severity as one of three qualitative categories (low, moderate, high). We evaluated buffer stressor severity in specific categories: general severity, hydroperiod, water contaminants, sedimentation, and vegetation stress. For example, a highway downstream from a wetland may affect a wetlands hydroperiod but is less likely to contribute water contaminants based on the landscape position.

3.3.4 Additional Site Data

We classified wetland sites by HGM class, Ecological System, and Cowardin class. We collected data for two metrics auxiliary to the main URAP metrics, related to the types of structural patches (snags, channels, beaver dams, animal tracks, seeps, floating mats, etc.) and amount of topographic complexity present at sites. We also collected percent cover data on the presence and overlap of different plant layers. Supplemental data can be used to make generalizations about expected features within specific wetland classes or to better understand habitat or other functional characteristics of wetlands.

At each site surveyors dug at least one soil pit at a representative location within the dominant vegetation type. An additional pit was dug if more than one dominant vegetation type was encountered or if no hydric soil indicators were found in the first pit. Soil pits were dug to 50 cm or more in depth whenever possible. For each soil layer, surveyors recorded the layer depth, the color of the matrix and any dominant and secondary redox features (based on a Munsell Soil Color Chart), soil texture, and percent of coarse material (>2mm). Hydric soil indicators were recorded using Field Indicators of Hydric Soils in the United States (U.S. Natural Resources Conservation Service, 2010) and U.S. Army Corps wetland delineation guides (U.S. Army Corps of Engineers, 2008; U.S. Army Corps of Engineers, 2010). Settling time for soil pits varied depending on total AA survey time, but was generally between 50 and 120 minutes. If water was evident after the settling period, we recorded the depths to saturated soil and free water and then used a bailer to obtain a water sample from just below the surface level of water in the pit.

Groundwater and surface water chemistry data was collected with a handheld Hanna Instruments Combo meter (HI98129 and HI98130). Data was collected within channels or pools, at points of groundwater discharge, and/or at the surface of flooded wetlands. We measured pH, electroconductivity (EC), total-dissolved-solids, and temperature of the water sample with the meter. We tested meter accuracy in known EC and pH solutions and calibrated meters as needed.

We collected surface water samples for laboratory analysis at some sites. Samples were collected when surface water was available and likely to reflect the dominant water source at a site. Samples were generally not taken from small pools or from water pooled in cattle tracks when the rest of the site was dry. Samples were also not generally taken when water depth was very low (<10 cm) due to the high probability of contamination from soil sediments. Water sample containers (three per sample location) were prepped by the Utah Public Health Laboratory Chemical and Environmental Services Laboratory (Utah Public Health Laboratory) with the necessary preservatives for general chemistry, total metals, and total non-filtered nutrients analysis (Utah Public Health Laboratory, 2013). After containers were filled, they were stored on ice until transferred to a refrigerator and then transferred to the Utah Public Health Laboratory within five days of collection. Samples were analyzed at the Utah Public Health Laboratory following the procedures outlined in the Client Services Manual (Utah Public Health Laboratory, 2013). Chemistry samples were analyzed for total suspended solids, total dissolved solids, pH, and chloride, sulfate, alkalinity, specific conductance, and total volatile solids. Non-filtered nutrient samples were analyzed for ammonia, nitrate plus nitrite, total Kjeldahl nitrogen, total phosphate, and total organic carbon. Total metal samples were analyzed for calcium, magnesium, sodium, and potassium.

3.3.5. Plant Community and Ground Cover Data

We recorded a list of all plant species found within the AA after thoroughly searching the area for up to one hour. For each species found, we recorded predominant height, percent cover within the AA, and phenology as vegetative, flowering, fruiting, or standing dead (from current year only). Plants not recorded to species in the field were collected for later identification in the office or at local herbaria. We also collected data on the percent cover within the AA of ground cover features including bare ground, litter, water, bryophytes, lichens, algae, and various types of woody debris.

We recorded plot-based plant community and ground cover data at three sites per stratum to compare the results of this more rigorous sampling to the standard vegetation sampling. At these sites, data were collected in four 10 m x 10 m plots that were established in predetermined locations at standard 40 m radius circular AAs or at randomly chosen locations in non-standard AAs. Surveyors first recorded plant species and ground cover data in all four plots and then spent additional time walking through the remainder of the AA to record values for the entire AA. An effort was made to record this data at three sequential sites per stratum to create a spatially balanced set of sites. However, uncertainty regarding which sites we would get permission to survey meant that in many cases this sampling order was not maintained.

4.0 Data Summarization and Analysis

We use a variety of methods to present survey results ranging from simple summaries and lists of observed attributes to ordination and correlation analysis and data extrapolation. Simple data summaries provide information on the frequency and types of various attributes observed during surveys, but do not estimate the true population mean or associated uncertainty. These simple summaries are useful to identify general trends in the data but cannot be used for robust inference. Ordination and correlation analysis are more quantitative exploratory methods that can evaluate groupings between sites and the strength of relationships between difference measures. Data extrapolation is used to estimate population-wide characteristics for all wetlands within each strata, ecoregion, or watershed. Population estimates include a measure of uncertainty, such as confidence intervals, and estimates can be compared between groups to look for differences. Confidence intervals were generally quite large due to small sample sizes so differences among strata were usually not statistically significant. We only produced population estimates for a few measures. All statistical analysis was conducted in R 3.2.1 statistical software (R Core Development Team, 2013).

4.1. Weight Adjustment and Population Estimates

To make population estimates for ecoregions or the entire watershed, each site was assigned a weight for the relative amount of wetland area represented by the site. For example, a site in the Wetlands has a higher weight than a site in the Foothills because the Wetlands stratum has much more total wetland area. Sites were assigned weights when they were originally selected by the R package spsurvey software, but needed to be adjusted based on the total number of sites evaluated in each strata. Weights are equal to stratum area divided by the total number of sites evaluated in the stratum, including surveyed sites, non-target sites, and sites where access was denied. Site evaluation did not deviate from the original sample order so additional adjustments to weights were not necessary.

We used the cat.analysis and cont.analysis functions in the spsurvey package in R to estimate parameters for categorical and continuous variables, respectively. We used strata and ecoregion as subpopulation variables rather than as strata in the design matrix to improve the estimate of the local mean variance, based on advice from one of the authors of the spsurvey package (T. Kincaid, personal communication, March 2015). We estimated the extent of sampled area, non-target area, and unknown (no access) area for each stratum and ecoregion and for the watershed. We also estimated the percent of wetland area in each URAP categorical and overall score rank (A, B, or C/D) and percent cover of noxious weeds and other non-native species in the watershed and each strata and ecoregion. We created cumulative density functions for overall URAP score, Mean C, and relative cover of native species. Cumulative density functions show the probability distribution across a range of values, for example, the probability of a site having an overall URAP score of 4 or lower. We compared cumulative density functions between strata using the cont.cdftest function in spsurvey with the default test statistic, an F-distribution version of the Wald statistic (Kincaid, 2015).

We estimated the percent of wetland area and wetland buffer area subject to two stressors—livestock grazing and motorized tracks. We first converted extent classes to the largest value in their class so that, for example, 1-10% cover was converted to 10% cover (trace cover was converted to 0.5% cover). Livestock grazing within the AA could be recorded up to three times, based on effects to vegetation, physical substrate, and hydroperiod. The maximum value of the three was used for the analysis. We produced estimates of total area with grazing and area with moderate to high severity grazing. Strata-wide estimates were made for each stressor; differences between cumulative density functions for each stratum were tested using the F-distribution of the Wald statistic.

4.2 Field and Office Stressor Data Summary

We present data on the abundance and severity of different stressors we also summarize stressor data into stressor indices to select reference sites and explore the relationship between stress levels and measures of wetland condition. To calculate stressor indices, we first converted low, medium, and high severity stressors to values of 1, 2, and 4, respectively. Stressors in the office were recorded in three categories—water quality stressors within 2 km of the site, overall water quality stressors, and overall hydroperiod stressors. We excluded livestock grazing from the office water quality stressors because we could not determine the presence or severity of grazing in GIS. We summed all stressor severity values by category to produce three different office-based stressor estimates.

For AA and buffer stressors, we converted extent estimates into weights based on the mid-point of the extent category, adjusting the overall weights so that the highest extent category received a weight of 1. Extent categories were converted as follows: <1%—0.001 to 1-10%—0.06, 10 to 25%—0.20, 25 to 50%—0.43, 50 to 75%—0.72, 75 to 100%—1.0. We multiplied each stressor severity value by the extent weight and then summed all values to obtain an estimate of stress. We calculated AA stress overall and within four categories: vegetation, hydroperiod, physical, and water quality stress. The first three categories were directly recorded in the field. We used two measures recorded under the heading of vegetation stress as indicators of AA water quality stress, chemical vegetation control, and grazing or browsing. We calculated buffer stress overall and within four categories: hydroperiod, water contaminants, sedimentation, and vegetation stress; stress related to each category was directly recorded in the field (table 5). For the calculation of hydroperiod stress, we did not adjust severity by

Table 5. Example of converting buffer stressor data into overall buffer and categorical indices.

Step 1: List all recorded stressors with their extent, general severity, and severity related to specific categories of stress.

Stressor		Severity				
	Extent	**General**	**Hydroperiod**	**Contaminants**	**Sediment**	**Vegetation**
Stressor 1	<1%	3	3	2	2	0
Stressor 2	10-25%	2	0	3	2	0
Stressor 3	>75%	1	0	0	0	3
Stressor 4	25-50%	2	1	1	1	1

Step 2: Convert extent categories to their midpoint divided by the midpoint of the highest extent category. Convert severity values of three to four. Greyed boxes indicate values changed from step 1 to step 2.

Stressor		Severity				
	Extent	**General**	**Hydroperiod**	**Contaminants**	**Sediment**	**Vegetation**
Stressor 1	**0.001**	**4**	**4**	2	2	0
Stressor 2	**0.2**	2	0	3	2	0
Stressor 3	**1**	1	0	0	0	**4**
Stressor 4	**0.43**	2	1	1	1	1

Step 3. Multiple extent value by severity for each severity value, except for hydroperiod which is kept as is. Sum values within categories.

Stressor		Severity				
		General	**Hydroperiod**	**Contaminants**	**Sediment**	**Vegetation**
Stressor 1		0.004	4	0.002	0.002	0
Stressor 2		0.4	0	0.6	0.4	0
Stressor 3		1	0	0	0	4
Stressor 4		0.86	1	0.43	0.43	0.43
	Final Values	**2.26**	**5.00**	**1.03**	**0.83**	**4.43**

extent because many hydroperiod stressors, such as dams and water control structures, are frequently small in size but large in impact. In general, only stressors evaluated specifically for a buffer category were included in that category's calculation, though there were some exceptions based on analysis of individual stressors.

We next combined office, AA, and buffer stress indices to create composition values. Overall field stress is the sum of the overall AA and overall buffer stress indices. Total sediment stress is the sum of the buffer sediment and AA physical stress indices. Total contaminant is the sum of the buffer contaminant and AA water quality stress indices. Total water quality stress is the sum of the buffer sediment, buffer contaminant, AA physical, AA water quality, and overall office water quality stressor indices. Total vegetation stress is the sum of buffer and AA vegetation stress indices. Total hydrologic stress was the sum of AA, office, and buffer hydrologic stress indices.

4.3 Rapid Assessment Results

Rapid assessment metric results are presented as summary data for individual metrics and as population estimates for URAP category and overall ranks (i.e., A, B, C, or D), as well as population estimates for numeric URAP scores. To obtain categorical scores, we first calculated the relative cover of native species and absolute cover of noxious species at each site using plant composition data. We converted the cover estimates to ranks using the thresholds shown in appendix C. Next, we converted metric ranks to point values based on the following: 5 (A or AB), 4.5 (A-), 4 (B), 3 (C), 2 (C-), and 1 (D). We combined metric scores for the percent buffer, buffer width, buffer soil condition, and buffer vegetation condition into an overall buffer score using the following equation:

$$overallBuffer=(percentBuffer*bufferWidth)^{0.5}*([bufferConditionSoil+bufferConditionVeg]/2)^{0.5}$$

We then calculated the mean metric score within each category (only using the overall buffer score and not the derivative components for the landscape context category), based on the categories shown in table 2. Means were taken across a variable number of metrics per site since not all metrics were evaluated at every site. The woody debris and woody species regeneration metric were only scored when woody species and debris were expected at sites and the turbidity and pollutants and algae growth metrics were generally only scored when water was present at sites, though one site had an excess amount of dry algae and received a final score for the algae metric. The horizontal interspersion metric was excluded from the vegetation structure and overall URAP calculations in the emergent marsh and alkaline depression Ecological Systems based on results of method calibration (appendix A). Overall URAP scores were obtained by taking the mean across all categorical scores. Categorical and overall URAP scores were converted back to ranks based on the following: A (≥4.5), B (<4.5 and ≥3.5), C (<3.5 and ≥2.5), and D (<2.5).

4.4 Analysis of Vegetation Data

Plant species not identified in the field were pressed in newspaper, brought to the office, and dried in a drying oven at approximately 38°C for at least 24 hours. We used a dissecting microscope, standard set of plant dissection tools, and several plant treatments to aid with identification, including *A Utah Flora* (Welsh and others, 2003), all volumes of the *Intermountain Flora series* (see introductory volume, Cronquist and others, 1972), *Vascular Plants of Northern Utah* (Shaw and others, 1989), *Field Guide to Intermountain Sedges* (Hurd and others, 1998), and *Flora of North America* (http://floranorthamerica.org). Specimens that were particularly difficult to identify were taken to Utah State University's Intermountain Herbarium for comparison with known specimens and for consultation with herbarium staff. We used species scientific names as listed in U.S. Natural Resources Conservation Service's Plants Database (http://plants.usda.gov). Species identification problems are detailed in appendix D.

We scored the absolute cover of noxious weed and relative cover of native species metrics using plant data collected in the field across the entire AA. To score the absolute cover of noxious weeds metric, we first developed a list of all noxious weed species. We included all species listed for the state of Utah or individual Utah counties and species listed in the surrounding states of Arizona, Colorado, Idaho, Nevada, and Wyoming. We considered all recorded *Phragmites australis* (common reed) to be the non-native, noxious subspecies of *Phragmites australis* when subspecies was not recorded. Even though *Galium aparine* (stickywilly), *Cicuta maculata* (spotted water hemlock), and *Cuscuta* ssp. (dodder) were included on some noxious weed lists, we excluded them from our final list because they are all native to Utah. For the relative cover of native species metric, cover of all native species was divided by the cover of all species with known nativity. Common names and species' attributes for species mentioned in this report are listed in appendix E.

4.4.1 Plant Summary Information

We provide summary information on the distribution and abundance within our study area of common plant species and species of management concern. We also present summary values for a number of FQA metrics, including many that make use of coefficient of conservatism values (C-values). C-values between 1 and 10 are assigned to species based on their association with disturbance through a combination of best professional judgment, literature review, and/or field observations. Low values indicate that species are usually found at disturbed sites, high values indicate that species are associated with pristine sites and values in the middle indicate that species may be found equally at either type of site. All non-native species are assigned a C-value of 0. Ideally, C-values are developed for individual states or regions to capture regional variability in how species respond to disturbance. However, the development of state-specific C-values requires substantial time and effort from a panel of experts and is ideally supported by qualitative field data that span the whole area of interest across a broad range of conditions. No C-values currently developed for the state of Utah. We instead contacted botanists and wetland scientists in surrounding states to determine which states had assigned C-values to species. We received C-value lists from Colorado (Rocchio, 2007), Montana (Jones, 2005), and Idaho (C-values used by the state of Idaho are from values developed for eastern Washington's Columbia Basin region (Rocchio and Crawford, 2013). We assigned Utah species the Mean C-value of the three states' lists. We then made sure that every non-native species, and no native species, had a C-value of 0. Eighteen species with a total of 24 occurrences were recorded and not assigned C-values. Of these, all occurrences were less than 1% cover except for one occurrence each of 1% and 2% cover.

Data on species with assigned C-values can be summarized in a number of ways. The simplest measure is simply the mean of the C-values for all species found at a site. The cover-weighted mean is similar, but weights the C-value for each species by that species' cover at the site. Floristic Quality Index (FQI) metrics adjust the Mean C-value or cover-weighted Mean C-value by the total number of species at a site, so a site with more species will have a higher score than a site with less species if other compositional elements are similar. Adjusted FQI metrics modify C-values based on the ratio of the number of all native species to the number of all species. All of these measures besides adjusted FQI can be calculated from data for all species or data just for native species. FQA metrics used in this report, including those that make use of C-values, are described in table 6.

4.4.2 Ordination and Cluster Analysis

We used non-metric multidimensional scaling (NMDS) with the vegan package (Oksanen and others, 2013) in R to explore plant community composition data. NMDS can be used to reduce complex multivariate data, such as plant abundance values, to a few primary axes that describe most of the variation found among sites. Axes can then be overlain with vectors showing the strength (represented by vector length) and direction (represented by vector orientation) of correlation between environmental variables of interest and species composition data. We used NMDS to visualize similarities among all sites and among sites within Level III ecoregions. We also used NMDS to identify groups of sites where species composition was not driven by environmental factors.

Table 6. Floristic Quality Assessment metrics used to analyze plant community composition data. C_x and Cov_x refer to the C-value and cover estimate for species *x*, where species *x* is a single species in the set of all species (*x*∈*all),* all native species (*x*∈*native*), all non-native species (*x*∈*non-native*), or all designated noxious species (*x*∈*noxious*). N_{all} and N_{native} refer to the total number of all species and all native species, respectively, per site. Only species with known nativity are used in calculations; only species with known C-values are used in calculations that make use of C-values. Formulas are adopted from Rocchio (2007).

Abbreviation	**Description**	**Formula**
Species Richness	Number of unique species	N_{all}
Pct. Non-native	Percent of all recorded species of known nativity that are introduced	$N_{Native} \div N_{all}$
Abs. Cover Non-native	Absolute cover of non-native species	$\sum_{x \in non-native} Cov_x$
Abs. Cover Noxious	Absolute cover of noxious weeds	$\sum_{x \in noxious} Cov_x$
Rel. Pct. Native Cover	Percent cover of all native species divided by the total cover of all recorded species with known nativity	$\sum_{x \in native} Cov_x \div \sum_{x \in all} Cov_x$
Mean C	Mean C value across all species	$\sum_{x \in all} C_x \div N_{all}$
Native Mean C	Mean C value across all native species	$\sum_{x \in native} C_x \div N_{native}$
CW Mean C	Mean C adjusted by the cover of each species	$\sum_{x \in all}(C_x * Cov_x) \div \sum_{x \in all} Cov_x$
Native CW Mean C	Native Mean C adjusted by the cover of each native species	$\sum_{x \in native}(C_x * Cov_x) \div \sum_{x \in native} Cov_x$
FQI	Mean C adjusted so that otherwise similar sites with more total species score higher	$Mean\ C * \sqrt{N_{all}}$
Native FQI	Native Mean C adjusted so that otherwise similar sites with more native species score higher	$Native\ Mean\ C * \sqrt{N_{native}}$
CW FQI	CW Mean C adjusted so that otherwise similar sites with more total species score higher	$CW\ Mean\ C * \sqrt{N_{all}}$
Native CW FQI	Native CW Mean C adjusted so that otherwise similar sites with more native species score higher	$Native\ CW\ Mean\ C * \sqrt{N_{native}}$
Adj. FQI	Mean C adjusted so that otherwise similar sites with a higher proportion of native species compared to total species score higher	$\left(\frac{Mean\ C}{10} * \frac{\sqrt{N_{native}}}{\sqrt{N_{all}}}\right) * 100$
CW Adj. FQI	CW Mean C adjusted so that otherwise similar sites with a higher proportion of native species compared to total species score higher	$\left(\frac{CW\ Mean\ C}{10} * \frac{\sqrt{N_{native}}}{\sqrt{N_{all}}}\right) * 100$

We excluded from analysis most species only identified to the genus level, but did include the genera *Atriplex*, *Dodecatheon*, *Eleocharis*, and *Salix* separate from species of those genera that were determined to the species level. We grouped all species within the genera *Picea*, *Tamarix*, and *Typha* into their respective genera rather than considering these species independently. Species identified to the subspecies level were grouped with other members of the same species.

We used the wrapper function metaMDS within vegan to transform and standardize data, calculate a dissimilarity matrix using Bray-Curtis distance, run NMDS multiple times with random starts to avoid local optima, and rotate the axes of the final configuration so that the variance of points was maximized on the first dimension. Plant abundance data were transformed using a Wisconsin-style double standardization where taxa are normalized to percent abundance and then abundances are normalized to the maximum for each species. Species that occurred at only one site were dropped from analysis. We determined the appropriate number of axes to use by obtaining stress values for four replicate

NMDS runs for each number of dimensions between one and four. We set the maximum number of random starts for each run at 500. We generally selected the lowest number of axes that had a stress value ≤0.20 as the final number of dimensions, based on rules of thumb for the threshold of usable results (McCune and Grace, 2002).

We calculated climate and elevation data for each site to include as an environmental variable in the NMDS. We calculated mean AA elevation using 10-m-resolution DEM data (http://gis.utah.gov/data/elevation-terrain-data/10-30-meter-elevation-models-usgs-ned). We also used monthly climate data from PRISM Climate Group (Daly and others, 2008) to calculate 30-year-mean temperature and precipitation values at each site. We calculated 30-year means (for water years 1984 to 2013) across the water year (October 1 to September 30) instead of the calendar year because water year is a more hydrologically relevant measure. Only provisional, rather than final, climate data was available for June through September 2014 at the time calculations were performed. We calculated mean, minimum, and maximum water-year temperatures and mean daily precipitation for each year, then used the mean of these values across the 30-year period of interest.

We fit site attribute data to the species NMDS axes using the envfit function in the vegan package. We tested the strength of evidence for each site attribute variable and each species using 10000 permutations in envfit. We reduced elevation and climate data to uncorrelated axes using principal components analysis (PCA) with the function princomp in R. We included the first one or two axes of the PCA as an environmental variable in the site attribute analysis, depending on the degree of variability captured by each axis. We considered several variables related to sampling effort, including the total area of the AA and the day of the year for each survey, converted to a number between 176 (indicating the first day of sampling) and 269 (indicating the last day of sampling). We also considered at the observer team, coded as either one of the two teams that conducted most of the field work or "other". "Other" included sampling efforts with more than two surveyors and efforts with uncommon team pairings. We considered whether plant community data had been collected only in the AA or within plots and the AA and the percent upland area included in each AA. We considered at site Ecological System, Cowardin system, class, and water regime, HGM class, stratum, and Level III and IV ecoregion. We also considered correlation with site stressor indices and categorical and overall URAP scores.

We used NMDS and cluster analysis to try to identify groups of sites within which major differences in composition were driven by differences other than natural factors such as climate or site hydrology. Strata on their own were not appropriate for grouping sites because strata contained a mixture of Ecological Systems with very distinctive vegetation communities. Furthermore, it was possible that low-elevation sites in the Uintas stratum would be more similar to high elevation sites in the Montane Zone stratum than to high elevation Uintas stratum sites. Sites with similar plant communities, climate, and hydrology are most appropriate for analyzing the relationship between stressors and vegetation and for development of a multi-metric index. For montane ecoregion sites, we conducted a preliminary analysis of groupings using NMDS and then used k-means clustering to develop cluster for sites in the Rocky Mountain Alpine-Montane Wet Meadow (wet meadow) and Rocky Mountain Subalpine-Montane Riparian Shrubland (upper montane shrubland) Ecological Systems. We clustered sites based on the four climate variables, percent deep (>20 cm) and shallow water at sites, and percent aquatic and woody vegetation. The optimal cluster size was determined using the elbow method by graphing number of clusters versus the ratio of between-group variance to total variance. The optimum cluster size is the number at which the marginal gain in variance explained drops, leading to a curve in the graph. We performed NMDS ordination on the resulting clusters to determine whether differences within clusters were associated with either of the first two axes of the climate PCA, Level III and IV ecoregion, Ecological System, or Cowardin water regime. We also included URAP overall and categorical scores, stressor indices, and Mean C in the environmental analysis. We did not perform a cluster analysis on basin and range sites because there were too few overall sites and much heterogeneity in characteristics of sites (including impoundment status, salinity level, water regime, etc.). Instead, we simply removed the most obvious outliers from the ordination to obtain a final ordination of the basin and range sites.

4.5 Multi-Metric Index Development

We conducted an exploratory analysis to determine attribute differences between least and most disturbed sites in the largest group of montane meadow and shrub sites identified in the cluster analysis described above. This grouping contained 18 sites, but two sites were dropped from the final grouping after the cluster analysis due to anomalous attributes and one site not included in the cluster analysis due to missing data was added to the group, for a total of 17 sites in the final grouping. The grouping, which we call the mid-elevation montane sites, included sites between 2188 and 2556 m in elevation classified as either slope or riverine HGM classes.

We used data on stressors and percent non-native cover to select sites that fell into high and low disturbance categories. We evaluated seven overall indicators: the overall AA stress index, individual buffer indices for hydrologic, sedimentation, vegetation, and contaminant stressors, stressor indices for hydroperiod and water quality from the office evaluation, and percent cover of non-native plant species. We determined thresholds based on a combination of the range of values available in the data and best professional judgement. For the least disturbed, we selected sites with values of less than one for overall AA stress scores and all buffer scores except for hydroperiod with values less than two for buffer hydroperiod and all office stressor indices, and with no more than 10% cover of non-native species. For the high disturbance, we selected sites that violated high disturbance thresholds for at least three indicators. Those thresholds were set at two or more for overall AA, overall AA stress index, and all buffer indices except for hydroperiod, four or more for evaluating buffer hydroperiod and all office stressor indices, and over 20% cover of non-native species. One high disturbance site exceeded threshold values for five indicators; all other sites exceeded values for three indicators.

We used t-tests to look for differences in URAP categorical and overall scores and in a variety of plant community composition, structural composition, and climatic metrics between most and least disturbed sites. We compared FQA metrics shown in table 6 expect for species richness and absolute cover of non-native species. We compared the richness, percent of species, and relative cover of species with C values in defined groups (i.e., C-values between 0 and 2 or C-values above 6). We looked at the number of species and the percent of species with defined wetland indicator ratings (i.e., percent facultative wetland or obligate species). We also compared the relative cover of annual species and relative cover of annual and biennial species and the percent of the AA with overlap of two or three species in different height categories. We compared cover of bare soil, litter, water (at different depths and overall), woody debris (in several different structural categories), and cover of different plant structural groups, including forbs, graminoids, and shrubs. We hypothesized that the metrics described above would differ based on extrinsic differences between sites, particularly level of disturbance. However, we also recognized that many of the above metrics might also differ based on intrinsic site differences, such as natural differences in water regime or surrounding vegetation. We compared climate variables between most and least disturbed sites to determine whether sites also had clear intrinsic differences. We did not correct p-values for multiple comparisons because the main purpose was to determine individual variables and variable types that were best able to differentiate between site types despite a small sample size rather than rigorous statistical inference.

We next assembled the best metrics we tested (those with p-values <0.05) into multi-metric indices. We converted all metrics with low values (indicating good condition) to the inverse. For example, 35% non-native species was converted to 65% native species. Each multi-metric index was composed of three non- or weakly correlated metrics (Pearson correlation coefficient <0.70). We limited each multi-metric index to three metrics because almost all groups of four contained at least two more strongly correlated metrics. For each possible combination of the top variables, we did the following calculations based loosely on analysis from the draft National Wetland Condition Assessment report (U.S. Environmental Protection Agency, in review). First, we set the minimum and maximum values for each variable as the 95th and 5th percentile of values in the data (for all 17 sites in the group), respectively. Next, we normalized the values between 0 and 10 for all sites in the mid-elevation montane group, using the equation:

normalizedValue=(inputValue-min)/(max-min)

Values less than 0 were converted to 0 and values greater than 10 were converted to 10. Last, we added the three metrics together, divided by three and multiplied by 100 to obtain the multi-metric index value. The final multi-metric index had the largest t-statistic for a t-test comparing the least and most disturbed sites.

Based on EPA's National Aquatic Resources Survey convention, multi-metric index values are considered good if they are within the top 25 percent of all values within the least disturbed sites and poor if they are within the bottom 5 percent of values within the least disturbed sites, and values in between are categorized as fair. However, this convention was not appropriate with our small sample size. Instead of making estimates of condition for our small sample size, we report on the number of sites with multi-metric values similar to the least and most disturbed site values.

4.6 Relationship Among Measures of Condition

We analyzed the strength of relationships between categorical and overall URAP scores and other measures of wetland condition by examining Pearson correlations between variables (Stein and others, 2009). We calculated correlations separately for basin and range and montane ecoregion sites. We also calculated correlations for the mid-elevation montane sites used in the development of the multi-metric index. We examined correlations between the URAP scores and summarized stressor data, values from the landscape stress model, two FQA metrics and, when appropriate, with the multi-metric index. Before calculating correlations, we created hypotheses regarding which variables we thought would have the strongest correlation with each URAP score. For example, the hydrologic category score was hypothesized to have a strong relationship with stress data related to hydroperiod and water quality, but not with vegetation stress or FQA data. Next, correlations were calculated between each URAP score and all of the other variables. Correlations were evaluated based on whether they were significant ($p<0.05$) or marginally significant ($0.05<p<0.10$) and on the strength of the correlation.

4.7 Watershed-wide Landscape Analysis

We attributed data in the sample frame of wetland sites with information on land ownership, riparian status, and location with respect to the Utah Division of Water Quality's assessment units for the integrated water quality report. We also attributed wetland sites with the mean value from the landscape stress model. This attribution allowed us to summarize information on the types, protection status, and potential vulnerability of all wetlands within the watershed. Since the attribution was applied only to the sample frame, summarized information only pertains to vegetated palustrine wetlands, including aquatic beds, emergent, scrub-shrub, and forested wetlands. Data does not include areas mapped as unvegetated, including many playas, lakes, and ponds.

We first summarized data on the amount of wetland area by wetland type within each stratum. We used the wetland types identified in the Utah wetland functional classification developed by Emerson (2014) to identify key aquatic habitats in the draft Utah Wildlife Action Plan (Utah Wildlife Action Plan Joint Team, 2015) as the basis for data summarization. Within our sample frame, four wetland types were present: emergent, open water, scrub/shrub, and forest. Our sample frame only includes open water features that are mapped as aquatic bed, not unvegetated open water; the open water habitat will be referred to as aquatic bed in this report to make this distinction clear. Within those four basic categories, we further characterized wetlands based on their mapped Cowardin water regime. Wetlands with temporarily flooded (A) regimes have surface water present for brief periods of the growing season and may not be wet enough to meet the U.S. Army Corps definition of wetland hydrology. Most forested wetlands in our study area have an A water regime. Wetlands with a saturated (B) water regime are usually associated with groundwater. Wetlands with a seasonally flooded (C) water regime are flooded for an extended period of time, but usually dry out by the end of the growing season. We grouped the semi-permanently flooded (F), intermittently exposed (G) and semi-permanently (H) water regimes into a single category. Wetlands with F, G, and H water regimes are wet throughout the growing season and often year-round. All aquatic bed wetlands are mapped as one of these three water regimes.

We attributed wetland polygons as riparian or not riparian based on proximity to stream and lake features in the 1:24,000-scale USGS's National Hydrography Database (http://nhd.usgs.gov). We attributed wetland polygons as riparian if they were within 50 m of any NHDFlowline attributed as artificial path, connector, or streamRiver. We also attributed polygons as riparian if they were within 50 m of NHDWaterbody or NHDArea features touching one of the NHDFlowline features above, if they were coded as lakePond or reservoir, for the former, or streamRiver, for the latter. We also attributed wetland polygons that were within 10 m of the selected wetland polygons as riparian. The riparian attribution must be considered relatively inexact; No set distance excludes and captures all appropriate features and "riparian" features have a wide range of relationships with adjacent waterbodies, including slope wetlands that contribute water to streams and riparian wetlands that receive water from streams.

Land ownership data was obtained from the Utah Automated Geographic Reference Center ([AGRC], http://gis.utah.gov/data/sgid-cadastre/land-ownership, accessed on April 1, 2015). The AGRC ownership data includes information on the ownership type (private, state, federal, tribal) as well as the managing agency and general classification. We used the AGRC layer in combination with an internal layer of management areas digitized by the UGS in 2013. The UGS management areas layer was created from a combination of parcel data and boundary data obtain from individual land managers. The layer includes boundaries of privately owned cooperative wildlife management units (CWMUs), privately owned mitigation and conservation reserves, private duck hunting reserves, and state and federal land managed for hunting, migratory birds, and other wildlife concerns. The CWMU program incentivizes land owners to make private land accessible to the public for hunting. Though land owners are not required to follow a management plan and are not restricted to certain land uses, they generally have a high degree of cooperation and motivation for maintaining and improving their wildlife habitat and thus may typically provide some level of conservation.

We assumed the UGS management areas layer was more accurate at depicting true management status than the AGRC layer, but used the latter to fill in data when it was otherwise missing. We classified ownership into seven categories based on focus of management and prevalence of ownership type within data. Categories included state wildlife management areas (e.g., wildlife areas and waterfowl management areas), other state land (e.g., state trust lands, state sovereign land, parks and recreation), Wasatch-Cache National Forest, other federal land (e.g., Bureau of Reclamation, Bureau of Land Management, Hill Air Force Base), private managed areas (e.g., The Nature Conservancy's Great Salt Lake Shorelands Preserve, privately owned duck clubs), CWMUs, and other private land.

We obtained data on the location and status of Utah Division of Water Quality's assessment units that are used to evaluate water quality in streams and lakes from the draft October 2012-2014 draft integrated report (Utah Division of Water Quality, 2014b and 2014c). We summarized the acreage of riparian wetland area by landscape stress class for those assessments units listed as impaired in the draft report based on the riparian attribution described above.

We attributed wetland polygons as located in landscape positions with low, moderate, or severe landscape distress based on the results of the landscape stress model (Menuz, 2015b). To develop the model, stressors were assigned weights based on their hypothesized severity and a decay function based on the hypothesized decrease in severity with increasing distance from the stressor. Stressors are then added together to create a final model value. We obtained the mean stress value for each wetland polygons and converted the values to low (≤200), moderate (>200 and ≤800), and severe (>800) stress. Because stressor weights decay with increasing distance from the stressor, many different combinations of stressors can result in the threshold values of 200 and 800. Sites immediately adjacent to a single minor stress such as unirrigated hayfield, canal, urban park, or minor road would fall into the low stress category. Wetlands immediately adjacent to a single impounded waterbody, major road, oil or gas well, or large mine would have a moderate stress value. Sites are only rated in the severe category when they are multiple adjacent stressors present. The model only includes data on stressors with readily available geospatial data; data on stressors such as livestock grazing intensity, off-road vehicle travel, and non-native species cover is not included in the model.

5.0 Survey Results

5.1 Sites Surveyed

5.1.1 Sample Frame Accuracy and Accessibility

We evaluated 142 sites to obtain 72 survey sites. We determined that 23 sites were not wetland based on evaluation in the office and five sites either were not wetland or did not contain enough wetland area to be surveyed based on assessment in the field. Sites in the Montane Zone had the most survey points that were not sampleable wetlands (46% of evaluated sites), followed by Footslopes and Foothills (approximately 25%); the remaining strata had 10% or less non-wetland sites (table 7). Difficulty in obtaining access to sites led to the exclusion of 42 sites. Access was rarely denied; more frequently, we were either unable to get ahold of landowners or landowners said they would like to work with us but did not follow up with requested paperwork or other information as needed. Access was most difficult to obtain in the Valleys and easiest in the Montane Zone and Wetlands, whereas other strata had similar levels of difficulty with access. In general, excluding sites from analysis only had a small impact on the proportion of sites in federal, state, or private ownership that were surveyed. However, 25% less private sites were surveyed in the Uintas and 18% less private sites were surveyed in the Valleys than originally selected. Overall, our survey results indicate approximately 10% less wetland area than originally estimated by the National Wetlands Inventory data, and an additional 27% of wetland area is unknown due to lack of access (table 7). If the wetland area is similar to the surveyed area in terms of proportion of non-target wetlands, then about 87% of the mapped wetland area is actually target wetland, or about 16,727 hectares.

To increase field efficiency, we only surveyed sites that we determined were probably (Class 1) or possibly (Class 2) target wetlands during office evaluation. Twenty-six survey sites were surveyed without first being classified as to their likelihood of containing target wetlands. All of the Class 1 wetlands and 74% of the Class 2 wetlands were able to be surveyed in the field. Of the excluded Class 2 sites, one was rejected because the land owner claimed that there was no wetland on his property and the other five all had areas of wetland that were too small or did not meet the minimum width requirement to be sampled. At least two of these sites may have altered wetland area due to changes in hydrology related to beaver activity.

We conducted a second office evaluation of the Class 3 (probably not wetland) and Class 4 (not wetland) sites to evaluate whether wetland mapping was incorrect or wetland screening was too liberal in rejecting wetland sites. We evaluated whether the National Wetland Inventory polygon appeared correct and whether any potential wetland was in the area, regardless of fidelity to the original polygons. Of the 22 reexamined sites, data appeared correct at 11 sites, incorrect at 5, and unclear at the remaining. Of the sites that appeared correct, eight were mapped as palustrine aquatic beds that were rejected either because they appeared too small to sample or because they appeared too deep in imagery to contain aquatic bed. Two of the remaining sites were mapped as forested wetlands along streams; these sites could have been wetland, but the dense canopy made it difficult to evaluate. National Wetland Inventory spatial data for the last site appears to be spatially shifted from the true wetland location and thus the selected sample point was too far from the actual wetland to survey. Of the sites where data appeared incorrect, four were in the Footslopes and one in the Foothills. Two of

Table 7. Estimates of the percent and area of non-target, no access, and sampled wetlands, for the Weber watershed, major ecoregions, and each stratum. Blank values indicate that no estimates were made because the category was not encountered for that analysis unit.

Analysis Unit	Non-target		No Access		Sampled	
	% area	Estimated area (ha)	% area	Estimated area (ha)	% area	Estimated area (ha)
Entire watershed	10.3	1986 (980-2992)	27.1	5214 (3280-7149)	62.6	12,034 (9310-14,758)
Basin and range ecoregion	10.2	1401 (414-2388)	21.6	2959 (1093-4825)	68.2	9349 (6717-11,981)
Wetlands stratum	6.3	675 (0-1849)	18.8	2026 (138-3914)	75.0	8105 (5911-10,299)
Footslopes stratum	25.0	725 (297-1154)	32.1	933 (492-1373)	42.9	1244 (844-1643)
Montane ecoregion	10.6	585 (329-841)	40.8	2255 (1750-2760)	48.6	2685 (2082-3288)
Valleys stratum	0		55.6	1470 (1049-1892)	44.4	1176 (754-1598)
Foothills stratum	24.0	379 (163-594)	28.0	442 (215-669)	48.0	757 (507-1008)
Montane Zone stratum	46.2	98 (63-133)	7.7	16 (0-36)	46.2	98 (65-130)
Uintas stratum	10.0	109 (0-239)	30.0	327 (165-489)	60.0	654 (449-859)

these sites may have contained some wetland (including a constructed pond) whereas the other three did not appear to have wetland in the vicinity of the point.

5.1.2 Surveyed Sites

We conducted surveys at 72 sites between June 25, 2014 and September 26, 2014 (figure 2). Surveyed sites included 33 40-m radius circular plots, 35 freeform plots, and 4 rectangular plots. All circular plots had an area of 5010 m^2; the remaining plots ranged in area from 569 to 5688 m^2, with a median area of 2288 m^2. Sites were frequently moved in the field away from the original sample point, usually due to large inclusions of upland or water (34 sites) or the presence of multiple Ecological Systems (13 sites); 16 sites were not moved. The original randomly selected site point was located within the final AA at 29 of the moved sites and was between 0.4 and 98.3 m of the new AA edge at the remaining moved sites, with a median distance of 28.7 m.

5.1.3 Wetland Indicators Present at Sites

We used a conservative approach to evaluate whether sites met the Army Corps definition of hydrophytic vegetation by assuming that all species with missing wetland indicator values were upland species. Despite this conservative approach, all but three sites met the Army Corps definition of hydrophytic vegetation based on the dominance test, meaning that the majority of the most abundant species across all strata were rated as obligate, facultative wetland, or facultative species. One additional site was not assessed for hydrophytic vegetation because it was a playa with less than 1% vegetation cover; this site had both hydric soils and indicators of wetland hydrology. Two of the three sites that did not pass the dominance test did meet the definition of hydrophytic vegetation based on the prevalence index, meaning that sites had mostly obligate, facultative wetland, or facultative species when all species were considered. The third site would also likely meet both the prevalence and dominance test if a less conservative method was used to evaluate species without indicators. Almost one-third of species at the site had no indicator rating, including one of the two dominant species. The site did not have clear indicators of wetland hydrology or soils.

Indicators of wetland hydrology were generally not recorded in the field. We used data collected on water cover, algae mats, soil cracking, and other features and data collected in soil pits to assess the presence of wetland hydrology indicators. We used plant data to determine whether sites passed the FAC-neutral test. All but three of the sites that did not pass the FAC-neutral test did pass the wetland hydrology test. We used GIS and soil profile data to evaluate the indicators D2 (Topographic Position-Western Mountains only), D3 (Shallow aquitard), and B7 (Inundation on aerial imagery) *only* at those sites that did not already meet wetland hydrology requirements through other indicators. We attempted to evaluate C9 (Saturation on aerial imagery) in GIS as well, but did not feel confident in the evaluations and did not assign this indicator to any sites. Four sites did not have unequivocal wetland hydrology indicators, including two in the Footslopes which had no indicators present and one each in the Wetlands and Montane Zone that had one secondary indicator each (table 8). The most common indicators of wetland hydrology included FAC-neutral test, saturation, high water table, and surface water.

Twenty-one sites did not have any hydric soil indicators present, including all but two sites in the Footslopes and between one and three sites in all other stratum (table 9). Depleted matrix, loamy mucky mineral, and histic epipedon were the most common indicators present. Indicators related to organic soils were much more common in the montane ecoregion than in the basin and range. Typically only one soil pit was dug per site, often in the middle of the wetland, even though hydric soil indicators were developed to determine wetland boundaries. Additional pits would need to be dug at sites to determine whether they definitively lack hydric soils.

5.1.4 Classification of Surveyed Sites

Sites were assigned Cowardin and HGM classifications based on their dominant class, though they could potentially contain more than one class. All surveyed sites were classified as the Cowardin palustrine system and aquatic bed, emergent, forested, or scrub-shrub classes, as intended by the sample frame, except for one riverine aquatic bed site in the montane ecoregion and one each lacustrine aquatic bed site and palustrine unconsolidated shore site in the basin and range ecoregion. Sites in the basin and range included 1 with a J (intermittently flooded), 5 with an A (temporarily flooded), 2 with a B (saturated), 9 with a C (seasonally flooded), 2 with an E (seasonally flooded and saturated), and 5 with F or G (semi-permanently flooded or wetter) Cowardin water regimes. In the montane ecoregion, sites included 6 with an A, 19 with a B, 4 with a C, 13 with an E, and 5 with an F or G water regime. Application of HGM classifications to some surveyed wetlands was difficult because of highly modified hydrology, particularly in the basin and range ecoregion. Sites around Great Salt Lake

Table 8. Wetland hydrology indicators observed at sites, per stratum. Indictors in italics were not uniformly evaluated across all sites and their totals are not representative. Underlined indicators are secondary indicators; two are required to meet the U.S. Army Corps definition of wetland hydrology. Indicators not evaluated for a particular region are indicated by *NA* under strata in the region. A total of 12 sites were evaluated per stratum.

Indicator Name	ID	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uintas	Total
Surface Water	A1	5	4	4	2	2	3	**20**
High Water Table	A2	5	4	8	4	4	9	**34**
Saturation	A3	8	8	10	5	10	11	**52**
Drift Deposits	*B3*	0	0	1	1	0	0	***2***
Algal Mat or Crust/Biotic Crust	B4/B12	0	1	2	0	0	1	**4**
Surface Soil Cracks	B6	4	3	0	0	1	0	**8**
Salt Crust	*B11*	1	1	0	0	0	0	***2***
Hydrogen Sulfide Odor	C1	1	0	0	1	1	2	**5**
Dry-Season Water Table	C2	0	2	2	0	4	1	**9**
Geomorphic Position	*D2*	*NA*	*NA*	0	7	2	1	***10***
Shallow Aquitard	*D3*	2	0	0	2	0	0	***4***
FAC-Neutral Test	D5	10	8	12	9	7	11	**57**
No indicator present (not in total)		1	2	0	0	1	0	**5**
Total		**36**	**31**	**39**	**31**	**31**	**39**	

Table 9. Hydric soil indicators observed in soil pits. Indicator in italics is only evaluated on problem soils. A total of twelve sites were surveyed per stratum, but multiple pits were dug at some sites.

Indicator Name	ID	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uintas	Total
Total number of pits		**14**	**15**	**14**	**13**	**13**	**12**	**81**
Histosol	A1	0	0	3	0	2	3	**8**
Histic Epipedon	A2	1	0	4	1	2	3	**11**
Black Histic	A3	0	0	3	0	2	1	**6**
Hydrogen Sulfide	A4	1	0	0	1	1	2	**5**
2 cm Muck	A10	0	0	1	0	0	0	**1**
Depleted Below Dark Surface	A11	2	0	0	3	0	1	**6**
Thick Dark Surface	A12	0	0	1	0	0	1	**2**
Loamy Mucky Mineral	F1	1	4	3	2	4	1	**15**
Loamy Gleyed Matrix	F2	2	1	1	0	0	0	**4**
Depleted Matrix	F3	8	3	2	2	1	2	**18**
Redox Dark Surface	F6	1	0	2	2	3	1	**9**
Red Parent Material	*TF2*	0	0	0	1	0	1	**2**
Totals		**16**	**8**	**20**	**12**	**15**	**16**	
Pits with no indicators		**3**	**10**	**3**	**4**	**3**	**1**	**24**
Sites with no indicators		**2**	**10**	**2**	**3**	**3**	**1**	**21**

that received water directly from canals were classified as riverine due to their connection to riverine inputs, even though they were often actually depressional impoundments. A more appropriate HGM-based classified should be developed from the basin and range sites. The majority of Wetlands sites received water from direct application via managed whereas the majority of sites in the Footslopes received water via irrigation from tail water run-off (table 10). In the montane ecoregion, 6 sites were classified as depressional, 2 as lacustrine fringe, 15 as riverine, and 25 as slope. Groundwater-dominated sites were less common in the Valleys than in other montane ecoregion strata and irrigation via tail water run-off was more common in the Valleys and Footslopes than any other strata.

We estimated the total area of each Ecological System within the sample frame using the spsurvey package (table 11). In the basin and range, approximately half of the wetland area is Inter-Mountain Basins Alkaline Closed Depression (alkaline depression) and approximately one third of the area is North American Arid West Emergent Marsh (emergent marsh). Estimates only apply to wetlands within the sample frame, which consisted of palustrine vegetated wetlands, so total area of playa, which are frequently unvegetated, and emergent marsh, which are often lacustrine, is likely much higher than the estimates in the basin and range ecoregion. In the montane ecoregion, wetland area is predominantly wet meadow with smaller components of upper montane shrubland and Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland (lower montane woodland). Another 11% of area is emergent marsh, though, as for the basin and range, there is probably additional emergent marsh that was not part of the original sample frame.

Table 10. Number of sites per strata with listed water source; number of dominant sites shown in parenthesis.

Water Source/Strata	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uintas
Natural Sources of Water						
Subsurface floodplain flow			5 (2)	5 (3)	3 (2)	6 (2)
Natural surface flow	1 (1)	1	1	3	1	5 (2)
Overbank flooding from channel			2	2 (2)	2	2
Overbank flooding from lake			1			
Direct precipitation	2	3 (1)	1	4	1	
Direct snowmelt				3	4 (2)	2
Groundwater discharge		2	6	8 (3)	9 (6)	9 (4)
Unnatural Sources of Water						
Irrigation via direct application	8 (7)	4 (2)	1 (1)			
Irrigation via seepage		1	2		1	
Irrigation via tail water run-off	3	10 (6)	5 (2)	3 (1)		1
Discharge from impoundment release	1					1
Overflow from artificial impoundment		1	1 (1)		1 (1)	
Pipes directly feeding wetlands			1			
Urban run-off, culverts	1 (1)	3	3			

Table 11. Percent of wetlands and total wetland area for each Ecological System, by ecoregion. Area was adjusted by removing non-target wetland area and a percent of the no-access wetland area from the total area estimate.

Ecological System by Ecoregion	% (95% CI)	Area (ha)
Central Basin and Range		
Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	1.1 (0-3.1)	133
Inter-Mountain Basins Alkaline Closed Depression	54.4 (32-76.8)	6535
Inter-Mountain Basins Greasewood Flat	1.1 (0-3.2)	133
Inter-Mountain Basins Playa	7.2 (0-19.3)	867
North American Arid West Emergent Marsh	36.1 (14.6-57.6)	4337
Wasatch and Uinta Mountains and Wyoming Basin		
North American Arid West Emergent Marsh	11.0 (2.5-19.4)	515
Rocky Mountain Alpine-Montane Wet Meadow	75.3 (66.1-84.5)	3540
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	4.7 (0-10.5)	221
Rocky Mountain Subalpine-Montane Riparian Shrubland	9.0 (3.1-15)	425

5.1.5 Water Quality Data

Water quality samples were collected at 29 sites, including three sites each in the Foothills and Montane Zone, four in the Valleys, five in each the Wetlands and Footslopes, and nine in the Uintas. We report pH data from field samples rather than laboratory samples because pH values can change rapidly after sample collection. At sites where laboratory data was collected, the widest range of pH values was found in the Uintas, where two sites had values below 7, and three sites had field pH values above 9, including one each in the Wetlands, Foothills, and Montane Zone (table 12). Foothills and Montane Zone sites had higher pH values and Footslopes sites had lower pH values. The majority of samples had specific conductance values below 800 µMhos, the threshold used to distinguish freshwater from oligohaline in National Wetland Inventory mapping (Federal Geographic Data Committee, 2013), though all Wetlands samples, three of five Footslopes samples, and one of four Valleys samples were oligohaline. Many sites in the Uintas had very low specific conductance values in comparison to all others sites, frequently below 50 µMhos/cm. The highest values for suspended solids and volatile solids were in the Footslopes. Most strata had volatile solids values below the minimum reporting limit, the value at which the signal is strong enough to accurately quantify the results.

Most samples had nitrogen in ammonium and in nitrate plus nitrite in very low concentrations, below the minimum reporting limit (table 13). Footslopes, however, had detectable levels of ammonium at all sites and the highest detected levels of ammonium across all sites, and half of the Valleys sites had detectable nitrate plus nitrite levels. Footslopes samples had the highest minimum, median, and maximum total nitrogen and total organic nitrogen values whereas Foothills, Montane Zone, and Uintas samples were almost always among the lowest. Total digested phosphorus showed a similar pattern. Ratios of total nitrogen (TN) to total phosphorus (TP) were highest in Valleys and Uintas samples, often

Table 12. Basic chemistry and organic matter minimum, median, and maximum values, per stratum. All data from laboratory analysis except for pH, obtained in the field from handheld multi-parameter meters. Number following each stratum indicates total number of samples in the strata. Number following units for each constituent, when present, indicates the minimum reporting limit, the value at which signal is strong enough to accurately quantify versus merely detect. Values below this limit are shown in grey.

Stratum	Minimum	Median	Maximum
pH (field data from water quality sample locations)			
Wetlands (n=5)	7.8	8.6	9.0
Footslopes (n=5)	7.2	7.7	8.2
Valleys (n=4)	7.3	8.0	8.2
Foothills (n=3)	7.9	8.4	9.4
Montane Zone (n=3)	8.0	8.5	9.2
Uintas (n=9)	6.1	8.3	9.0
Specific Conductance at 25°C (µS/cm)			
Wetlands (n=5)	846	1640	3580
Footslopes (n=5)	399	958	3070
Valleys (n=4)	450	632	1938
Foothills (n=3)	432	565	639
Montane Zone (n=3)	173	263	410
Uintas (n=9)	14	36	525
Dissolved Solids, Total (TDS) (mg/l)			
Wetlands (n=5)	490	982	1940
Footslopes (n=5)	232	546	1758
Valleys (n=4)	262	385	1028
Foothills (n=3)	238	356	366
Montane Zone (n=3)	150	204	246
Uintas (n=9)	16	28	298
Suspended Solids, Total (TSS) (mg/l) (4)			
Wetlands (n=5)	2.0	4.4	85.3
Footslopes (n=5)	26.0	42.4	463.0
Valleys (n=4)	5.6	12.6	114.0
Foothills (n=3)	5.2	5.2	12.4
Montane Zone (n=3)	8.0	24.8	36.0
Uintas (n=9)	2.0	2.0	36.0
Volatile Solids, total (TVS) (mg/l) (5)			
Wetlands (n=5)	2.0	2.0	12.8
Footslopes (n=5)	2.0	16.8	138.4
Valleys (n=4)	2.0	2.0	12.7
Foothills (n=3)	2.0	2.0	2.0
Montane Zone (n=3)	2.0	2.0	9.2
Uintas (n=9)	2.0	2.0	10.8
Organic Carbon, total (mg/l) (0.5)			
Wetlands (n=5)	6.1	12.4	32.6
Footslopes (n=5)	5.0	5.8	34.8
Valleys (n=4)	2.1	6.5	15.9
Foothills (n=3)	1.9	2.8	6.0
Montane Zone (n=3)	2.0	3.7	5.8
Uintas (n=9)	2.1	5.2	9.9

Table 13. Nutrient and constituent ratio minimum, median, and maximum values, per stratum. Number following each stratum indicates total number of samples in the strata. Number following units for each constituent, when present, indicates the minimum reporting limit, the value at which signal is strong enough to accurately quantify versus merely detect. Values below this limit are shown in grey.

Stratum	Minimum	Median	Maximum
Ammonium (NH4)-N, total (mg/l) (0.05)			
Wetlands (n=5)	0.02	0.07	0.38
Footslopes (n=5)	0.07	0.23	1.55
Valleys (n=4)	0.02	0.02	0.02
Foothills (n=3)	0.02	0.02	0.09
Montane Zone (n=3)	0.02	0.02	0.02
Uintas (n=9)	0.02	0.02	0.02
Nitrate + Nitrite (NO3 + NO2)-N, total (mg/l) (0.1)			
Wetlands (n=5)	0.01	0.02	2.47
Footslopes (n=5)	0.00	0.04	2.58
Valleys (n=4)	0.05	0.48	1.38
Foothills (n=3)	0.06	0.08	0.45
Montane Zone (n=3)	0.00	0.00	0.25
Uintas (n=9)	0.00	0.00	0.04
Nitrogen, total (mg/l) (0.2)			
Wetlands (n=5)	0.53	1.48	4.01
Footslopes (n=5)	1.10	3.60	7.67
Valleys (n=4)	0.97	1.14	1.68
Foothills (n=3)	0.13	0.64	0.65
Montane Zone (n=3)	0.28	0.60	0.86
Uintas (n=9)	0.26	0.48	0.75
Organic N, total (mg/l)			
Wetlands (n=5)	0.49	1.39	2.83
Footslopes (n=5)	0.76	1.58	6.96
Valleys (n=4)	0.18	0.59	1.12
Foothills (n=3)	0.06	0.10	0.55
Montane (n=3)	0.26	0.58	0.59
Uintas (n=9)	0.24	0.44	0.73
Phosphorus, total (digested) (mg/l) (0.02)			
Wetlands (n=5)	0.04	0.21	0.86
Footslopes (n=5)	0.14	0.60	2.93
Valleys (n=4)	0.03	0.05	0.38
Foothills (n=3)	0.03	0.08	0.11
Montane Zone (n=3)	0.05	0.08	0.11
Uintas (n=9)	0.01	0.02	0.07
Total Nitrogen: Total Phosphorus (ratio)			
Wetlands (n=5)	4.6	7.0	15.7
Footslopes (n=5)	1.0	6.0	17.7
Valleys (n=4)	3.2	28.3	45.4
Foothills (n=3)	4.9	5.7	8.3
Montane Zone (n=3)	2.6	10.4	11.3
Uintas (n=9)	4.2	38.9	62.6
Total Organic Carbon: Total Organic Nitrogen			
Wetlands (n=5)	5.6	9.3	12.5
Footslopes (n=5)	0.7	6.2	20.3
Valleys (n=4)	7.4	12.0	14.2
Foothills (n=3)	10.9	26.8	31.6
Montane Zone (n=3)	3.4	9.9	14.1
Uintas (n=9)	5.9	11.0	41.7

exceeding 35. Previous work captured that lakes and oceans are typically nitrogen-limited when TN:TP<9.0 (by mass, reported as 20 molar by Guildford and Hecky, 2000) and phosphorus-limited when TN:TP>22.6 (by mass, reported as 50 by Guildford and Hecky, 2000). Wetland vegetation may obtain more nutrients from soil than the water column, so these ratios do not necessarily reflect nutrient limitation in wetlands. However, under those thresholds, Wetlands, Footslopes, and Foothills typically had low (nitrogen-limited) ratios, Valleys and Uintas had both low and high ratios, and Montane Zone sites were in the middle. Sites in the Uintas had the highest ratio values. However total phosphorus values were often below the minimum reporting limit which may suggest that ratios are not entirely accurate. The ratio of total organic carbon to total organic nitrogen can indicate the source of organic matter in the water and the relative decomposition rates. Ratios below 15:1 indicate more algae or proteins in the water that are more readily decomposed; ratios between 15 and 25:1 can indicate green emergent leaves such as cattails and *Phragmites australis;* and ratios over 30 can indicate non-photosynthetic stems and woody debris. Almost all samples had ratios below 15, except for one site each in the Footslopes and Uintas that had ratios between 15 and 25 and two Foothills and one Uintas site that had ratios between 25 and 42.

Sulfate was highest in the Wetlands samples and below the minimum reporting level for all Montane Zone and Uintas samples (table 14). Footslopes and Wetlands samples had amongst the highest values for most cations and anions, including chloride, calcium, magnesium, and sodium, though results were more mixed between low and high values for potassium. Samples from the Valleys and Foothills tended to have the lowest potassium values and highest calcium values, whereas Montane Zone sites tended to be low for all anions and cations except for calcium. The Uintas were low for almost all values.

5.2 Stressors on the Landscape

5.2.1 Water Quality Stressors

Potential water quality stressors were identified prior to site visits based on GIS analysis of land cover surrounding sites and probable sources of water flow to sites. In the field, stressors within 200 m of sites were evaluated to determine their likely contribution to nutrient, water contaminant, and sediment stress effects to the AA based on their hydrologic connectivity to the site and severity of stress. Water quality stressors directly within the AAs were not recorded. Pasture and rangeland in the 200 m buffer and development and cropland, identified in the office evaluation, were the most common stressors overall (table 15). The Footslopes had the most stressors identified in both the office and the 200 m buffer and had the most stressors listed as moderate or severe instead of low, in contrast Wetlands had many stressors identified in the office, but very few in the 100 m buffer. The Wetlands and Footslopes sites were frequently hydrologically connected to point source dischargers with Utah Pollutant Discharge Elimination System (UPDES) permits. The most common stressors identified in the Montane Zone and Uintas sites were found in the 100 m buffers rather than in the more landscape-scale office evaluation, including pasture and rangeland, small dikes, and paved roads. Valleys and Foothills sites had a moderate number of water quality stressors recorded at both scales. Valleys sites were the most likely to have paved roads and agricultural stressors within 100 m, and Foothills sites were the most likely to potentially be affected by oil and gas extraction or mines based on the office evaluation. Overall, low severity water quality stressors were the most common. High severity stressors were only

Table 14. Major anions and cations and alkalinity minimum, median, and maximum values, per stratum. Number following each stratum indicates total number of samples in the strata. Number following units for each constituent, when present, indicates the minimum reporting limit, the value at which signal is strong enough to accurately quantify versus merely detect. Values below this limit are shown in grey.

Stratum	Minimum	Median	Maximum
Sulfate (mg/l) (20)			
Wetlands (n=5)	38.0	42.8	168.0
Footslopes (n=5)	26.6	29.7	44.5
Valleys (n=4)	8.0	22.9	43.5
Foothills (n=3)	4.7	26.8	37.3
Montane Zone (n=3)	7.4	10.6	18.9
Uintas (n=9)	4.6	5.7	7.8
Chloride (mg/l) (1)			
Wetlands (n=5)	86.3	260.0	843.0
Footslopes (n=5)	5.7	88.9	599.0
Valleys (n=4)	17.7	38.6	424.0
Foothills (n=3)	26.7	48.3	204.0
Montane Zone (n=3)	2.5	2.6	8.6
Uintas (n=9)	1.8	2.4	5.2
Calcium (mg/l) (1)			
Wetlands (n=5)	15.5	46.0	78.6
Footslopes (n=5)	41.6	59.4	85.0
Valleys (n=4)	30.6	65.2	83.2
Foothills (n=3)	63.9	71.2	78.8
Montane Zone (n=3)	17.1	71.9	81.1
Uintas (n=9)	1.3	3.3	83.7
Magnesium (mg/l) (1)			
Wetlands (n=5)	16.0	42.7	60.8
Footslopes (n=5)	12.2	25.1	34.8
Valleys (n=4)	9.1	16.8	21.6
Foothills (n=3)	8.8	17.5	21.5
Montane Zone (n=3)	1.7	4.4	4.7
Uintas (n=9)	0.5	0.5	16.8
Potassium (mg/l) (1)			
Wetlands (n=5)	4.9	16.8	71.3
Footslopes (n=5)	3.9	9.7	26.0
Valleys (n=4)	1.6	3.0	4.0
Foothills (n=3)	0.5	1.8	2.3
Montane Zone (n=3)	0.5	0.5	3.7
Uintas (n=9)	0.5	0.5	5.9
Sodium (mg/l) (1)			
Wetlands (n=5)	64.7	179.0	490.9
Footslopes (n=5)	23.6	96.3	520.0
Valleys (n=4)	12.0	22.6	279.0
Foothills (n=3)	3.1	26.3	34.8
Montane Zone (n=3)	1.7	2.1	7.6
Uintas (n=9)	0.5	2.3	6.0
Alkalinity, total (mg CaCO3/l)			
Wetlands (n=5)	127.0	279.0	320.0
Footslopes (n=5)	155.0	239.0	609.0
Valleys (n=4)	175.0	219.0	262.0
Foothills (n=3)	203.0	216.0	261.0
Montane Zone (n=3)	61.0	180.0	215.0
Uintas (n=9)	4.0	12.0	274.0

Table 15. Number of sites with moderate or high stress for the most common water quality stressors identified in the office evaluation or in the field and percent of sites with stressor recorded at any severity level, in parenthesis. For the office evaluation, any potential stressor that may reach the site was identified; in the field evaluation, only stressors within 200 meters of sites were listed.

Stressor		Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uintas	Total % of sites
Stressor identified in the office	**Cropland**	10 (100%)	10 (100%)	4 (50%)	2 (25%)	0 (0%)	0 (0%)	45.80%
	Impervious surface, development	4 (75%)	8 (100%)	5 (91.7%)	0 (50%)	1 (8.3%)	0 (8.3%)	55.60%
	UPDES permit facilities	6 (91.7%)	6 (83.3%)	0 (25%)	0 (8.3%)	0 (0%)	0 (0%)	34.70%
	Mines, oil and gas extraction	0 (8.3%)	0 (8.3%)	0 (0%)	1 (50%)	0 (16.7%)	0 (0%)	13.90%
Stressor identified in 200 m buffer around site	**Pasture, rangeland, managed grazing**	3 (58.3%)	4 (91.7%)	3 (58.3%)	2 (83.3%)	2 (75%)	1 (33.3%)	65.30%
	Agriculture (crops, haying, holding pens)	0 (0%)	1 (33.3%)	2 (41.7%)	0 (16.7%)	0 (0%)	0 (0%)	15.30%
	Off-road vehicle substrate disturbance	0 (25%)	0 (16.7%)	0 (25%)	0 (16.7%)	0 (0%)	0 (8.3%)	15.30%
	Dikes, dams, levees	0 (0%)	3 (33.3%)	0 (25%)	0 (0%)	1 (25%)	0 (8.3%)	15.30%
	Dirt road or high use ATV road	0 (0%)	0 (25%)	0 (16.7%)	0 (16.7%)	0 (16.7%)	0 (16.7%)	15.30%
	Paved, gravel road or railroad tracks	0 (25%)	1 (25%)	1 (41.7%)	1 (25%)	0 (0%)	1 (25%)	19.40%
	Residential homes	0 (0%)	0 (25%)	2 (33.3%)	0 (16.7%)	0 (8.3%)	0 (0%)	15.30%

recorded twice in the buffer and 14 times in the office evaluation; all of the high severity stressors occurrences were in the Valleys, Footslopes, and Wetlands.

5.2.2 Hydroperiod Stressors

Similar to water quality stressors, potential hydroperiod stressors were recorded in both the office based on a landscape evaluation and within a 100 m buffer during field surveys. Hydroperiod stressors were very common at the landscape scale; every site in the Footslopes, Valleys, and Wetlands and all but two sites in the Foothills had at least one stressor recorded and a mean of 3.7. Hydroperiod modifications were much less common in the Montane Zone and Uintas, recorded at 3 and 6 sites, respectively. Most sites in the Footslopes (n=11), Valleys (n=10), and Wetlands (n=12) had at least one stressor recorded as moderate to high severity; other strata had three or less sites with severity above low for any landscape stressor. Sites in the Wetlands were the most likely to have controlled hydrology with water level control structures, managed dams, and managed ditches. Footslopes were the most likely to have less directly managed hydrologic modification, including impoundments, ditches, and irrigation return flows (table 16). More stressors were identified in the office than in the 200 m buffer surrounding sites, though some stressors for some strata were identified more frequently in the field and some stressors could only be evaluated in the field. More sites in the Montane Zone were identified as affected by dams or roads than were recorded in the office and more ditching was recorded in Valleys sites than recorded in the office. Substrate disturbance from livestock or from off-road vehicles affected ponding of water at about 50% of sites but was almost always recorded at low severity. Dredged depressions were at 13.9% of sites. Modification of natural flow paths (n=2) and plugging of natural channels (n=1) were only recorded at sites in the Foothills.

Table 16. Number of sites with moderate or high severity hydroperiod stressors and overall percent of sites with stressor recorded for common hydroperiod stressors, listed as # moderate, # high (overall percent). Stressors in italics were recorded during the office evaluation; other stressors were recorded within a 200 m buffer surrounding the survey site.

Potential Hydroperiod Stressor	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uintas
Control structures that regulate inflow into AA	*3, 3 (66.7%)*	*1, 2 (33.3%)*	*1, 1 (16.7%)*	*0, 0 (8.3%)*	*0, 0 (0%)*	*1, 0 (8.3%)*
Control structures that regulate outflow from AA	*3, 1 (41.7%)*	*0, 0 (0%)*	*1, 1 (16.7%)*	*0, 0 (0%)*	*0, 0 (0%)*	*0, 0 (0%)*
Water level control structure	*2, 1 (25%)*	*0, 0 (8.3%)*	*1, 0 (8.3%)*	*0, 0 (0%)*	*0, 0 (0%)*	*0, 0 (8.3%)*
Impounding dam, road, etc. affecting outflow	*1, 3 (50%)*	*1, 1 (66.7%)*	*1, 2 (41.7%)*	*0, 1 (16.7%)*	*0, 0 (0%)*	*0, 0 (0%)*
Impounding dam, road, etc. affecting inflow	*3, 4 (91.7%)*	*1, 3 (66.7%)*	*1, 0 (33.3%)*	*0, 2 (50%)*	*0, 1 (16.7%)*	*1, 0 (25%)*
Dikes/dams/levees/berm	*0, 1 (8.3%)*	*1, 3 (33.3%)*	*3, 0 (33.3%)*	*1, 1 (16.7%)*	*0, 2 (25%)*	*1, 0 (16.7%)*
Roads or railroad tracks (any substrate)	*2, 3 (58.3%)*	*0, 1 (33.3%)*	*1, 1 (58.3%)*	*0, 0 (33.3%)*	*0, 0 (25%)*	*0, 0 (16.7%)*
Ditches or modified channels feeding AA	*4, 4 (91.7%)*	*4, 2 (66.7%)*	*2, 0 (16.7%)*	*0, 0 (16.7%)*	*0, 0 (8.3%)*	*0, 1 (16.7%)*
Ditches, drain tiles increasing outflow from AA	*0, 0 (8.3%)*	*3, 2 (83.3%)*	*0, 0 (0%)*	*0, 0 (16.7%)*	*0, 0 (0%)*	*0, 0 (0%)*
Ditching	*0, 1 (16.7%)*	*3, 3 (75%)*	*1, 1 (33.3%)*	*2, 0 (16.7%)*	*0, 0 (0%)*	*1, 0 (16.7%)*
Irrigation return flows	*3, 2 (83.3%)*	*4, 5 (91.7%)*	*4, 1 (50%)*	*2, 0 (41.7%)*	*0, 0 (8.3%)*	*0, 0 (0%)*
Agriculture (crops, haying, etc.)	*0, 0 (0%)*	*1, 0 (25%)*	*2, 0 (41.7%)*	*0, 1 (16.7%)*	*0, 0 (0%)*	*0, 0 (0%)*
Impervious surface in contributing area	*2, 0 (66.7%)*	*4, 0 (83.3%)*	*2, 1 (91.7%)*	*0, 0 (41.7%)*	*1, 0 (8.3%)*	*0, 0 (25%)*
Dredged depression	*0, 1 (8.3%)*	*0, 2 (16.7%)*	*1, 0 (16.7%)*	*0, 0 (16.7%)*	*1, 1 (25%)*	*0, 0 (0%)*
Off-road vehicles or livestock substrate disturbance	*2, 0 (66.7%)*	*3, 1 (58.3%)*	*0, 0 (41.7%)*	*2, 0 (75%)*	*1, 0 (66.7%)*	*0, 0 (41.7%)*

Hydroperiod stressors observed directly within sites were also recorded. The highest impact hydroperiod stressors were generally absent from sites because sites were moved to encompass a single wetland not divided by major changes in hydrology. Nonetheless, one site had a water control structure recorded directly within the site. This site had a PVC pipe going into a small pond within the AA. One site had a dike within the site and two sites had evidence of channelization. Soil compaction and pugging from off-road vehicles and livestock, however, were by far the most hydroperiod stressors within AAs. One or both stressors were recorded at 41 sites, though off-road vehicle compaction was usually recorded in only a small portion of the AA. Moderate to high severity livestock pugging covering over 10% of sites was at four Footslopes sites, one Foothills site, and one Uintas site.

5.2.3 Other Common Stressors

At least one stressor was recorded in each site's surrounding 200 m buffer except for two sites in the Uintas; the mean number of buffer stressors per site was 4.8 with a maximum of 10 stressors recorded at one site. Forty-six sites had at least some land in the surrounding buffer converted to unnatural land covers such as agriculture, development, or roads (table 17). Linear disturbance features such as roads, railroad tracks, and utility corridors were common in all strata, whereas agricultural and development stressors were almost exclusively in Footslopes, Valleys, and Foothills buffers. Over 25% of the buffer area at eight sites was converted to development, agriculture, or linear disturbance features, including one Foothills, two Footslopes, and five Valleys sites.

Table 17. Common stressors found in 200 meter area surrounding wetland assessment sites. Data is presented as the mean percent of the assessment area occupied by stressor (converted from the midpoint of cover classes) followed by the number of sites where the stressor was found in parenthesis.

Stressors	**Mean percent of buffer area, for sites where stressor found (total number of sites)**						**Total # sites**
	Wetlands	**Footslopes**	**Valleys**	**Foothills**	**Montane Zone**	**Uintas**	
Row crops, hay, recreational park	0% (0)	19.4% (5)	11.5% (6)	20.3% (3)	0% (0)	0% (0)	**14**
Development[1]	0% (0)	10.8% (4)	18.9% (6)	3.9% (4)	10% (1)	0% (0)	**15**
Roads, railroads, utility corridors	2.6% (7)	7.7% (7)	5.7% (9)	9.4% (7)	3.5% (6)	5.2% (5)	**41**
Total land conversion[2]	2.6% (7)	19.4% (10)	23.4% (10)	17.8% (8)	5.2% (6)	5.2% (5)	**46**
Off-road vehicle disturbance	2.0% (6)	4.1% (5)	5.0% (4)	5.0% (3)	0% (0)	5.0% (2)	**20**
Pasture, rangeland, managed grazing	49.0% (10)	72.8% (12)	53.6% (7)	60.5% (11)	66.1% (11)	74.0% (5)	**56**
Nuisance algae	2.8% (2)	13.3% (5)	5% (1)	2.8% (2)	2.8% (5)	0% (0)	**15**
Non-native plant cover	35.5% (11)	32.9% (12)	41.5% (12)	30.0% (10)	23.9% (9)	14.8% (8)	**62**

[1]Includes residential and commercial buildings, oil and gas wells, and livestock holding pens.

[2]Sum of previous three categories.

Disturbances besides land conversion were also common. Non-native plant species cover was the most commonly recorded stressor. Each stratum had six or seven sites where non-native cover was recorded with at least 10% cover and at moderate or high severity, except for in the Uintas and Montane Zone. Rangeland, pasture, or managed grazing was also very common, found at over three-quarters of sites. Moderate severity grazing covering at least 10% of the buffer was most common in the Footslopes, where it was found at seven sites; all other strata had only two or three such sites. High severity grazing was only recorded at over 10% of the buffer at one site each in the Footslopes and Valleys. Off-road vehicle substrate disturbance was recorded at between two and six sites per strata, but was almost always low severity and always less than 10% of the AA. Nuisance algae was most common and severe in the buffer of Footslopes sites, where it was found at five sites, had up to 38% cover at one site, and was the only strata with severity above low recorded. Other stressors recorded in buffers included trash (n=19), trails (n=8), and vegetation control such as mowing, chemical control, and mechanical plant removal (n=5).

We recorded stressors present directly in the AA in three categories: hydroperiod, vegetation, and physical structure (table 18). Thirty-two sites had stressors recorded in all three categories, 17 in two categories, and 11 in one, and 12 sites had no stressors recorded. The mean number of stressors per site was 2.6, and a maximum of nine stressors were recorded at one site. Livestock pugging and trampling that affected hydroperiod and physical structure of sites were most common, followed by browse on vegetation from domestic grazing. No other stressors were found at over one fifth of the sites. These stressors, along with moderate to heavy formation of algae, were also the only stressors that were commonly recorded as moderate to high severity.

Table 18. Stressors present in the assessment area at least at three sites, by strata. Stressors were evaluated separately for effects on hydroperiod, physical structure, and vegetation.

Stressor	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uinta
Hydroperiod						
Livestock pugging, trampling, digging	42%	75%	25%	67%	67%	33%
Rutting, soil compaction from vehicles	33%	25%	8%	17%	0%	0%
Physical						
Trash	17%	25%	33%	8%	17%	8%
Rutting, soil compaction from vehicles	25%	33%	8%	25%	0%	0%
Livestock pugging, trampling, digging	33%	83%	33%	50%	58%	25%
Vegetation						
Grazing and browsing by domestic animals	33%	67%	25%	58%	58%	25%
Moderate, heavy formation of filamentous algae	17%	33%	25%	8%	25%	8%
Off-road travel by vehicle, machinery, etc.	17%	8%	8%	17%	0%	0%
Upland plant species encroachment	17%	8%	8%	25%	17%	8%

5.2.4 Parameter Estimates on Select Stressors

An estimated 28.9% of all target wetland area in the Weber River watershed has visible evidence of some livestock grazing disturbance (figure 3). Footslopes wetlands have significantly more grazing than other strata, based on the Wald statistic; about 79.2% of the area is grazed. The Uintas, Valleys, and Wetlands had less within-wetland grazing than other strata. The percent of wetland area with moderate to high severity grazing in the montane ecoregion is almost twice as much as the basin and range, 30.7% versus 16.8%, though differences in the cumulative density functions were not statistically significant. About two-thirds of Footslopes wetland area and just under half of Foothills wetland area is estimated to be subject to moderate to heavy grazing, compared to approximately one-quarter or less in other strata.

The amount of wetland buffer area estimated to have grazing ranged from 35.4% in the Uintas to 84.2% in the Footslopes. Strata had between 16.7 and 27.1% of buffer area with moderate to heavy grazing, except for the Footslopes, which had 58.3% of the wetland area. Cumulative density functions for extent of buffer grazing did not differ between sites. A much higher percent of area was grazed in the buffer rather than the wetlands themselves in the Montane Zone and Wetlands; other strata showed much smaller difference. The Foothills had more than twice as much moderate to heavily grazed area in wetlands themselves compared to the buffers. The Uintas and Footslopes both had slightly more moderate to heavily grazed area in the wetlands than the buffer and all other strata had more intense grazing in the buffer than in the wetlands.

About 1% of all wetland area in the watershed and in each ecoregion has substrate disturbance from off-road vehicle use (figure 3). The disturbance is most widespread in the Footslopes (6.7% of area) and in the Foothills (2.5% of area). About twice as much substrate disturbance is in the buffer as in the wetlands for the whole watershed and in each ecoregion, though the Footslopes had almost twice as much disturbance in the wetlands as in buffers and substantially more disturbance was in the buffer than in the wetlands in the Wetlands, Valleys, and Uintas.

5.3 Rapid Assessment Results

The majority of sites in the watershed, each ecoregion, and all but the Uintas stratum received an overall score of B (figure 4). Only twelve sites received scores of C, including four in the Footslopes, four in the Foothills, three in the Wetlands, and one in the Valleys. One site in the Footslopes received an overall score of D. Valleys, Wetlands, and Foothills each had one site scored as A and the Footslopes had none. The Montane Zone and Uintas differed from all other strata in their cumulative distribution of overall URAP scores and had higher scores in general (figure 5).

The Uintas and Montane Zone had the highest percent of sites scored as A for the landscape category score and no sites scored as C, whereas most other strata had predominantly B sites (figure 4). Only one site, in the Valleys, was scored as D for the landscape category. The majority of sites in all strata were surrounded by an average of 95 m of buffer land cover extending out from their entire edge (figure 6). Only three sites received scores of C or D for buffer width, indicating average widths less than 50 and 25 m, respectively. These sites included one site in the Valleys and Footslopes surrounded by roads and one Valleys site surrounded by agriculture and rural development. Soil and non-native species' disturbances within the buffers were common, but generally minor; most sites were scored as A or B for the two metrics. Soil disturbances were most common in the Footslopes; sites in this stratum

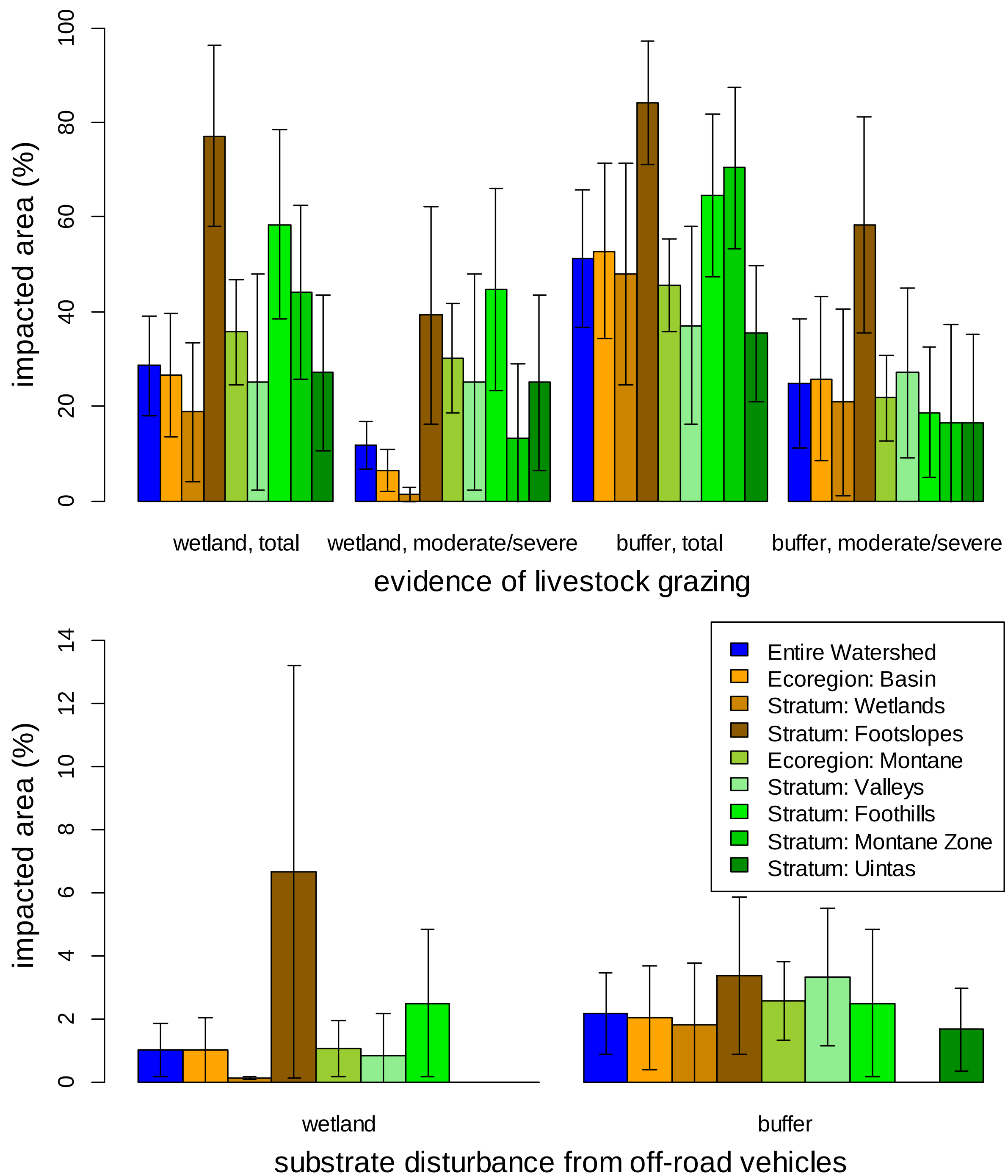

Figure 3. Percent of total area with evidence of livestock grazing or substrate disturbance from off-road vehicles, for wetlands and surrounding buffers in the Weber watershed, the basin and range and montane ecoregions, and strata. Area with grazing is shown for total area and area with moderate to high severity grazing. Estimates were taken from the top of the extent classes, so stressor extents may be overestimated.

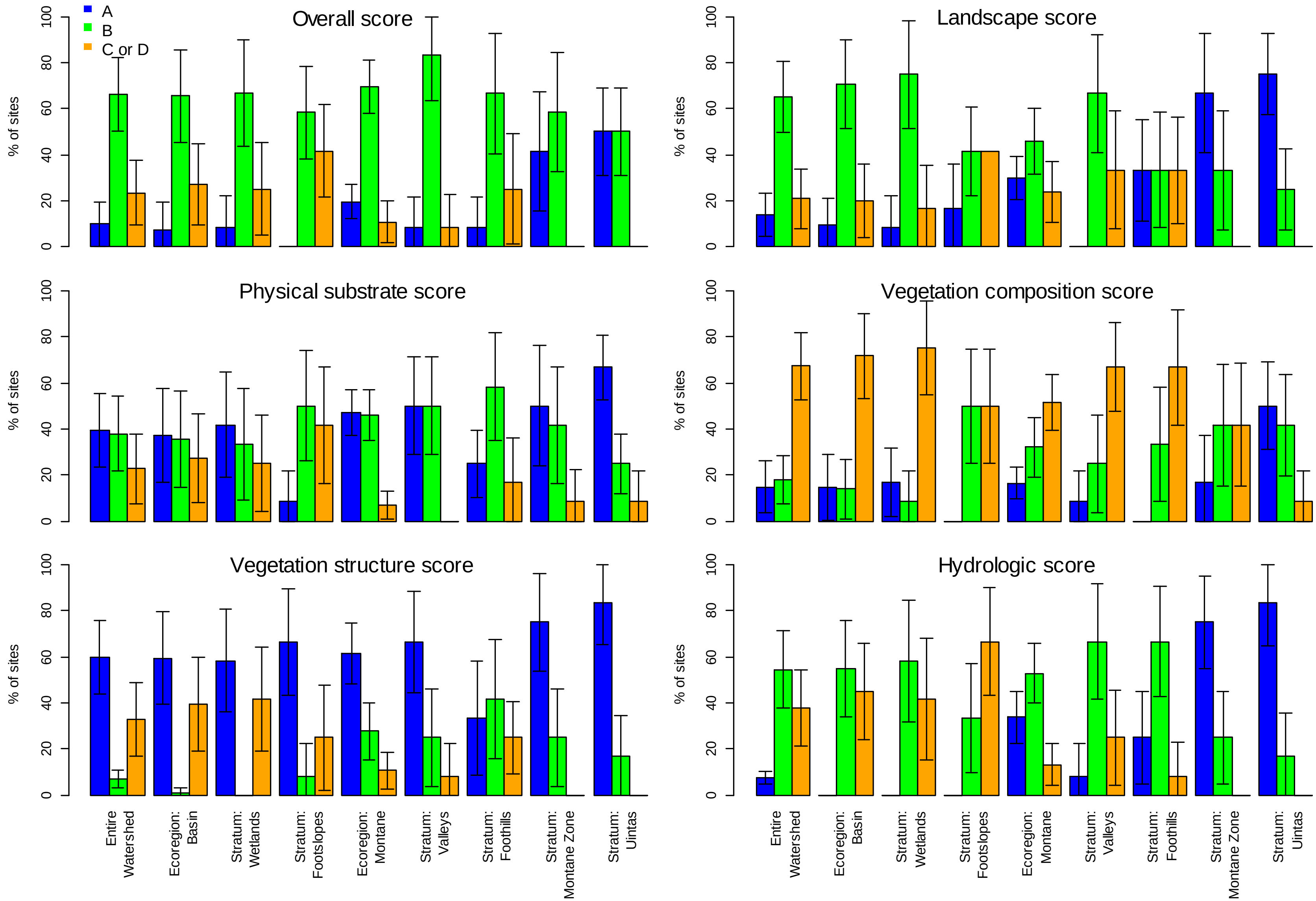

Figure 4. Percent of sites with URAP category and overall scores in the A, B, or C/D ranks, with 95% confidence intervals.

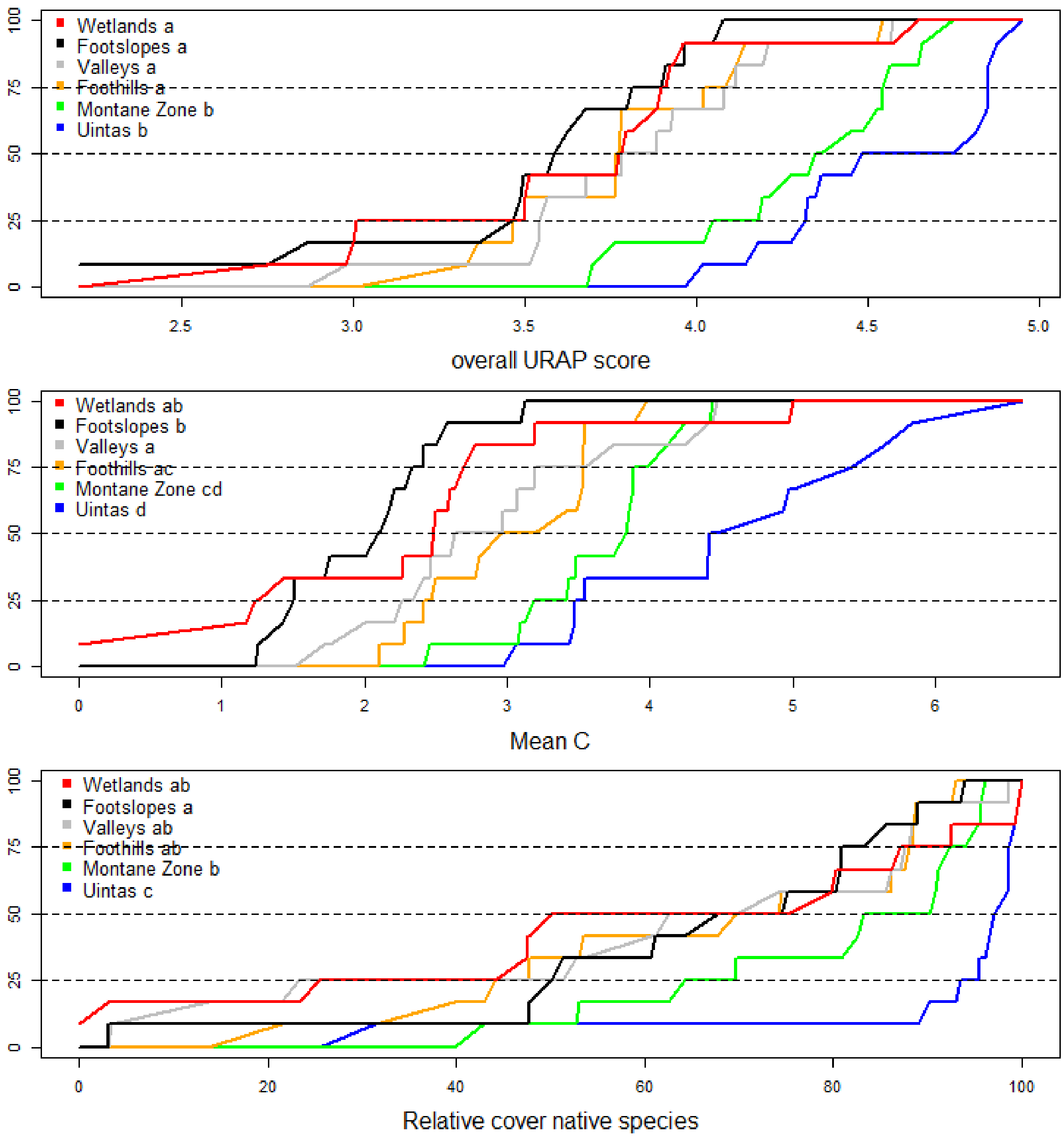

Figure 5. Cumulative density functions showing overall URAP score, Mean C, and relative cover of native species by strata. Strata that share a letter in the legend do not have significantly different distributions based on the Wald statistic.

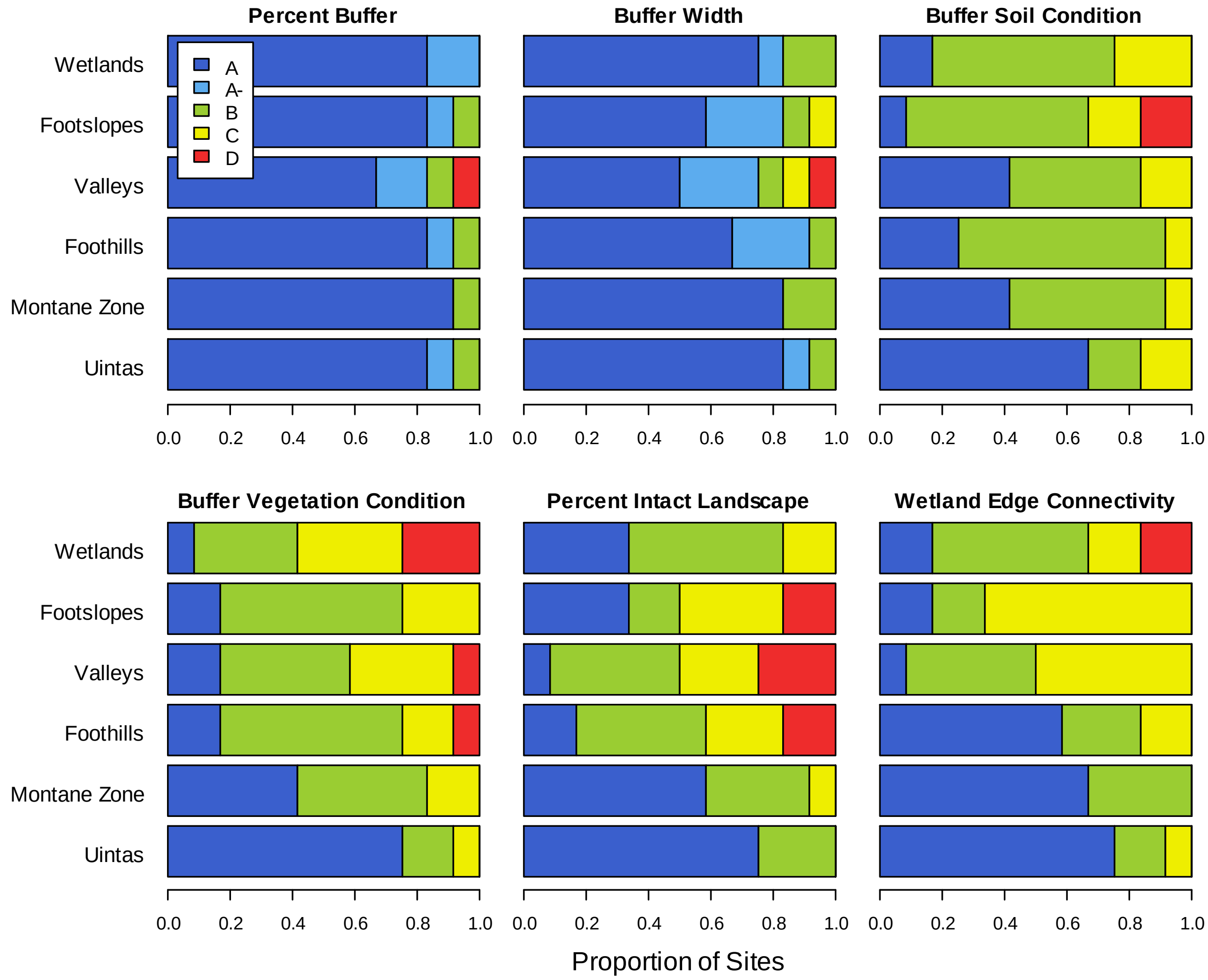

Figure 6. Landscape metric ratings by stratum, showing proportion of sites in each rank.

were also the only to be scored as D. At least one site in the Valleys, Wetlands, and Foothills was scored as D for buffer vegetation; Wetlands sites in general had the lowest buffer vegetation condition scores. Despite relatively intact buffers, the larger landscape around sites was frequently fragmented. Five or more sites each in the Footslopes, Valleys, and Foothills were rated as C or D in the percent intact landscape metric, which is evaluated up to 500 m from sites. Sites were also frequently embedded within wetlands that were not entirely hydrologically intact, due to features such as berms, entrenched channels and roads.

Footslopes and Foothills sites had the poorest physical substrate condition and were also the only strata with sites that received scores of D (figure 4). The remaining strata had at least 42% of sites scored as A; sites in the Uintas and Valleys had the most intact physical substrate. The physical substrate category was composed of a single metric, soil and substrate disturbance, so metric results are identical to category results (figure 7).

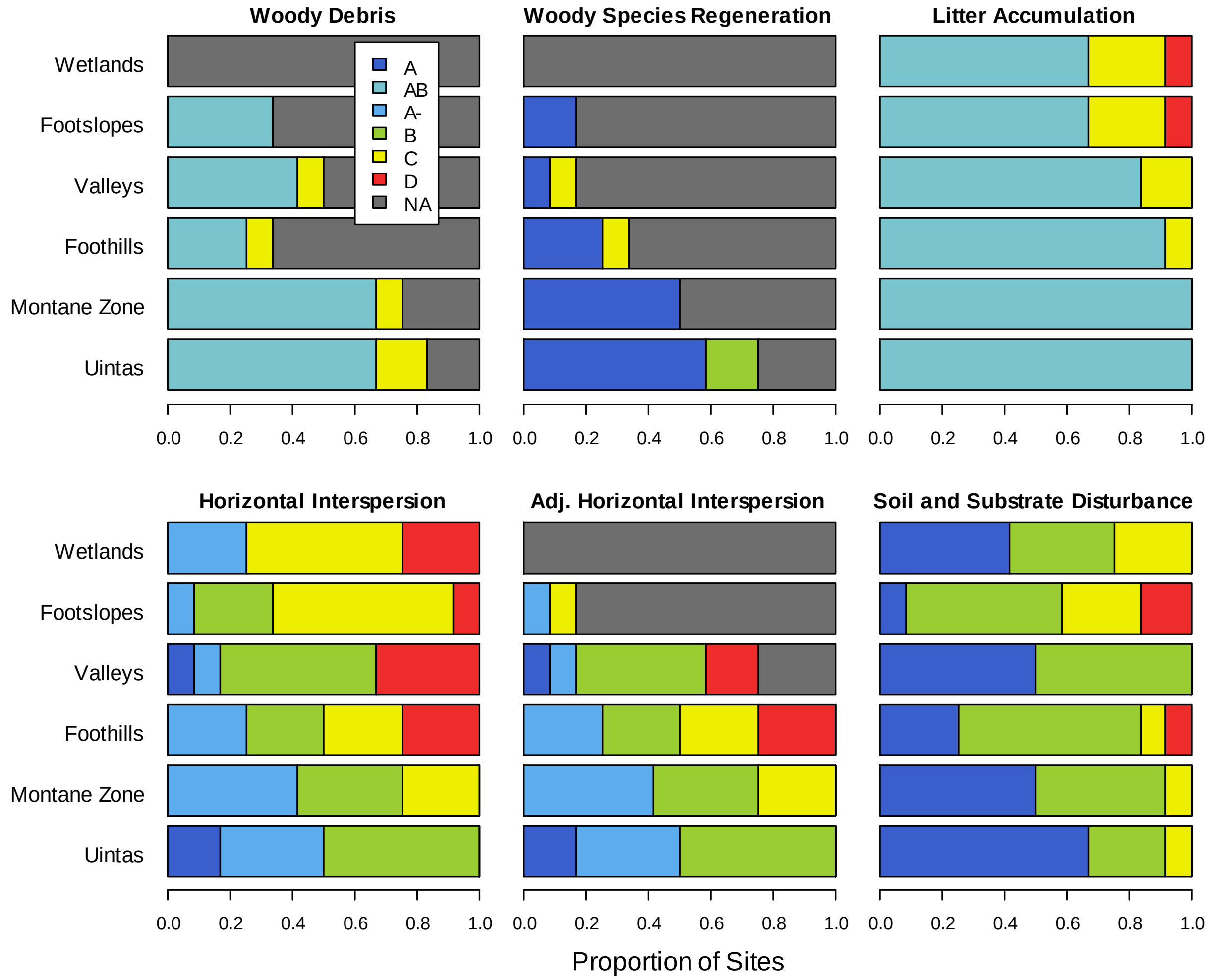

Figure 7. Vegetation structure and soil and substrate disturbance metric ratings by stratum, showing proportion of sites in each rank. The adjusted horizontal interspersion metric lists ratings for the playa, alkaline depression, and marsh sites as NA.

Almost all survey sites in the basin and range ecoregion were either in A condition or C or D condition in the vegetation structure category; only one site, in the Footslopes, was scored as B (figure 4). At most sites in the ecoregion, only the litter accumulation metric, which does not have a B ranking, was evaluated for the vegetation structure category. Woody species were largely absent and the interspersion metric was dropped for the common Ecological Systems in the ecoregion. Over half of wetlands in all strata in ecoregions except the Foothills were scored as A in this category. Sites were almost always scored as A for litter accumulation and, when applicable, for woody debris and woody species regeneration (figure 7). Litter accumulation was somewhat lacking or completely lacking at three Footslopes and Foothills sites. Little litter accumulation was likely from the removal of vegetation due to grazing pressure. Litter accumulation was somewhat excessive or excessive at eight sites in the Footslopes, Valleys, and Wetlands. For the majority of excessive litter sites, litter accumulation was due to build-up of litter from the invasive grass *Phragmites australis,* but other sites sometimes appeared to have changes in litter accumulation for unknown reasons. One Montane Zone site had less woody debris than expected, and two Uintas sites and one site each in the Valleys and Foothills had somewhat excessive debris. Two sites were scored as C for woody species regeneration due to heavy over-browsing of woody species. Sites had a moderate amount of interspersion, only a few sites scored as A. Only the Valleys stratum had sites scored as both A and D for interspersion, and only the Uintas stratum had no sites scored below B. Footslopes and Wetlands had the lowest scores in general. However, most sites in these strata were playa, emergent marsh, or alkaline depressions. Based on preliminary analysis, we did not include interspersion in the metric for scoring these systems. Soil and substrate disturbance was common in sites, though usually not extensive.

At least half of the survey sites in each stratum, except for the Montane Zone and Uintas, were scored as C or D in the species composition category. The Valleys and Wetlands had the most D sites, three each (figure 4). The Uintas had the most wetland area, over 90%, rated as B or better whereas the Wetlands had the least, at 25%. Plant community composition metrics were scored relatively low for all sites (figure 8). Only the Wetlands and Uintas had any sites that scored as A for relative cover of native species, indicating greater than 99% native species cover. The high scoring sites in the Wetlands are one impounded wetland with only four species and a *Salicornia rubra* (red swampfire) flat with two species. Most Uintas sites, several Montane Zone sites, and one Valleys site were scored as B, greater than 95% native cover; the Valleys site was frequently flooded by Pineview Reservoir and only had five species. A total of 18 sites had less than 50% cover of native species, scored as D. At the six Foothills, Montane Zone, and Uintas sites that scored as D, *Trifolium repens* (white clover), *Trifolium fragiferum* (strawberry clover), *Agrostis stolonifera* (creeping bentgrass), and/or *Poa pratensis* (Kentucky bluegrass) were the dominant or co-dominant species. In the Valleys, D-scoring sites were dominated by *Phleum pratense* (timothy) and *Agrostis gigantea* (redtop), *Alopecurus pratensis* (meadow foxtail) and *Phalaris arundinacea* (reed canarygrass), or *Elymus repens* (quackgrass) and *Phalaris arundinacea.* In the Footslopes *Poa trivialis* (rough bluegrass), *Phragmites australis*, and *Echinochloa crus-galli* (barnyard grass) dominated one site each. Four of the six D-scoring Wetlands sites were dominated by *Phragmites australis*; the other two were dominated by *Puccinellia distans* (weeping alkaligrass) or *Thinopyrum ponticum* (tall wheatgrass). At least two sites in each stratum had no noxious weed species present and at least half had less than 3% noxious weed cover. Six sites had 10% or more noxious weed cover, due to *Phragmites australis* at five sites and *Elymus repens* at one site.

Few sites overall were scored as A, and none as D, in the hydrologic category, except in the Montane Zone and Uintas where the majority of wetland area is estimated to be A (figure 4). Footslopes and Wetlands sites had the poorest hydrologic condition of all strata. The immediate edge of each AA was hydrologically connected to the surrounding landscape, but, because most sites were in the middle of wetlands, they were often connected to surrounding wetlands (figure 9). Hydroperiod scores tended to be somewhat lower than scores for timing of inundation. Sites in the Wetlands and Footslopes almost always scored as C or C- due to pervasive influence of irrigation return flows, impoundments, and water level control structures. Uintas and Montane Zone sites were almost always scored as A; hydroperiod

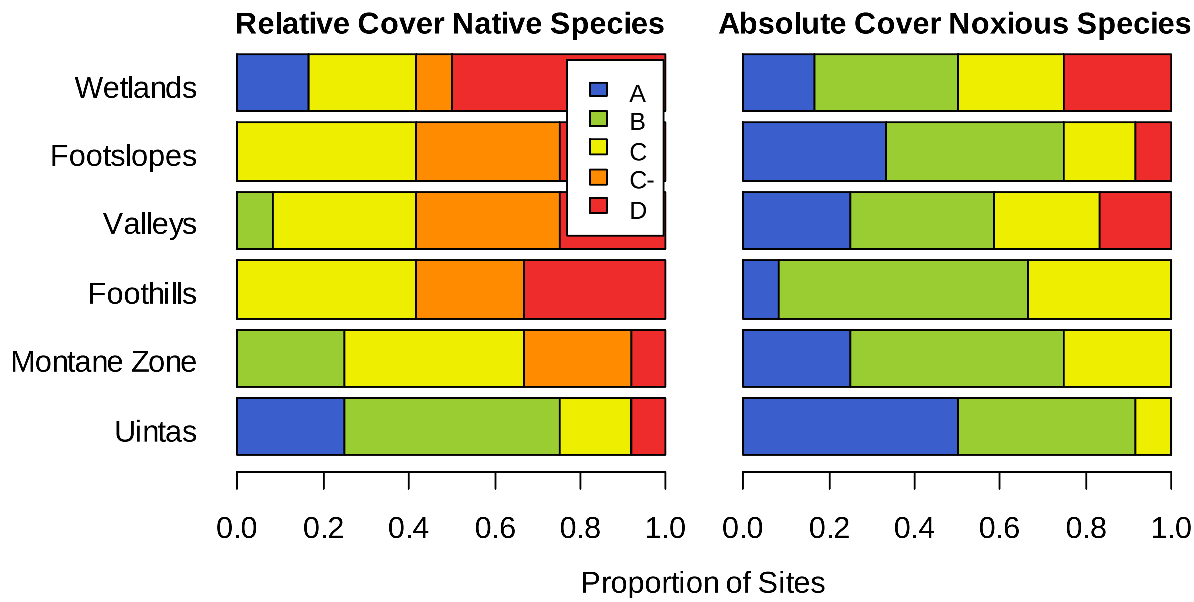

Figure 8. Vegetation composition metric ratings by stratum, showing proportion of sites in each rank.

and timing stressors in these strata, when present, were often related to local rather than landscape-scale manipulations. One site, located in the Foothills, was scored as D because it was located downslope from an impounded stock pond and no longer receiving much input of water. Sites in the Wetlands, Footslopes, and Valleys almost always scored as C or C- for water quality, often due to larger landscape issues such as impaired water sources or heavy development but sometimes due to intense local grazing pressures. Over half of the sites in the Uintas and Montane Zone were scored as A, and most of the remaining sites scored as B due to grazing influence. Most sites were scored as B or C for turbidity and pollutants in the Wetlands and Footslopes and as A in other strata. Scores were usually due to turbidity, often from livestock grazing, rather than evidence of pollutants. All strata showed some evidence of nuisance algae, though it was the most common in the Footslopes.

5.4 Wetland Vegetation

5.4.1 Survey and Floristic Quality Assessment Data

We recorded 1950 encounters with 410 unique plant species, including 156 species found at only one site. We were not able to identify to species 176 of the plants we encountered, 129 were identified to genus only and 47 not identified. *Typha* spp. (cattail) was the most frequent genus not identified to species due to lack of reproductive parts necessary for identification. All *Typha* spp. in the study area are native and have a C-value of 2, so we were able to include unidentified *Typha* spp. in the floristic data analysis. The most common families with unidentified species included Asteraceae, Ranunculaceae, Poaceae, and Polygonaceae. Unidentifiable species usually lacked flowering and/or fruiting parts, though in some cases specimen were not obtained or were lost. In general, unidentified species had low cover at sites. Excluding *Typha* spp., only 15 unidentified plants had more than 1% cover at a site and only 4 had 10% or more cover. Several *Carex* spp. and members of Poaceae were the most frequently unidentified higher cover species.

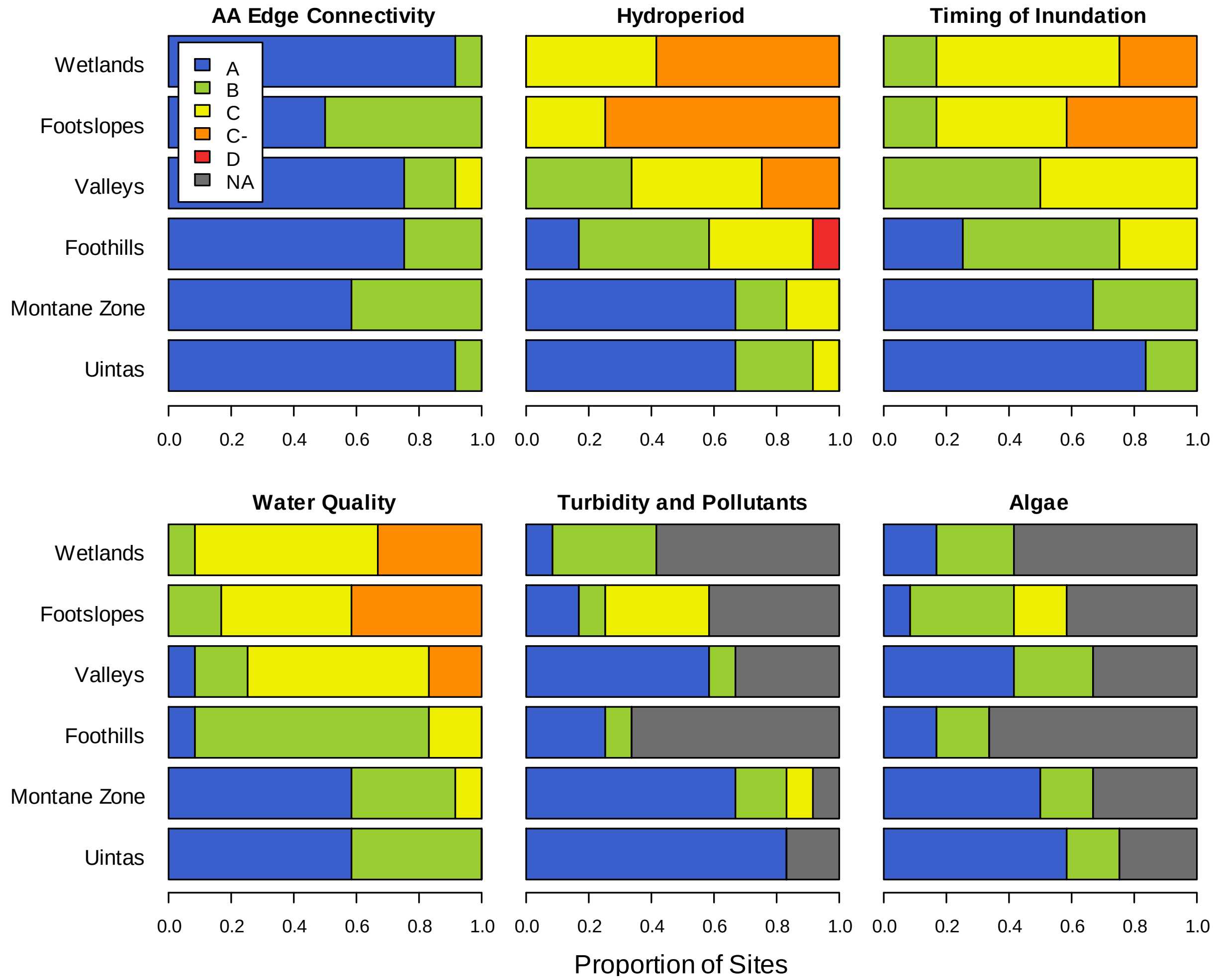

Figure 9. Hydrologic metric ratings by stratum, showing proportion of sites in each category.

Most FQA metrics indicated healthier plant communities at higher elevations. Valleys and Footslopes sites showed poorer performance than Wetlands sites for some metrics, though most differences were not statistically significant (table 19). Uintas and Montane Zone had the best FQA metrics and Wetlands and Footslopes had the worst. Wetlands sites frequently had significantly worse FQA metrics than all but Footslopes sites. Footslopes had the poorest mean values for two metrics, percent non-native species and Mean C. Valleys and Foothills had the two lowest mean values for absolute cover of non-native species and Valleys also had the lowest mean value for absolute cover of noxious weeds. Both Valleys and Foothills had higher overall plant cover than Wetlands and Footslopes sites which may explain why these metrics did not follow the elevational trend. Based on cumulative density function analysis, the distribution of Mean C values in the Footslopes is significantly different, and generally poorer, than that in the Valleys, Montane Zone and Uintas, and the distributions of Mean C values in the Uintas and Montane Zone are significantly different, and generally better, than all other

Table 19. Mean Floristic Quality Assessment metric values, by strata, followed by standard deviation in parenthesis. Strata that share small letters are not significantly different (p>0.05) based on post-hoc Tukey test on one-way ANOVA.

Metric	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uinta
Species Richness	11.8 (10.4)[a]	23.9 (12.3)[b]	22.8 (8.4)[ab]	27.3 (10)[bc]	37.7 (8.7)[c]	37.4 (9.3)[c]
Pct. Non-native	38.4 (30.2)[ab]	48.1 (11.2)[a]	35.9 (15)[ab]	33.9 (13.4)[ab]	21.3 (7.8)[bc]	12.5 (11.6)[c]
Abs. Cover Non-native	19.4 (23.1)[a]	17.7 (13.7)[a]	25.4 (21.9)[a]	21.0 (14.9)[a]	13.3 (13.7)[a]	5.1 (11.1)[a]
Abs. Cover Noxious	15.7 (24.1)[a]	4.4 (10.7)[ab]	5.6 (9.4)[ab]	2.4 (2.9)[b]	1.7 (2.3)[b]	0.7 (1.5)[b]
Rel. Pct. Native Cover	59.4 (35.9)[a]	65.5 (25.2)[ab]	61.7 (32.3)[ab]	66.3 (24)[ab]	79.7 (18.1)[ab]	91.6 (19.2)[b]
Mean C	2.3 (1.2)[ab]	2.0 (0.6)[a]	2.9 (0.9)[ab]	3.0 (0.6)[ab]	3.7 (0.6)[bc]	4.6 (1.1)[c]
Native Mean C	3.5 (1.3)[a]	3.9 (0.6)[ab]	4.6 (0.8)[bc]	4.7 (0.4)[bc]	4.6 (0.3)[bc]	5.3 (0.6)[c]
CW Mean C	1.9 (1.3)[a]	2.4 (0.9)[ab]	3.0 (1.7)[ab]	3.0 (1.4)[ab]	3.6 (0.9)[bc]	4.6 (1.2)[c]
Native CW Mean C	3.1 (1.3)[a]	3.8 (0.7)[ab]	4.6 (0.9)[bc]	4.5 (0.7)[bc]	4.6 (0.5)[bc]	5.0 (0.7)[c]
FQI	6.4 (3.8)[a]	9.5 (3.7)[ab]	13.4 (5.3)[b]	14.9 (4.6)[b]	21.4 (4.9)[c]	27.7 (8.8)[c]
Native FQI	8.0 (4.5)[a]	12.9 (4.3)[ab]	16.7 (5.6)[b]	18.3 (4.5)[bc]	24.0 (4.7)[cd]	29.3 (7.7)[d]
CW FQI	5.2 (3.5)[a]	11.7 (5)[ab]	13.0 (7.4)[ab]	15.4 (8.7)[b]	21.1 (6.1)[bc]	27.3 (8.9)[c]
Native CW FQI	6.8 (3.6)[a]	12.4 (3.8)[ab]	16.3 (5.1)[b]	18.0 (6.4)[bc]	23.9 (5.8)[cd]	27.9 (7.6)[d]
Adj. FQI	27.7 (11.8)[a]	27.8 (5.3)[a]	36.6 (7.8)[ab]	37.4 (4.2)[b]	41.2 (4.4)[bc]	49.4 (8.9)[c]
CW Adj. FQI	24.3 (12)[a]	26.9 (3.8)[ab]	36.6 (10.4)[bc]	36.4 (7.3)[bc]	40.6 (5.6)[cd]	47.0 (8.9)[d]

strata (figure 5). The distribution of relative cover of native species values differed between the Uintas and all other strata and between Montane Zone and Footslopes sites.

When FQA metrics are compared within single Ecological Systems, not all of the above patterns remained the same (table 20). In particular, wet meadow sites in the Valleys have slightly better mean FQA values than Foothills sites except for in the percent non-native, absolute cover non-native, and absolute cover of noxious species metrics. Mean absolute cover of noxious weeds was also lower in the Foothills wet meadow sites than in the Montane Zone wet meadow sites. Footslopes more consistently and by a larger margin had better mean FQA values than Wetlands sites when comparing only alkaline depression sites rather than all sites in each stratum; half of the Wetlands alkaline depressions had 35% or more cover of *Phragmites australis* while none of the Footslopes sites had more than 2% cover of this

Table 20. Mean Floristic Quality Assessment metric values, by Ecological System and strata, followed by standard deviation in parenthesis. Values were not compared for significant differences between strata due to the low and unequal sample sizes.

	Wet Meadow			
Metrics	**Valleys (n=9)**	**Foothills (n=9)**	**Montane Zone (n=10)**	**Uintas (n=9)**
Species Richness	25.7 (6.7)	24.7 (8.1)	36.3 (8.9)	35.2 (9.4)
Pct. Non-native	38.8 (15.7)	33.9 (14.4)	20.9 (8.3)	12.3 (12.9)
Abs. Cover Non-native	31 (22.4)	22.8 (16.7)	11 (12.1)	5.5 (12.9)
Abs. Cover Noxious	7.3 (10.4)	1.2 (2.0)	1.9 (2.5)	0.8 (1.7)
Rel. Pct. Native Cover	51.8 (31.4)	61.0 (25.3)	81.3 (17.4)	90.7 (22.3)
Mean C	3.0 (1.0)	3.0 (0.6)	3.7 (0.6)	4.8 (1.2)
Native Mean C	4.9 (0.6)	4.5 (0.3)	4.7 (0.3)	5.4 (0.7)
CW Mean C	2.6 (1.8)	2.6 (1.2)	3.7 (1)	4.6 (1.4)
Native CW Mean C	4.6 (0.9)	4.2 (0.4)	4.5 (0.5)	5.1 (0.7)
FQI	15.0 (5.2)	13.9 (3.8)	21.1 (5.3)	27.7 (9.6)
Native FQI	18.8 (4.7)	17.0 (3.7)	23.6 (5)	29.3 (8.4)
CW FQI	12.9 (8.5)	12.4 (6.8)	20.8 (6.4)	26.5 (9.5)
Native CW FQI	17.5 (5)	16.0 (4.3)	23.0 (6)	27.5 (7.8)
Adj. FQI	38.2 (8.3)	36.5 (4.1)	41.4 (4.7)	50.6 (9.7)
CW Adj. FQI	35.9 (10.6)	34.1 (5.5)	40.1 (6)	47.6 (9.4)
	Alkaline Depression		**Emergent Marsh**	
	Wetlands (n=6)	**Footslopes (n=10)**	**Wetlands (n=5)**	**Valleys (n=3)**
Species Richness	11.5 (9.7)	22.6 (9.8)	14.2 (12.1)	14.0 (7.8)
Pct. Non-native	53.2 (34.1)	47.5 (11.8)	18.4 (13.6)	27.3 (10.1)
Abs. Cover Non-native	34 (25.5)	15.6 (11.7)	5.7 (3.4)	8.3 (6.4)
Abs. Cover Noxious	27.4 (30.6)	1.5 (1.5)	4.6 (3.8)	0.7 (1.2)
Rel. Pct. Native Cover	37.3 (37)	68.7 (26.6)	87.9 (8.6)	91.2 (6.5)
Mean C	1.9 (1.7)	2.1 (0.5)	2.7 (0.3)	2.7 (0.4)
Native Mean C	3.4 (1.7)	4.0 (0.6)	3.3 (0.5)	3.8 (0.5)
CW Mean C	1.5 (1.8)	2.5 (0.9)	2.3 (0.4)	4.2 (1)
Native CW Mean C	3.1 (1.7)	3.8 (0.8)	2.6 (0.4)	4.6 (1.1)
FQI	4.9 (3.3)	9.5 (3.1)	8.8 (3.7)	8.7 (1.4)
Native FQI	6.9 (4.5)	12.8 (3.5)	10 (4.7)	10.4 (2.5)
CW FQI	3.6 (2.9)	11.5 (4.6)	7.5 (3.5)	13.3 (2.9)
Native CW FQI	6.3 (3.9)	12.0 (2.9)	7.7 (3.8)	12.5 (3.8)
Adj. FQI	24.7 (16.4)	28.3 (5)	29.8 (3.7)	31.8 (3.9)
CW Adj. FQI	23.3 (16.7)	26.9 (3.9)	23.2 (4)	39.0 (11.6)

species. Mean values for species richness, Mean C, FQI, native FQI and adj. FQI were very similar between emergent marshes in Wetlands and Valleys, though Valleys had much better FQA values for most metrics that incorporated species cover into calculations.

5.4.2 Common Wetland Plant Species

In the basin and range ecoregion, three species in the Wetlands and twelve species in the Footslopes were at half or more of the sites (table 21). *Distichlis spicata* (saltgrass)*, Typha* spp., *Phragmites australis, and Eleocharis palustris* (common spikerush) were both common and often abundant, whereas other widespread species had a mean of less than 5% cover. All of the common species were found in both strata, except for *Carex praegracilis* (clustered field sedge) and *Juncus arcticus* (arctic rush), found only at Footslopes sites.

Table 21. Plant species found at ≥50% of surveyed wetland sites within at least one stratum (wetlands or footslopes) in the basin and range ecoregion; the number of sites, mean cover where detected, and plant characteristics are listed. Wetland indicator status is taken from the U.S. Army Corps of Engineers National Wetland Plant List for the Arid West region. Underlined nativity indicates species that are annual; all other listed species are perennial.

Scientific Name (Common Name)	Nativity	C-value	Wetland Indicator Status	Wetlands		Footslopes	
				# Sites	Mean % Cover	# Sites	Mean % Cover
Atriplex micrantha (twoscale saltbush)	Introduced	0		4	0.7	6	1.0
Carex praegracilis (clustered field sedge)	Native	4	FACW	0	*NA*	6	0.6
Distichlis spicata (saltgrass)	Native	4	FAC	5	3.6	11	10.1
Eleocharis palustris (common spikerush)	Native	4	OBL	1	2.0	6	8.5
Hordeum jubatum (foxtail barley)	Native	2	FAC	4	2.9	10	2.7
Juncus arcticus (arctic rush)	Native	3	FACW	0	*NA*	8	3.9
Phragmites australis spp. australis[1] (common reed)	Introduced	0	FACW	10	18.4	6	5.8
Polygonum ramosissimum (bushy knotweed)	Native	2	FAC	3	0.1	8	1.0
Polypogon monspeliensis (annual rabbitsfoot grass)	Introduced	0	FACW	3	2.0	10	0.7
Rumex crispus (curly dock)	Introduced	0	FAC	1	0.1	6	0.2
Schoenoplectus acutus (hardstem bulrush)	Native	5	OBL	6	1.5	4	3.1
Spergularia maritima (media sandspurry)	Introduced	0	FACW	3	0.5	6	1.1
Trifolium fragiferum (strawberry clover)	Introduced	0	FACU	1	1.0	6	4.9
Typha spp.[2] (cattail)	Native	2	OBL	6	14.3	4	9.0

[1]Observations in the field may include both the native and the non-native subspecies of *Phragmites australis*, though all observations whether recorded as the European subspecies or recorded without subspecies are assumed to be non-native.
[2]Includes *Typha latifolia* (broadleaf cattail), and *Typha* specimen that were not identified to species. Nativity, C-Value, and Wetland Indicator Status for all *Typha* species known from the study area are the same and are reported even when individuals were not identified to species.

Only two common basin and range species were also common in the montane ecoregion, *Juncus arcticus* and *Rumex crispus* ([curly dock], table 22). Five species were found at over half of all montane ecoregion sites, including three introduced species (*Taraxacum officinale* [common dandelion], *Poa pratensis,* and *Cirsium arvense* [Canada thistle]). Most common species were found at least once in three of the four strata, and the Uintas strata was the only one to have common species not shared by any other strata.

5.4.3 Nuisance Plant Species

In the basin and range ecoregion, *Phragmites australis* was the most widespread and abundant noxious weed species, found at 67% of sites and had an estimated 13.7% cover in wetlands in the ecoregion (table 23). The species was recorded as the European subspecies at 13 sites and with no subspecies designation at three sites; all records for this species were assumed to be non-native. The estimated cover for all noxious weed species pertains to cover within the sample frame of the study (i.e., within mapped vegetated palustrine wetlands). Species are likely to occupy more area than indicated by the estimates, particularly species that are commonly found in upland areas. Nonetheless, cover estimates of *Phragmites australis* in the Weber River watershed are similar to reserve-wide estimates made from a remote sensing project conducted in 2014—9.3% *Phragmites australis* cover estimated at Harold Crane Waterfowl Management Area and between 14.5 and 14.9% cover estimated at other nearby reserves (Long, 2014). *Lepidium latifolium* (broadleaved pepperweed) and *Cirsium vulgare* (bull thistle) were the only other species found at over one fifth of sites in the basin and range, though usually with very low cover. Only 0.45% of wetland area in the basin and range is estimated to be invaded by noxious weeds other than *Phragmites australis*, equivalent to 54 hectares of infestation.

Three noxious weed species in the montane ecoregion are estimated to have approximately 1% overall cover each, including *Phragmites australis*, *Elymus repens*, and *Cirsium arvense*; all other species have 0.15% cover or less overall (table 24). *C. arvense* was the most widespread noxious weed, found at 56% of sites and at five or more sites per strata. The species often had low cover, but had between 4 and 8% cover at five sites. *Phragmites australis* was only found at two sites, but had very high cover at one of the two sites. The subspecies identity was not recorded in the field, and it is unclear whether native or non-native strains were found. *Elymus repens* was recorded at four sites: three sites with 1% or less cover and one site with 25% cover. The species was collected at three of the sites, and the specimen was shown to Mary Barkworth, director of the Intermountain Herbarium and co-editor of Grasses of the Intermountain West (Anderton and Barkworth, 2009). Barkworth identified the specimen tentatively as *Elymus repens*, but thought that some characteristics were not completely fitting. Many of the other recorded noxious weed species were facultative upland or upland species only found at a few sites with 1% or less cover, though both *Arctium minus* (lesser burdock) and *Leucantheumum vulgare* (oxeye daisy) were each found at a site with 4 or 5% cover. An estimated 158 ha of wetland area in the montane ecoregion is composed of noxious weeds.

Table 22. Plant species found at ≥50% of surveyed wetland sites within at least one stratum in the montane ecoregion; the number of sites, mean cover where detected, and plant characteristics are listed. Wetland indicator status is taken from the U.S. Army Corps of Engineers National Wetland Plant List for the Western Mountains, Valleys, and Coast region. Underlined nativity indicates species that are annual; all other listed species are perennial.

Scientific Name (Common Name)	Nativity	C-value	Wetland Indicator Status	Valleys		Foothills		Montane Zone		Uintas	
				# Sites	Mean % Cover	# Sites	Mean % Cover	# Sites	Mean % Cover	# Sites	Mean % Cover
Achillea millefolium (common yarrow)	Native	3	FACU	2	0.3	4	0.9	10	1.2	7	0.5
Aconitum columbianum (Columbian monkshood)	Native	6	FACW	0	*NA*	0	*NA*	6	0.4	4	0.4
Arnica mollis (hairy arnica)	Native	6	FAC	0	*NA*	0	*NA*	2	0.3	6	1.2
Calamagrostis canadensis (bluejoint)	Native	5	FACW	0	*NA*	0	*NA*	1	8.0	10	7.6
Caltha leptosepala (white marsh marigold)	Native	6	OBL	1	2.0	0	*NA*	0	*NA*	6	3.9
Carex microptera (smallwing sedge)	Native	4	FACU	0	*NA*	0	*NA*	5	1.3	7	1.1
Carex nebrascensis (Nebraska sedge)	Native	5	OBL	6	5.9	8	6.3	7	4.2	3	0.5
Carex utriculata (Northwest Territory sedge)	Native	4	OBL	2	1.5	2	9.0	8	19.6	8	17.9
Cirsium arvense (Canada thistle)	Introduced	0	FAC	8	1.4	5	3.5	9	1.9	5	1.2
Cirsium vulgare (bull thistle)	Introduced	0	FACU	4	0.2	6	0.3	3	0.2	3	0.2
Danthonia intermedia (timber oatgrass)	Native	6	FACU	0	*NA*	0	*NA*	0	*NA*	6	0.8
Deschampsia cespitosa (tufted hairgrass)	Native	5	FACW	5	4.5	5	6.2	1	1.0	7	10.6
Epilobium ciliatum (fringed willowherb)	Native	3	FACW	5	0.4	6	0.4	8	0.4	11	0.5
Equisetum arvense (field horsetail)	Native	3	FAC	2	0.3	2	0.5	6	1.4	4	1.8
Geranium richardsonii (Richardson's geranium)	Native	6	FAC	0	*NA*	0	*NA*	8	1.1	6	0.2
Geum macrophyllum (largeleaf avens)	Native	5	FAC	0	*NA*	6	0.4	11	0.4	7	0.5
Hordeum brachyantherum (meadow barley)	Native	4	FACW	2	0.8	6	5.4	6	1.3	3	0.7
Juncus arcticus (arctic rush)	Native	3	FACW	8	7.5	10	7.5	8	2.4	5	0.6
Juncus mertensianus (Mertens' rush)	Native	7	OBL	0	*NA*	0	*NA*	0	1.1	6	0.9
Juncus saximontanus (Rocky Mountain rush)	Native	6	FACW	0	*NA*	1	0.1	7	2.7	4	0.6
Madia glomerata (mountain tarweed)	Native	1	FACU	1	0.5	0	*NA*	7	0.5	2	0.5
Mimulus guttatus (seep monkeyflower)	Native	5	OBL	4	1.5	1	0.5	9	0.8	5	0.6
Phalaris arundinacea (reed canarygrass)	Introduced	0	FACW	7	11.6	3	9.2	0	*NA*	0	*NA*
Phleum alpinum (alpine timothy)	Native	6	FAC	0	*NA*	0	*NA*	3	0.4	7	0.5
Phleum pratense (timothy)	Introduced	0	FAC	3	6.4	8	0.6	6	0.7	5	1.6
Pinus contorta (lodgepole pine)	Native	4	FAC	0	*NA*	0	*NA*	0	*NA*	10	1.1
Poa pratensis (Kentucky bluegrass)	Introduced	0	FAC	6	0.8	10	7.4	11	5.3	4	0.5
Rudbeckia occidentalis (western coneflower)	Native	6	FAC	0		1	0.5	9	1.7	5	0.6
Rumex crispus (curly dock)	Introduced	0	FAC	5	0.3	3	0.4	10	0.6	4	0.2
Symphyotrichum eatonii (Eaton's aster)	Native	6	FAC	3	0.5	1	0.5	6	0.6	2	0.5
Taraxacum officinale (common dandelion)	Introduced	0	FACU	5	1.9	8	0.8	11	1.0	8	0.8
Urtica dioica (stinging nettle)	Native	3	FAC	1	0.5	1	0.5	8	1.1	3	0.4
Veratrum californicum (California false hellebore)	Native	3	FAC	0		0		6	0.6	8	0.8

Table 23. Basin and range ecoregion non-native species and noxious weed data, including ecoregion-wide estimates of cover within wetlands and number of sites and mean cover where detected by strata. Species included are those on state noxious species lists for Utah (UT) or surrounding states, including Arizona (AZ), Colorado (CO), Idaho (ID), Nevada (NV), and Wyoming (WY) or on county lists in Utah (UT Cos).

Scientific Name (Common Name)	Noxious Weed Listing States	Westland Indicator Status	Percent Cover in Wetlands in Ecoregion (S.E.) (n=24)	Wetlands		Footslopes	
				# Sites	Mean Cover Where Found (%)	# Sites	Mean Cover Where Found (%)
Relative percent cover of native species	*NA*	*NA*	60.2 (7.2)	*NA*	59.4	*NA*	65.4
All noxious weeds combined	*NA*	*NA*	14.2 (4.8)	10	18.8	8	6.6
Anthemis cotula (stinking chamomile)	CO, NV	FACU	0.006 (0.005)	0	*NA*	1	0.5
Arctium lappa (greater burdock)	UT Cos	None listed	0.006 (0.005)	0	*NA*	1	0.5
Bromus tectorum (cheatgrass)	CO	None listed	0.04 (0.03)	1	0.5	0	*NA*
Cardaria draba (whitetop)	AZ, CO, ID, NV, UT, WY	None listed	0.05 (0.03)	2	0.3	1	0.5
Cichorium intybus (chicory)	CO	FACU	0.007 (0.005)	0	*NA*	2	0.3
Cirsium arvense (Canada thistle)	AZ, CO, ID, NV, UT, WY	FAC	0.006 (0.005)	0	*NA*	1	0.5
Cirsium vulgare (bull thistle)	CO, UT Cos	FACU	0.03 (0.01)	1	0.1	4	0.5
Dipsacus fullonum (Fuller's teasel)	CO	FAC	0.03 (0.03)	0	*NA*	1	3
Elaeagnus angustifolia (Russian olive)	CO, UT Cos, WY	FAC	0.06 (0.05)	0	*NA*	3	1.7
Lepidium latifolium (broadleaved pepperweed)	CO, ID, NV, UT, WY	FAC	0.2 (0.07)	3	0.7	5	1
Phragmites australis (common reed)[1]	CO, ID	FACW	13.7 (4.8)	10	18.4	6	5.8
Tamarix spp. (tamarisk)[2]	CO, ID, NV, UT, WY	None listed	0.05 (0.03)	2	0.3	1	0.5

[1]Observations in the field may include both the native and the non-native subspecies of *Phragmites australis*, though all observations whether either recorded as the European subspecies or recorded without subspecies are assumed to be non-native.

[2]Utah lists only *Tamarix ramosissimum* (saltcedar), Colorado lists three separate species, and all other lists apply to all species in the genus.

Table 24. Montane ecoregion non-native species and noxious weed data, including ecoregion-wide estimates of cover within wetlands and number of sites and mean cover where detected by strata. Species included are those on state noxious species lists for Utah (UT) or surrounding states, including Arizona (AZ), Colorado (CO), Idaho (ID), Nevada (NV), and Wyoming (WY) or on county lists in Utah (UT Cos).

Scientific Name (Common Name)	**Noxious Weed Listing States**	**Westland Indicator Status**	**Percent Cover in Wetlands in Ecoregion (S.E.) (n=48)**	**Valleys**		**Foothills**		**Montane Zone**		**Uintas**	
				# Sites	**Mean Cover Where Found (%)**	**# Sites**	**Mean Cover Where Found (%)**	**# Sites**	**Mean Cover Where Found (%)**	**# Sites**	**Mean Cover Where Found (%)**
Relative percent cover of native species	*NA*	*NA*	70.9 (4.2)	NA	61.7	NA	66.3	NA	79.7	NA	91.6
All noxious weeds combined	*NA*	*NA*	3.4 (1.1)	9	7.5	11	2.6	9	2.3	6	1.4
Arctium minus (lesser burdock)	CO, WY, UT Cos	UPL	0.12 (0.11)	0	*NA*	2	2.6	0	*NA*	0	*NA*
Bromus tectorum (cheatgrass)	CO	None listed	0.004 (0.003)	1	0.1	0	*NA*	0	*NA*	0	*NA*
Carduus nutans (musk thistle)	CO, ID, NV, UT, WY	UPL	0.016 (0.011)	0	*NA*	2	0.3	2	0.3	0	*NA*
Cirsium arvense (Canada thistle)	AZ, CO, ID, NV, UT, WY	FAC	0.99 (0.23)	8	1.4	5	3.5	9	1.9	5	1.2
Cirsium vulgare (bull thistle)	CO, UT Cos	FACU	0.088 (0.024)	4	0.2	6	0.3	3	0.2	3	0.2
Cynoglossum officinale (gypsyflower)	CO, ID, NV, UT, WY	FACU	0.023 (0.018)	0	*NA*	1	0.1	1	0.1	1	1
Dipsacus fullonum (Fuller's teasel)	CO	FAC	0.018 (0.015)	1	0.5	0	*NA*	0	*NA*	0	*NA*
Elaeagnus angustifolia (Russian olive)	CO, UT Cos, WY	FAC	0.018 (0.015)	1	0.5	0	*NA*	0	*NA*	0	*NA*
Elymus repens (quackgrass)	UT, WY	FAC	0.942 (0.791)	2	12.6	2	0.6	0	*NA*	0	*NA*
Isatis tinctoria (Dyer's woad)	AZ, CO, ID, NV, UT, WY	None listed	0.013 (0.011)	0	*NA*	1	0.5	1	0.5	0	*NA*
Leucanthemum vulgare (oxeye daisy)	ID, UT, WY	FACU	0.15 (0.12)	1	4	0	*NA*	0	*NA*	0	*NA*
Phragmites australis (common reed)[1]	CO, ID	FACW	0.92 (0.80)	1	25	1	0.5	0	*NA*	0	*NA*
Poa bulbosa (bulbous bluegrass)	CO	None listed	0.0003 (0.0003)	0	*NA*	0	*NA*	1	0.1	0	*NA*
Potamogeton crispus (curly pondweed)	ID	OBL	0.018 (0.015)	1	0.5	0	*NA*	0	*NA*	0	*NA*
Verbascum thapsus (common mullein)	CO	FACU	0.047 (0.017)	1	0.1	4	0.3	4	0.4	1	0.5

[1]Observations in the field did not specify whether species was the native or non-native subspecies.

5.4.4 Ordination and Cluster Analysis

With NMDS analysis, complex data on plant species presence and cover at sites is reduced to a few simple axes, each representing a large fraction of the variability in species composition data. Values along the axes are not readily interpretable (e.g., positive values are not "better" than negative values), but two sites that plotted close to one another on an NMDS plot have similar species composition. Vectors for species or environmental variables can be overlain on a plot to show the strength (represented by vector length) and direction (represented by vector orientation) of correlation with the plot, and the statistical significance of the correlation is determined through permutation testing. Plots are useful for visually evaluating the degree to which sites with similar attributes, such as strata or HGM class, have similar species composition (i.e., tend to cluster together). We did not use NMDS plots to objectively determine whether some sites have healthier species composition than other sites, but instead look for patterns to show how environmental variables, species, and sites cluster.

The optimal NMDS solution for the ordination of all sites consisted of two axes and had a stress value of 0.17 (figure 10). Strong evidence ($p<0.05$) exists for the relationship between the axes and 54 of the 253 species used in the analysis based on permutation testing. Plant community composition varied by the area of the AA ($p=0.01$) and day of the season ($p=0.01$), but did not vary by the observer group ($p=0.66$), by whether or not vegetation data was collected in plots ($p=0.50$), or by the percent of the AA with upland inclusions ($p=0.57$). These sample design effects may have been significantly correlated because sites at higher elevations were surveyed later in the season and were more likely to be less than 0.5 ha. The first axis of the climate and elevation PCA explained 87% of the variation and was positively correlated with higher temperatures and negatively correlated with lower precipitation and elevation; we only included the first axis in the NMDS analysis. Plant community composition was correlated with the first axis of the climate PCA, wetland origin, Ecological System, Cowardin water regime, HGM class, strata, and Level III and Level IV ecoregions ($p<0.001$ for all). Sites were loosely clustered by Ecological System, and alkaline depressions were mostly separate from emergent marshes but wet meadows and upper montane shrublands were fairly intermixed (figure 10). The first axis split sites between the basin and range and montane ecoregions and somewhat separated sites along an elevational gradient, having Uinta subalpine forests on one end of the spectrum and Wetlands sites on the other end. However, considerable overlap occurred between sites in the mountain valleys and semiarid foothills Level IV ecoregions and between sites in the mid-elevation Uinta Mountains and Wasatch montane zone Level IV ecoregions.

We next explored NMDS solutions for groups of sites within the montane ecoregion. The optimal NMDS solution for both the ordination of all montane ecoregion sites and the ordination of only wet meadow and upper montane shrubland sites (meadow-shrub sites) was three axes and a stress value of 0.16 for both. Both groups of sites still showed very strong correlation with the first axis of the climate PCA ($p<0.001$), but were no longer correlated with survey variables including day of the season and AA area. Both were also correlated with Cowardin water regime, stratum, and Level IV ecoregion, though only the ordination of all montane ecoregion sites was correlated with Ecological System.

Data from 42 sites were used in the k-means cluster analysis; one meadow-shrubland site was not included because of missing ground cover data. The optimal number of clusters was four based on k means analysis, with group sizes of 5, 7, 12, and 18 (table 25). Elevational cut-offs between groups

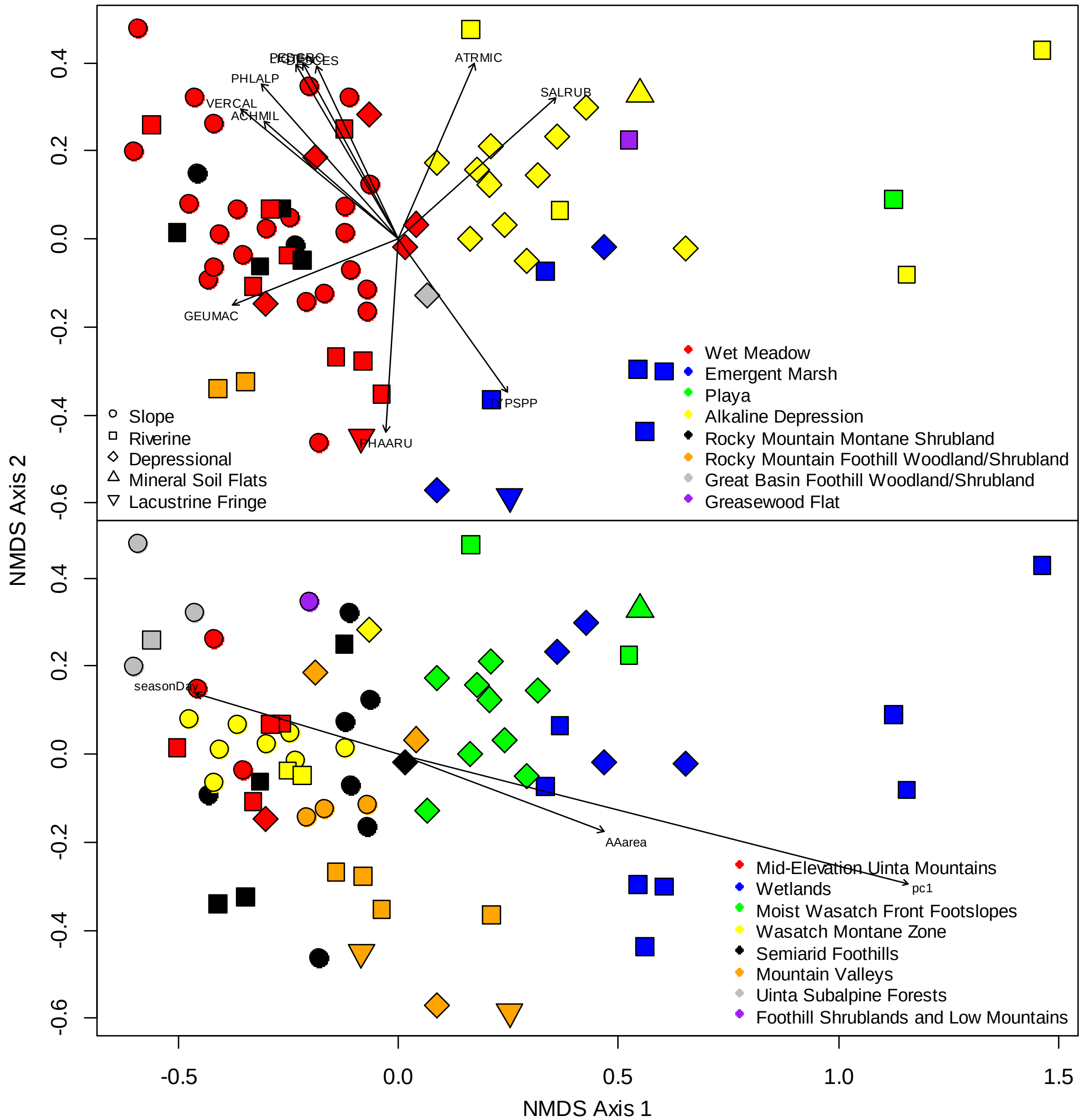

Figure 10. Plant community composition plot of all sites surveyed in the Weber watershed, color coded by Ecological System and HGM class (top) and by level IV ecoregion (bottom). Vectors show direction and strength of correlations with plant species (top, $p<0.003$) and with quantitative environmental variables (bottom, $p<0.02$). Species in the top plot include *Atriplex micrantha* (ATRMIC), *Salicornia rubra* (SALRUB), *Typha* spp. (TYPSPP), *Phalaris arundinacea* (PHAARU), *Geum macrophyllum* (GEUMAC), *Achillea millefolium* (ACHMIL), *Veratrum californicum* (VERCAL), *Phleum alpinum* (PHLALP), *Deschampsia cespitosa* (DESCES), *Ligusticum tenuifolium* (LIGTEN), and *Pedicularis groenlandica* (PEDGRO). The latter three species are clustered together and difficult to distinguish. Environmental variables include day of season (seasonDay), area of AA (AAarea), and the first axis of the climate PCA (pc1).

Table 25. Site attributes of groups developed through cluster analysis of all wet meadow and shrubland montane ecoregion sites.

# of Sites		5	12	181	7
Elevation Range (m)		1530 - 1770	1841 - 2125	2188-2556	2691 - 3098
Mean Value Across Sites Within Group	**Woody Species Cover (%)**	0.3	1.8	9.9	5.2
	Water Cover (%)	1.2	12.8	17	10
	Max. Temp. (°C)	30.5	29.1	25.1	21.3
	Mean Temp. (°C)	7.6	6.3	4.9	2
	Min. Temp. (°C)	-11.6	-12.4	-11.5	-14.3
	Mean Annual Precip. (mm)	464	459	774	1039
Level IV Ecoregions		foothills (3); valleys (2)	foothills (5); valleys (7)	foothills (2); low mountains (1); mid-elevation Uintas (5); montane zone (10)	mid-elevation Uintas (3); subalpine Uintas (4)
# Sites with Water Regime		B (4); C (1)	A (4); B (4); C (1); E (3)	A (1); B (7); C (1); E (7); F (2)	B (4); C (1); E (2)
# Sites with HGM Class		dep (1); riv (2); slo (2)	dep (2); lf (1); riv (2); slo (7)	dep (1); riv (7); slo (10)	dep (1); riv (2); slo (5)
Ecological Systems		wet meadow	wet meadow	shrubland (6); wet meadow (12)	wet meadow
Species Common to ≥75% of Sites (# Sites, C-value, Wetland Rating)		*Argentina anserina* (n=4, C=3, OBL), *Juncus arcticus* (n=4, C=3, FACW), *Trifolium repens* (n=4, C=0, FAC)	*Carex nebrascensis* (n=10, C=5, OBL), *Juncus arcticus* (n=11, C=3, FACW), *Poa pratensis* (n=10, C=0, FAC)	*Epilobium ciliatum* (n=14, C=3, FACW), *Geum macrophyllum* (n=16, C=5, FAC), *Taraxacum officinale* (n=16, C=0, FACU)	*Calamagrostis canadensis* (n=7, C=5, FACW), *Epilobium ciliatum* (n=6, C=3, FACW), *Phleum alpinum* (n=6, C=6, FAC)

[1]Summary data includes the 18 sites grouped through the cluster analysis, though the final set of sites used for development of the multi-metric index did not include the one depressional site and the one site with an A water regime and did include an additional site that was excluded from the cluster analysis.

[2]Water regimes include temporarily flooded (A), saturated (B), seasonally flooded (C), both seasonally flooded and saturated (E), and semi-permanently flooded (F) and indicate the dominate water regime listed at each site.

[3]HGM classes include depressional (dep), riverine (riv), slope (slo), and lacustrine fringe (lf)

occurred at approximately 1800, 2150, and 2600 meters and corresponded perfectly with elevation bands. All groups included sites from multiple Level IV ecoregions; sites in the semiarid foothills ecoregion were spread between three groups, and sites in the Wasatch montane zone, subalpine Uinta forests and foothill shrublands, and low mountains ecoregions were in one group each. The two lowest elevation groups contained sites in the semiarid foothills and mountain valleys Level IV ecoregions and had similar climatic means, but the higher one of the two (upper foothills group) occasionally had high cover of shallow water and/or woody species. The third group (mid-elevation montane group) was the only group that contained both wet meadow and upper montane shrubland sites. These sites frequently contained both shallow and deep water and beaver modifications, and they all contained at least some cover by woody species. The fourth group consisted of high elevation sites in the mid-elevation and subalpine Uinta Level IV ecoregions. Most of these sites had at least some woody species and water cover, though cover of deep water was never as high as that found in the mid-elevation montane group.

We only performed ordination on the two largest groups, represented by the second and third elevation bands, because the smaller groups had insufficient data for analysis. For the upper foothills sites, the two-axis NMDS solution had a stress value of 0.18. Plant species composition was significantly or weakly correlated with URAP landscape (p=0.01), vegetation composition (p=0.05) and hydrologic (p=0.06) category scores and with Mean C values (0.04). Composition was also correlated with water regime (p=0.03) and HGM class (p=0.04). Sites with high Mean C values had higher URAP categorical and overall scores and less cover of the non-native species *Phalaris arundinacea* and *Sisymbrium altisimum* ([tall tumblemustard], figure 11). Sites in the upper right of the NMDS plot are correlated with less strictly wetland-associated species with a range of C-values and with the temporarily flooded (A) water regime whereas sites in the lower left of the plot are correlated with more wetland-associated species and with a saturated (B) water regime. Differences between sites based on HGM class were difficult to determine, though the only lacustrine fringe site in the group appeared to be distinctive from all other sites.

The cluster analysis included 18 sites in the mid-elevation montane group, but we added an additional site that was excluded from the cluster analysis due to missing data, for a total of nineteen sites. This additional site fell within the appropriate elevation band and had many of the same indicator species as other sites in the group. Plant community composition was still strongly correlated with climate PCA axes (p<0.03) and with water regime (p=0.01) and weakly correlated with Level IV ecoregion (p=0.08) and HGM class (p=0.06). Removing the only depressional site and the only site with a temporarily flooded water regime eliminated all four of these environmental correlations. The two removed sites also shared few dominant species with other sites in the group. The resulting two-axis NMDS solution of the seventeen remaining sites had a stress value of 0.21. We used the two axis solution despite a stress value slightly above the rule-of-thumb threshold due to ease of interpretation. Plant species composition was weakly correlated with two sampling measures, AA area (p=0.05) and day of the season (p=0.09). Composition was also correlated with buffer stress (p<0.01) and total stress (p=0.05) and with Mean C (p<0.01). Composition was weakly correlated with disturbance status of sites (p=0.07). Sites on the lower half of the ordination plot tended to be sampled later in the season, have more buffer and total stress, and were natural but altered, whereas sites on the top half of the plot had higher Mean C values, a larger AA area, and more of the native species *Aconitum columbianum* (Columbian monkshood).

The two-axis NMDS on basin and range ecoregion sites had a stress value of 0.15. Composition was correlated with two sampling effect factors—day of the season and the observer group. Sites

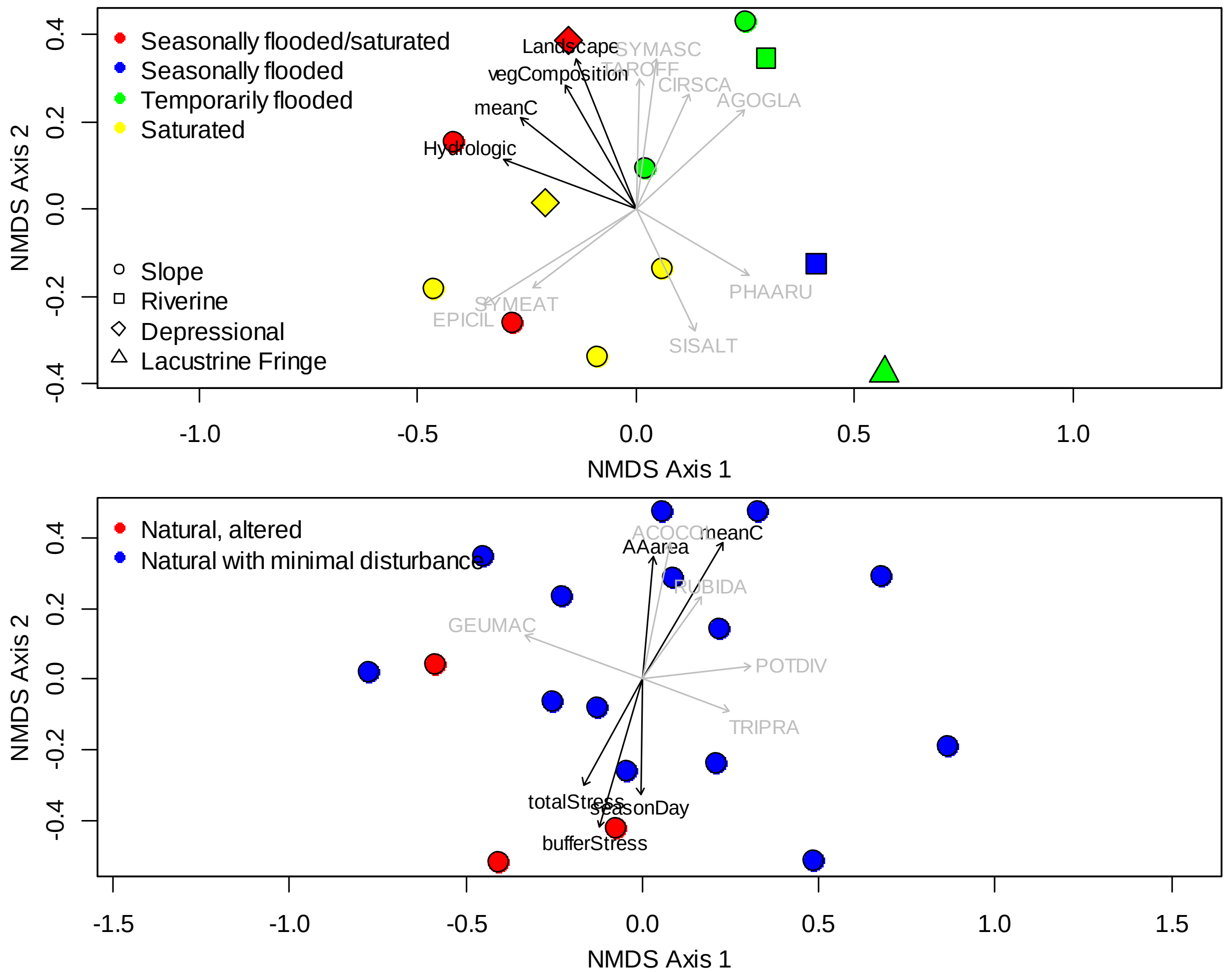

Figure 11. Plant community composition plot of upper foothills (top) and mid-elevation montane (bottom) shrubland and meadow sites. Vectors show direction and strength of correlations with plant species, in grey, and with quantitative environmental variables, in black. Plant species with p-values <0.10 and quantitative environmental variables with p-values <0.06 (top) or <0.022 (bottom) are shown, including both vectorized continuous variables and color-coded factors. Species include *Taraxacum officinale* (TAROFF), *Symphyotrichum ascendens* (SYMASC), *Cirsium scariosum* (CIRSCA), *Agoseris glauca* (AGOGLA), *Phalaris arundinacea* (PHAARU), *Sisymbrium altissimum* (SISALT), *and Epilobium ciliatum* (EPICIL) in the top plot and *Aconitum columbianum* (ACOCOL), *Potentilla diversifolia* (POTDIV), *Geum macrophyllum* (GEUMAC), and *Trifolium pratense* (TRIPRA) in the bottom plot. Environmental variables in the top plot includes the continuous variables Landscape, Vegetation Composition (vegComposition), and Hydrologic scores and Mean C (meanC) and the categorical variables water regime and HGM class. Environmental variables in the bottom plot include the continuous variables day of the season (seasonDay), area of AA (AAarea), total stress (totalStress), buffer stress (bufferStress), and Mean C (meanC) and the categorical variable disturbance class (natural and altered or natural with minimal disturbance).

managed by The Nature Conservancy and privately owned sites not managed as wetland habitat were frequently visited by non-standard groups of observers and much later in the growing season, which may explain these relationships. Composition was also correlated with the second axis of the climate PCA ($p<0.01$), Ecological System ($p<0.01$), water regime ($p<0.01$), HGM class ($p=0.02$), and Level IV ecoregion ($p<0.01$). Emergent marsh sites clustered together with the obligate wetland species *Typha* spp. and *Stuckenia pectinata* (sago pondweed) and had wetter water regimes (figure 12). Alkaline depression sites were intermixed with sites classified as Inter-Mountain Basins Playa (playa) and Inter-Mountain Basins Greasewood Flat (greasewood flat) and did not appear to be distinctive based on water regime, though intermittently flooded and temporarily flooded sites tended to be near one another. Differences in composition between Footslopes and Wetlands sites occur along a gradient rather than being abrupt.

Basin and range ecoregion sites were difficult to group so that differences would be driven primarily by anthropogenic factors rather than intrinsic differences between sites since there were few sites overall and no clear clusters of sites. We decided to display species composition data based on broad types defined by unique Ecological Systems, hydrology, and ownership to better visualize the relationship between site types in the basin and range ecoregion (figure 13). Impoundments with high salinity clustered close to one another and somewhat apart from the only low salinity impoundment. Two playa-like sites had similar scores on the first axis of the ordination and two sites that received water from impoundment releases had similar scores on the second axis. Most sites on land owned by The Nature Conservancy, which are spatially close to one another, are similar compositionally. The greasewood flat and Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland (Great Basin shrubland) sites, only one of each class, are not as distinct from all other sites as one of the playa-like sites.

We removed several sites that were clearly distinct from other sites in the basin and range ecoregion, including all the impoundments and the greasewood flat, Great Basin shrubland, and playa Ecological System sites (since there was only one site of each type). We also removed a *Salicornia rubra* flat with only two recorded species and a site composed entirely of *Phragmites australis* because the very low number of species makes it difficult to compare composition. Eight species were found at eight or more of the remaining fifteen sites, including *Distichlis spicata* (n=14), *Hordeum jubatum* ([foxtail barley], n=13), *Polypogon monspeliensis* ([annual rabbitsfoot grass], n=10), *Atriplex micrantha* ([twoscale saltbush], n=9), *Polygonum ramossimum* ([bushy knotweed], n=9), *Lepidium latifolium* (n=8), *Phragmites australis* (n=8), and *Spergularia maritima* ([media sandspurry], n=8). Two sites had only two or three of these species and the remaining sites had between four and eight species. The excluded sites had a median of only one of these dominant species though one impounded site shared five species. The NMDS two-axis solution for the group of fifteen sites had a stress value of 0.19. Composition was still correlated with the second axis of the climate PCA ($p=0.01$), water regime ($p=0.04$), and Level IV ecoregion (0.04), but not with HGM class or Ecological System. Composition was also correlated with total stress ($p=0.02$), buffer plus AA stress ($p=0.003$), AA stress ($p=0.002$), and physical structure categorical URAP scores ($p=0.01$). Sites with more stress (based on any of the stress indices) had more

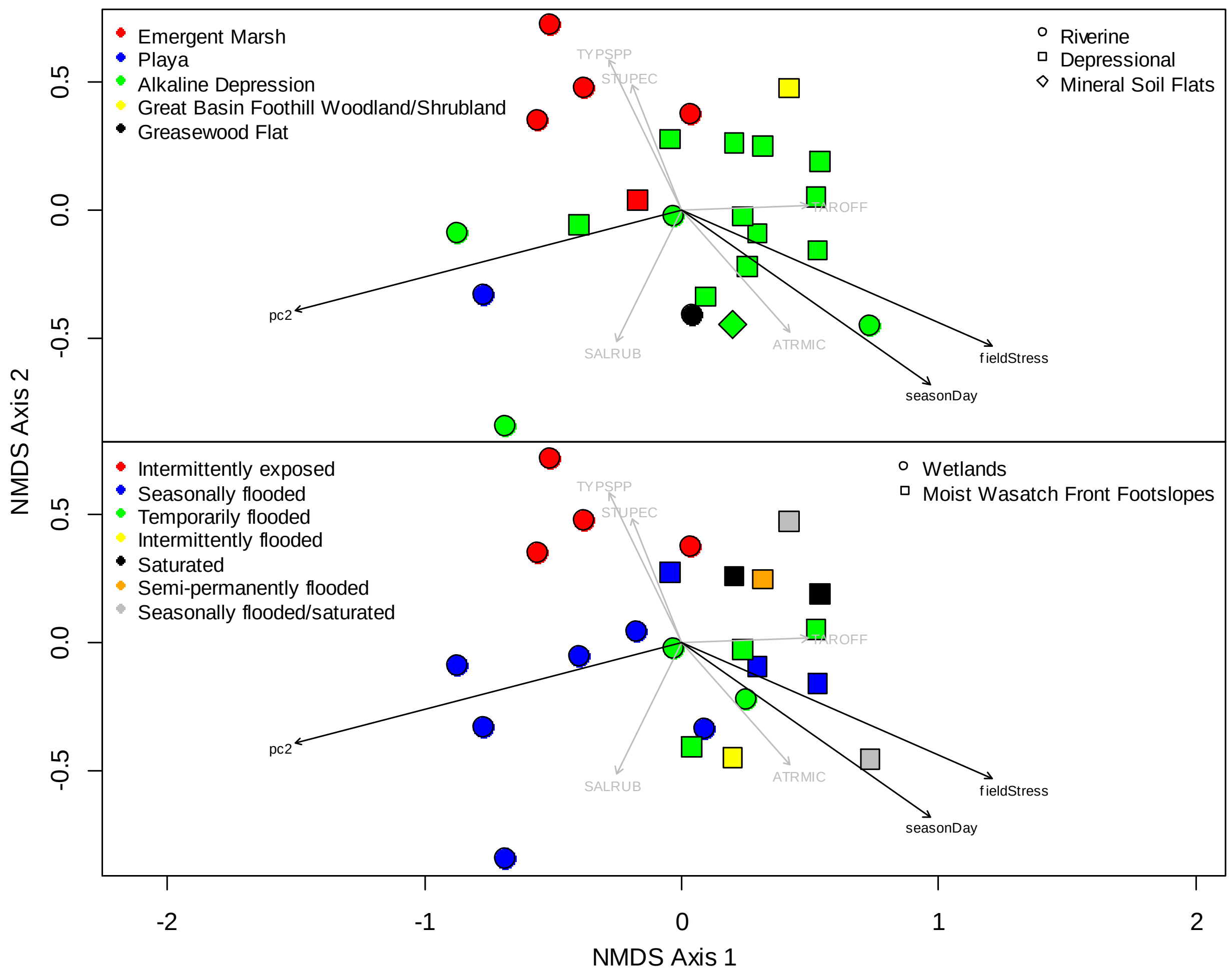

Figure 12. Plant community composition plot of all sites surveyed in the basin and range ecoregion. In the top plot, sites are color coded by Ecological System and symbolized based on HGM class. In the bottom plot, sites are color coded by Cowardin water regime and symbolized based on Level IV ecoregion. Vectors show direction and strength of correlation with plant species ($p<0.05$) and with three environmental variables: the second axis of a climate and elevation principle components analysis (pc2), day of the season (seasonDay), and an index of site and buffer field stress (fieldStress). Species include *Taraxacum officinale* (TAROFF), Atriplex micrantha (ATRMIC), Salicornia rubra (SALRUB), Typha spp. (TYPSPP), and Stuckenia pectinata (STUPEC).

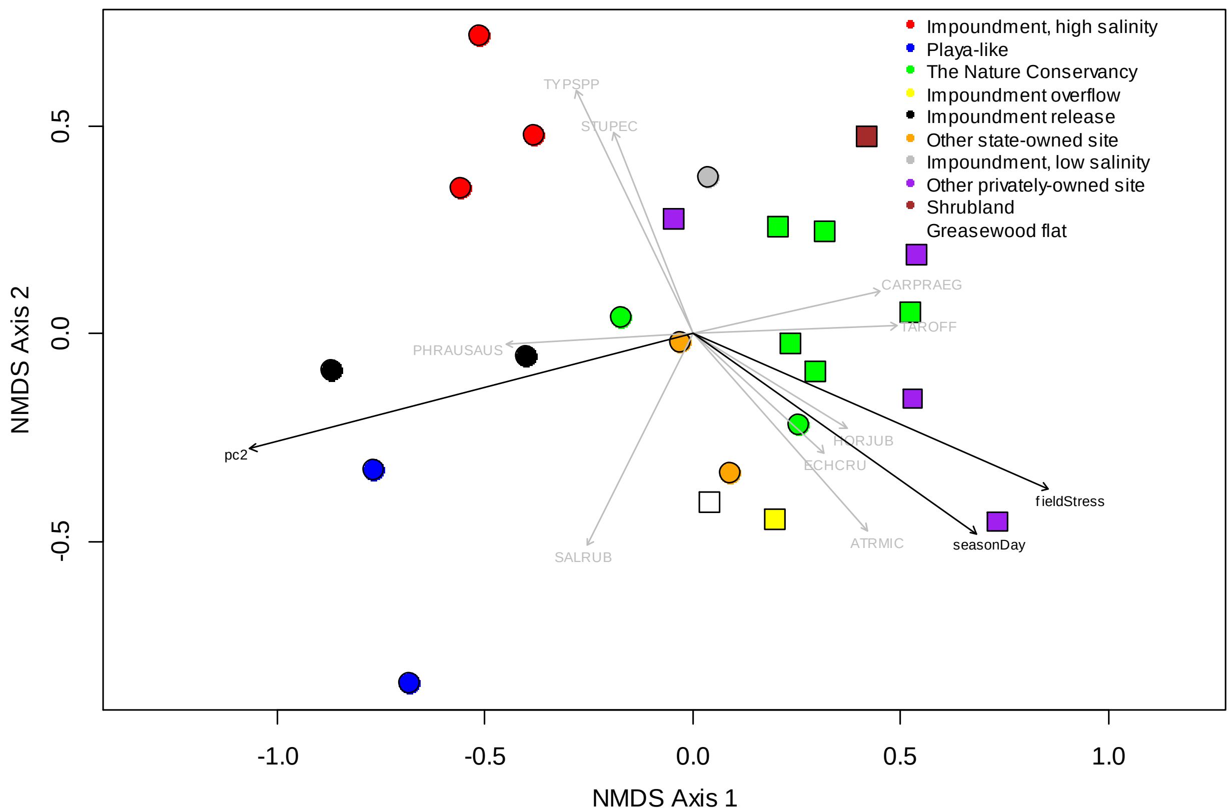

Figure 13. Plant community composition plot of all sites surveyed in the basin and range ecoregion, color coded by subjective grouping factors. Vectors show direction and strength of correlation with plant species (p<0.10) and with quantitative environmental variables (p<0.10). All impoundment sites and the shrubland site were state-owned. Other sites, if not otherwise stated, were privately owned. Species include Carex praegracilis (CARPRAEG), Taraxacum officinale (TAROFF), Hordeum jubatum (HORJUB), Echinochloa crus-galli (ECHCRU), *Atriplex micrantha* (ATRMIC), *Salicornia rubra* (SALRUB), *Phragmites australis* ssp. *australis* (PHRAUSAUS), *Typha* spp. (TYPSPP), and *Stuckenia pectinata* (STUPEC). Environmental variables include buffer stress (bufferStress), day of the season (seasonDay), and assessment area stress (aaStress).

cover of the non-native species *Echinochloa crus-galli* and *Atriplex micrantha* and lower physical structure scores (figure 14).

5.5 Multi-Metric Index Development

Of the 17 mid-elevation montane sites, four were categorized as reference (least disturbed) and four as most disturbed based on thresholds in the stressor indices. Both the least and most disturbed sites included two each in the slope and riverine HGM class. Most selected sites had 3% or less water cover, though one most disturbed and two least disturbed sites had 25% or more water cover. Three of the four least disturbed sites were classified as upper montane shrubland and all of the remaining sites were classified as wet meadow. The least disturbed sites all had standard size AAs while the highly

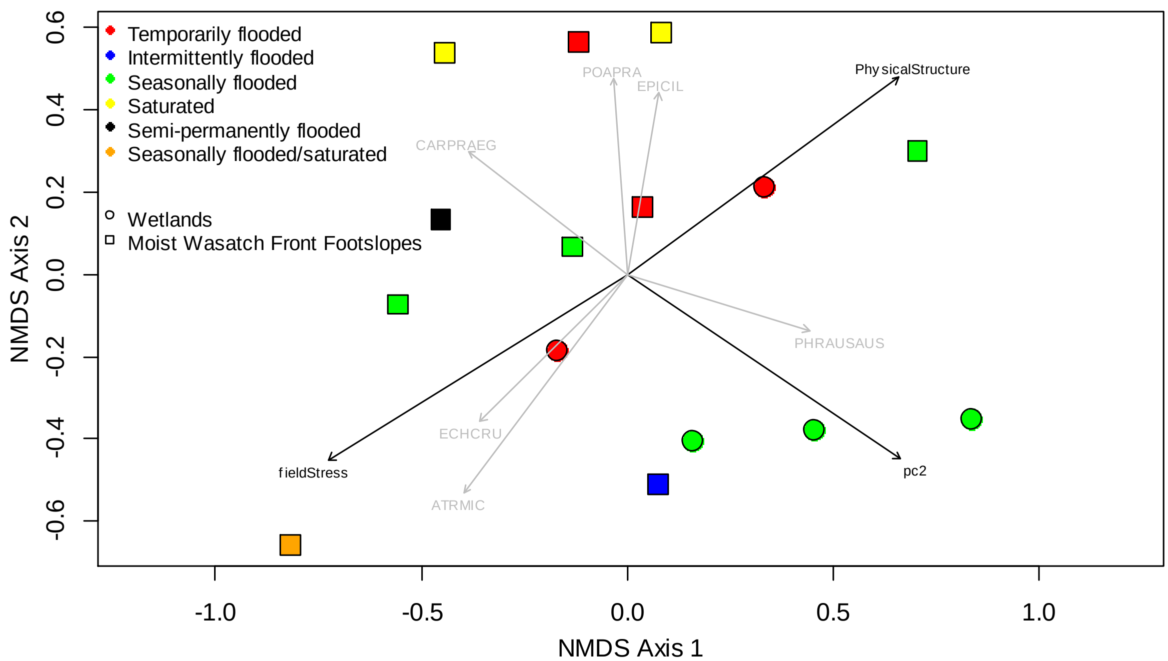

Figure 14. Plant community composition plot of select sites surveyed in the basin and range ecoregion, color coded by water regime and symbolized by Level IV ecoregion. Vectors show direction and strength of correlation with plant species ($p<0.07$) and with three environmental variables including the second axis of a climate and elevation principle components analysis (pc2), an index of site and buffer field stress (fieldStress), and URAP category score in the Physical Structure category (PhysicalStructure). Species include Atriplex micrantha (ATRMIC), Echinochloa crus-galli (ECHCRU), Carex praegracilis (CARPRAEG), Poa pratensis (POAPRA), Epilobium ciliatum (EPICIL), and Phragmites australis ssp. australis (PHRAUSAUS).

disturbed sites had AAs between 0.12 and 0.21 ha. The least disturbed group consisted of two sites each in the mid-elevation Uinta and montane zone Level IV ecoregions and the most disturbed group had one sites in the Wasatch montane zone, one in the semiarid foothills, and two in the mid-elevation Uinta Mountains.

Least disturbed sites had higher physical structure and overall URAP scores ($p\leq0.03$) and a trend towards higher vegetation composition and hydrologic scores ($0.09>p>0.05$) than sites in the most disturbed group (figure 15). The mean vegetation structure score was higher for reference sites and the mean landscape score was slightly higher for disturbed sites, though the differences were slight and not significant.

Over 60% of the FQA metrics shown in table 6 and 70% of metrics based on the relative number of species in defined C-value groups differed between reference and highly disturbed sites (figure 16). In contrast, none of the metrics related to species duration and 30% or fewer of the metrics based on raw and relative cover of species within defined C-value groups differed between disturbance groups. Reference sites always showed healthier composition (e.g., more native species, higher proportion of high C-value species, lower proportion of low C-value species, etc.) compared to highly disturbed sites.

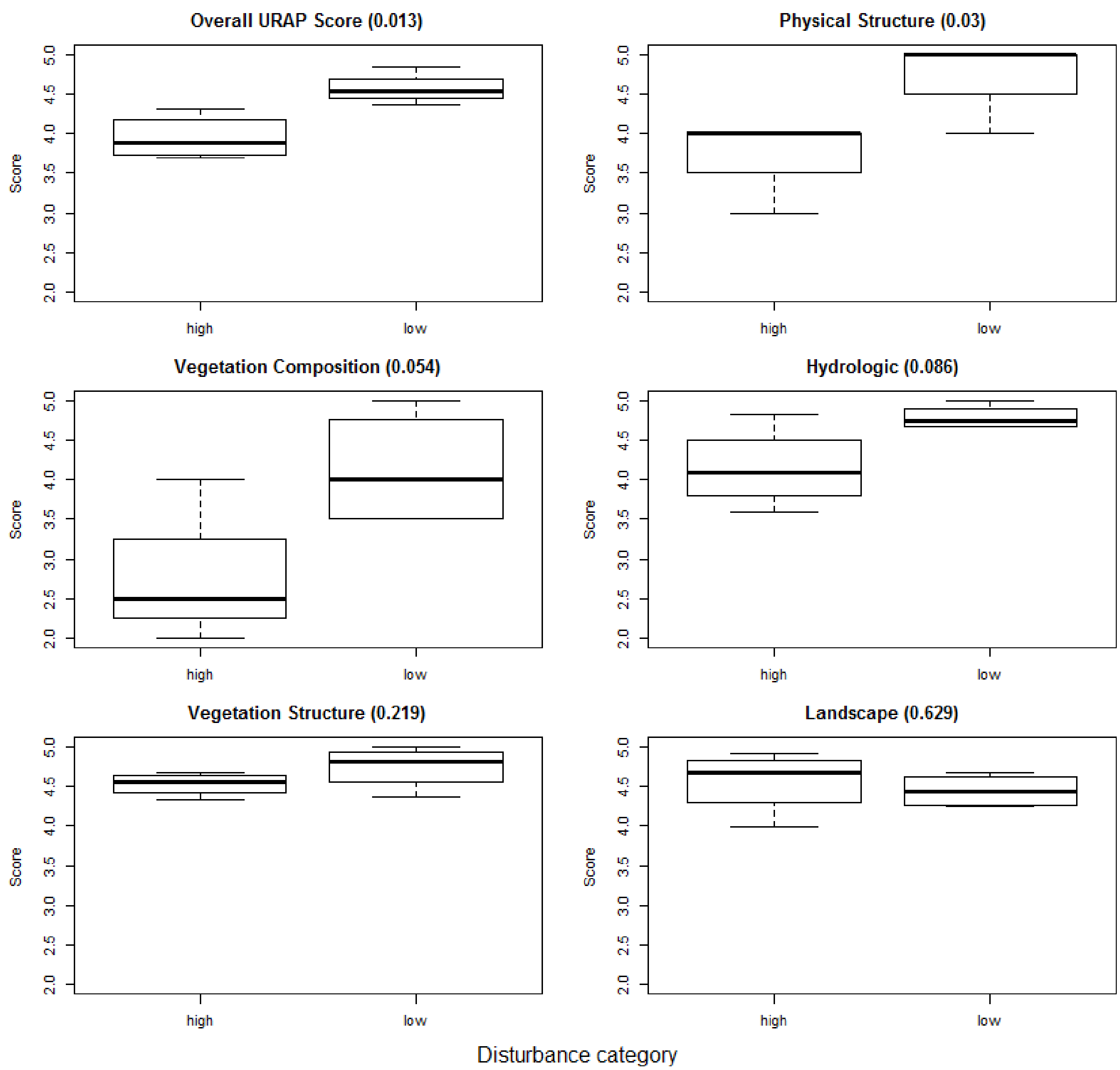

Figure 15. Boxplots showing overall and categorical URAP values for highly disturbed ("high") and least disturbed reference standard ("low") mid-elevation montane sites (n=4 for each category). P-values for t-tests between site types shown in parenthesis following name of each plot. The y-axis is held constant for all plots to show the scale of difference between all measures.

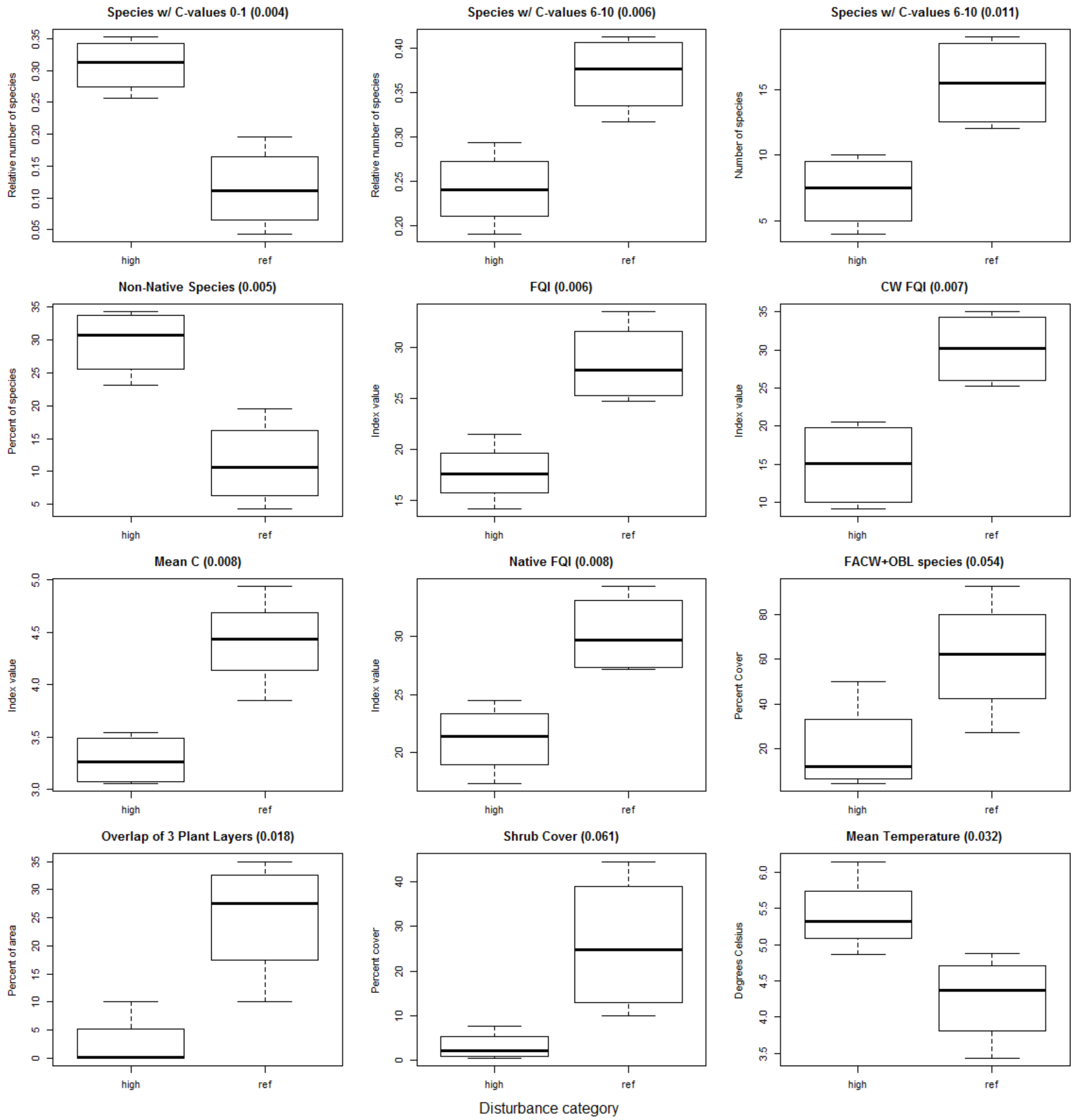

Figure 16. Boxplots showing site attribute values for highly disturbed ("high") and least disturbed reference standard ("ref") sites. P-values for t-tests between site types shown in parenthesis following attribute names. Attributes shown include the three C-value groups and five FQA metrics with the lowest p-values as well the only wetland indicator rating, structural characteristic, vegetation composition, and climatic variable with p<0.10.

Four variables not related to unambiguous measures of health had p-values less than 0.10. Reference sites had lower mean temperatures (p=0.03), higher cover of facultative wetland and obligate species (p=0.05), higher shrub cover (p=0.06) and higher amount of area with an overlap of three plant layers (p=0.02) than highly disturbed sites (figure 16). The slight difference in mean temperature suggests that high disturbance sites were in a somewhat different climate regime than least disturbed sites, though differences in elevation, precipitation, and minimum and maximum temperatures were not significant. The degree to which differences in the other variables are due to intrinsic or extrinsic factors is unclear. The four reference sites may have more woody cover and more overlap between plant layers because they are naturally a different Ecological System type than the disturbed sites or they may have these characteristics in response to disturbances such as overgrazing which may have artificially reduced shrub cover at the highly disturbed sites. The four reference sites were all rated as A for the woody regeneration metric whereas two disturbed sites were rated as B and NA. Similarly, reference sites may naturally be wetter than disturbed sites by chance or may have more wetland-associated species due to hydrologic alterations or other disturbances causing conversion of species at the disturbed sites. Interestingly, none of the structural characteristic variables related to the cover of water differed between reference and disturbed sites based on t-tests, though total water cover (Pearson's r=0.56, p=0.03) and shallow water cover (Pearson's r=0.56, p=0.02) are correlated with number of facultative wetland and obligate species across all eighteen mid-elevation montane sites (Pearson's r=0.82, p= 0.01).

The best performing vegetation multi-metric indices all contained the metric related to vegetation layer overlap. However, the degree to which the differences in this metric were driven by natural factors (i.e., Ecological System) versus disturbance differences (i.e., grazing pressure) is unclear; therefore the variable was excluded from the final index. The top remaining index was composed of three variables—the percent of all species that were native, the number of species with C-values from 8 to 10, and the percent of species with C-values between 6 and 10. The final index reliably separated reference and high disturbance sites better than any individual variable (p=0.001, figure 17).

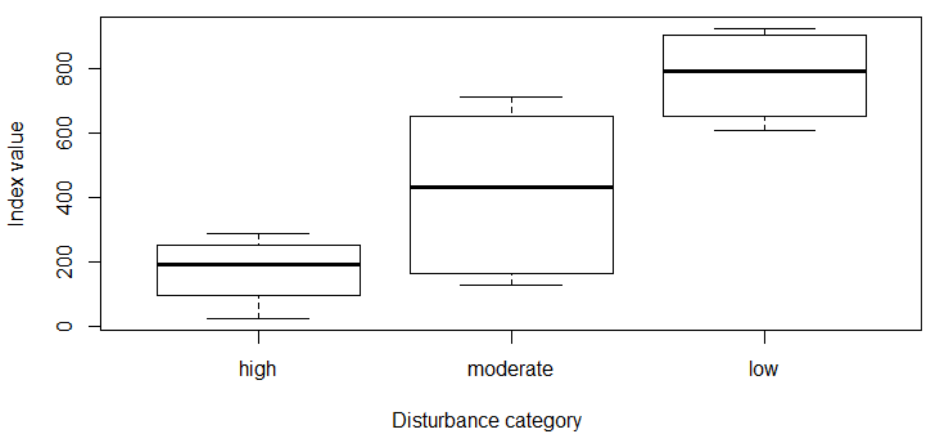

Figure 17. Boxplots showing multi-metric index values for mid-elevation montane sites with high, moderate, and low levels of disturbance. High and low disturbance sites were used to develop the multi-metric index.

The four reference sites had index values of 609 or above and the four highly disturbed sites had index values of 290 or below. A total of seven sites had index values of 609 or above and 290 or below. The seven lowest and seven highest scoring sites were similarly divided between ecoregions, HGM classes, and water regimes, but had different representation of Ecological Systems. About 57% of high multi-metric index sites were upper montane shrubland versus only 29% of low scoring sites.

We examined the degree to which multi-metric index scores were correlated with other measures of wetland stress. Scores were correlated with stress indices for the overall buffer (Pearson's r=-0.63, p<0.01), total AA and buffer (r=-0.57, p=<0.01), total vegetation (r=-0.63, p=<0.01), total water quality (r=-0.59, p=0.01), and total hydrologic (r=-0.51, p=0.04), but not with overall AA stress (p=0.07). Multi-metric index scores were not correlated with landscape stress model scores (p=0.89), but was correlated with hydrologic (r=0.58, p=0.01) and vegetation composition (r=0.56, p=0.02) category scores and overall URAP scores (r=0.56, p=0.02).

5.6 Relationship Among Measures of Condition

5.6.1 Landscape Scores

Landscape category scores were hypothesized to most strongly correlate with overall buffer stress, landscape stress model, and FQA scores. Both overall buffer stress and the landscape stress model directly capture stressor information in the vicinity of the area evaluated by the landscape scores. We also assumed that the surrounding landscape would have a large effect on plant community composition through the introduction of non-native species.

Landscape scores were not correlated with any of the hypothesized values in the mid-montane elevation sites, but were correlated with landscape stress model scores in each ecoregion group, with buffer overall scores in the basin and range, and with FQA metrics in the montane ecoregion sites (table 26). The landscape stress model value had the highest correlations for both ecoregions. Stressor summaries related to hydroperiod and water quality stressors were also frequently correlated with the landscape category scores; buffer hydroperiod stress and total hydroperiod stress were correlated in both ecoregions and some water quality related stressor indices were correlated in the montane ecoregion.

5.6.2 Hydrologic

Hydrologic scores were hypothesized to correlate with AA hydroperiod and water quality stress, buffer hydroperiod, contaminant, sediment stress, office water quality and hydroperiod stress, and total hydroperiod and water quality stress because these stressor variables relate directly to several of the metrics being evaluated in the hydrologic category and indirectly to others. Since the URAP hydrologic category combines both water quality and hydroperiod-related metrics, we also anticipated that these correlations would be the strongest in systems where water quality and hydroperiod stress co-occurred, though we did not directly evaluate this assumption.

Hydrologic scores were at least weakly correlated with three, seven, and five of the nine hypothesized variables in the basin and range ecoregion, montane ecoregion, and mid-elevation montane sites, respectively (table 26). In the mid-elevation montane sites, hydrologic scores were correlated with Mean C and the vegetation multi-metric index in addition to some buffer, office, and total hydroperiod and water quality stressors. Correlations were strongest with office hydroperiod stress

Table 26. Pearson correlation coefficients (p-values) for correlations between URAP overall and categorical scores and summarized stressor data from field and office site evaluations, score from GIS-based landscape integrity model, two Floristic Quality Assessment values (Mean C and CW Mean C), and a vegetation multi-metric index (for the last group of sites only). Bold values indicate $p<0.05$ and grey indicates $p>0.10$; cells shaded in grey were hypothesized to have a significant relationship.

	Landscape	Hydrologic	Physical Structure	Vegetation Structure	Vegetation Composition	Overall Score
Central Basin and Range Level III Ecoregion sites (n=24)						
AA physical stress	-0.01 (0.96)	-0.25 (0.23)	**-0.80 (<0.01)**	-0.11 (0.62)	0.21 (0.33)	-0.36 (0.08)
AA hydroperiod stress	-0.03 (0.87)	-0.1 (0.64)	**-0.71 (<0.01)**	-0.24 (0.26)	0.16 (0.46)	-0.39 (0.06)
AA water quality stress	-0.31 (0.15)	**-0.41 (0.05)**	**-0.55 (0.01)**	-0.36 (0.08)	0.17 (0.44)	**-0.49 (0.01)**
AA vegetation stress	**-0.44 (0.03)**	-0.30 (0.15)	**-0.47 (0.02)**	-0.38 (0.06)	0.25 (0.23)	**-0.46 (0.03)**
AA overall stress	-0.16 (0.47)	-0.26 (0.22)	**-0.79 (<0.01)**	-0.25 (0.23)	0.24 (0.27)	**-0.45 (0.03)**
Buffer hydroperiod stress	**-0.53 (0.01)**	-0.36 (0.09)	-0.06 (0.78)	-0.30 (0.16)	0.21 (0.34)	-0.28 (0.18)
Buffer contaminant stress	-0.03 (0.90)	-0.27 (0.20)	**-0.62 (<0.01)**	-0.07 (0.76)	0.19 (0.38)	-0.28 (0.19)
Buffer sediment stress	-0.17 (0.42)	**-0.51 (0.01)**	**-0.74 (<0.01)**	-0.11 (0.6)	0.08 (0.7)	**-0.47 (0.02)**
Buffer vegetation stress	-0.20 (0.34)	**-0.57 (<0.01)**	-0.35 (0.09)	**-0.60 (<0.01)**	**-0.43 (0.04)**	**-0.78 (<0.01)**
Buffer overall stress	**-0.49 (0.02)**	-0.13 (0.54)	-0.20 (0.35)	**-0.45 (0.03)**	-0.32 (0.13)	**-0.60 (<0.01)**
Overall field (AA + buffer) stress	-0.31 (0.14)	-0.25 (0.25)	**-0.67 (<0.01)**	-0.37 (0.07)	0.05 (0.82)	**-0.58 (<0.01)**
Office hydroperiod stress	-0.12 (0.58)	-0.01 (0.98)	-0.29 (0.17)	-0.11 (0.61)	0.04 (0.87)	-0.20 (0.35)
Office water quality stress	0.07 (0.75)	-0.06 (0.77)	-0.15 (0.47)	-0.09 (0.68)	0.31 (0.14)	0.02 (0.91)
Total (AA+buffer+office) hydroperiod stress	**-0.41 (0.04)**	-0.24 (0.27)	-0.37 (0.08)	-0.30 (0.15)	0.18 (0.41)	-0.38 (0.06)
Total (AA+buffer+office) water quality stress	-0.04 (0.84)	-0.32 (0.13)	**-0.68 (<0.01)**	-0.19 (0.37)	0.35 (0.09)	-0.3 (0.15)
Total (AA+buffer) vegetation stress	-0.36 (0.08)	**-0.56 (<0.01)**	**-0.48 (0.02)**	**-0.62 (<0.01)**	-0.18 (0.41)	**-0.78 (<0.01)**
Landscape stress model value	**-0.66 (<0.01)**	-0.25 (0.23)	-0.29 (0.16)	-0.04 (0.85)	0.01 (0.97)	-0.35 (0.09)
Mean C	0.16 (0.46)	0.35 (0.10)	0.29 (0.16)	**0.43 (0.04)**	**0.52 (0.01)**	**0.65 (<0.01)**
CW Mean C	0.21 (0.33)	0.35 (0.09)	0.18 (0.40)	**0.57 (<0.01)**	**0.67 (<0.01)**	**0.76 (<0.01)**
Wasatch and Uinta Mountains and Wyoming Basin Level III Ecoregion sites (n=48)						
AA physical stress	0.13 (0.39)	-0.21 (0.15)	**-0.68 (<0.01)**	-0.05 (0.75)	-0.22 (0.14)	**-0.33 (0.02)**
AA hydroperiod stress	0.17 (0.26)	-0.20 (0.18)	**-0.76 (<0.01)**	-0.12 (0.41)	-0.10 (0.49)	**-0.32 (0.03)**
AA water quality stress	-0.01 (0.94)	-0.17 (0.25)	**-0.37 (0.01)**	-0.26 (0.07)	**-0.35 (0.02)**	**-0.37 (0.01)**
AA vegetation stress	-0.10 (0.48)	**-0.38 (0.01)**	**-0.35 (0.02)**	**-0.38 (0.01)**	**-0.46 (<0.01)**	**-0.51 (<0.01)**
AA overall stress	0.04 (0.80)	**-0.37 (0.01)**	**-0.70 (<0.01)**	-0.28 (0.05)	**-0.39 (0.01)**	**-0.52 (<0.01)**
Buffer hydroperiod stress	**-0.35 (0.02)**	**-0.64 (<0.01)**	-0.26 (0.07)	-0.07 (0.62)	**-0.48 (<0.01)**	**-0.54 (<0.01)**
Buffer contaminant stress	0.03 (0.86)	**-0.29 (0.05)**	-0.23 (0.11)	-0.17 (0.24)	-0.19 (0.18)	-0.25 (0.08)
Buffer sediment stress	0.03 (0.83)	**-0.28 (0.05)**	**-0.38 (0.01)**	0.04 (0.79)	-0.25 (0.09)	-0.26 (0.07)
Buffer vegetation stress	-0.04 (0.79)	-0.27 (0.06)	-0.21 (0.15)	**-0.33 (0.02)**	**-0.42 (<0.01)**	**-0.39 (0.01)**
Buffer overall stress	-0.13 (0.37)	**-0.38 (0.01)**	**-0.30 (0.04)**	-0.14 (0.34)	**-0.43 (<0.01)**	**-0.43 (<0.01)**
Overall field (AA + buffer) stress	-0.03 (0.82)	**-0.42 (<0.01)**	**-0.61 (<0.01)**	-0.26 (0.08)	**-0.46 (<0.01)**	**-0.56 (<0.01)**
Office hydroperiod stress	**-0.54 (<0.01)**	**-0.54 (<0.01)**	0.02 (0.88)	0.04 (0.81)	-0.13 (0.38)	**-0.32 (0.03)**
Office water quality stress	**-0.62 (<0.01)**	**-0.39 (0.01)**	0.17 (0.26)	-0.23 (0.12)	**-0.32 (0.03)**	**-0.40 (<0.01)**
Total (AA+buffer+office) hydroperiod stress	**-0.52 (<0.01)**	**-0.72 (<0.01)**	-0.21 (0.15)	-0.03 (0.84)	**-0.35 (0.01)**	**-0.53 (<0.01)**
Total (AA+buffer+office) water quality stress	**-0.32 (0.03)**	**-0.44 (<0.01)**	**-0.30 (0.04)**	-0.25 (0.09)	**-0.43 (<0.01)**	**-0.52 (<0.01)**
Total (AA+buffer) vegetation stress	-0.08 (0.60)	**-0.36 (0.01)**	**-0.31 (0.03)**	**-0.40 (<0.01)**	**-0.50 (<0.01)**	**-0.50 (<0.01)**
Landscape stress model value	**-0.76 (<0.01)**	**-0.49 (<0.01)**	0.09 (0.54)	0.04 (0.78)	**-0.36 (0.01)**	**-0.43 (<0.01)**
Mean C	**0.60 (<0.01)**	**0.69 (<0.01)**	**0.35 (0.01)**	0.16 (0.29)	**0.73 (<0.01)**	**0.77 (<0.01)**
CW Mean C	**0.36 (0.01)**	**0.60 (<0.01)**	**0.36 (0.01)**	**0.33 (0.02)**	**0.82 (<0.01)**	**0.77 (<0.01)**
Mid-Elevation Montane Shrubland/Meadow sites (n=17)						
AA physical stress	0.05 (0.84)	-0.32 (0.2)	**-0.69 (<0.01)**	-0.07 (0.79)	-0.42 (0.09)	**-0.57 (0.02)**
AA hydroperiod stress	-0.23 (0.38)	0.16 (0.54)	-0.40 (0.11)	0.15 (0.58)	-0.14 (0.59)	-0.22 (0.39)
AA water quality stress	0.39 (0.12)	-0.42 (0.09)	**-0.56 (0.02)**	-0.18 (0.49)	-0.39 (0.12)	-0.47 (0.06)
AA vegetation stress	0.39 (0.12)	-0.44 (0.08)	**-0.56 (0.02)**	-0.18 (0.48)	-0.38 (0.13)	-0.47 (0.06)
AA overall stress	0.20 (0.45)	-0.38 (0.14)	**-0.76 (<0.01)**	-0.11 (0.69)	-0.46 (0.06)	**-0.61 (0.01)**
Buffer hydroperiod stress	-0.22 (0.39)	-0.38 (0.14)	-0.05 (0.86)	0.01 (0.97)	-0.14 (0.58)	-0.24 (0.36)
Buffer contaminant stress	**0.58 (0.01)**	-0.23 (0.38)	-0.22 (0.39)	-0.23 (0.38)	-0.23 (0.38)	-0.16 (0.54)
Buffer sediment stress	0.28 (0.28)	**-0.53 (0.03)**	-0.43 (0.08)	0.10 (0.70)	**-0.51 (0.04)**	**-0.48 (0.05)**
Buffer vegetation stress	0.18 (0.50)	-0.35 (0.17)	-0.38 (0.13)	-0.16 (0.54)	**-0.57 (0.02)**	**-0.52 (0.03)**
Buffer overall stress	0.28 (0.28)	-0.25 (0.34)	-0.25 (0.32)	-0.06 (0.83)	**-0.58 (0.02)**	-0.41 (0.11)
Overall field (AA + buffer) stress	0.25 (0.33)	-0.36 (0.15)	**-0.64 (0.01)**	-0.1 (0.71)	**-0.56 (0.02)**	**-0.59 (0.01)**
Office hydroperiod stress	-0.09 (0.74)	**-0.82 (0)**	**-0.53 (0.03)**	-0.24 (0.35)	-0.21 (0.43)	**-0.58 (0.01)**
Office water quality stress	-0.26 (0.32)	-0.02 (0.95)	-0.04 (0.89)	-0.34 (0.18)	0.03 (0.91)	-0.12 (0.64)
Total (AA+buffer+office) hydroperiod stress	-0.21 (0.41)	**-0.64 (0.01)**	-0.32 (0.21)	-0.1 (0.71)	-0.21 (0.42)	-0.46 (0.06)
Total (AA+buffer+office) water quality stress	0.32 (0.21)	-0.44 (0.07)	**-0.58 (0.01)**	-0.22 (0.4)	-0.44 (0.08)	**-0.53 (0.03)**
Total (AA+buffer) vegetation stress	0.29 (0.26)	-0.41 (0.1)	**-0.48 (0.05)**	-0.18 (0.49)	**-0.50 (0.04)**	**-0.52 (0.03)**
Landscape stress model value	-0.38 (0.13)	-0.19 (0.46)	0.29 (0.27)	-0.29 (0.26)	0.26 (0.32)	0.06 (0.82)
Mean C	-0.01 (0.98)	**0.55 (0.02)**	0.34 (0.19)	0.04 (0.88)	**0.70 (<0.01)**	**0.64 (0.01)**
CW Mean C	-0.13 (0.61)	0.23 (0.37)	**0.51 (0.04)**	0.12 (0.63)	**0.80 (<0.01)**	**0.67 (<0.01)**
Vegetation Multi-Metric Index value	0.02 (0.95)	**0.58 (0.01)**	0.32 (0.21)	-0.05 (0.86)	**0.56 (0.02)**	**0.56 (0.02)**

and then with total hydroperiod stress. In the basin and range ecoregion, hydrologic scores were correlated with buffer and total vegetation stress in addition to the hypothesized variables. In the montane ecoregion, hydrologic scores were correlated with 16 of 20 possible variables, though not with AA hydroperiod or AA water quality stress. The strongest correlations were with total hydroperiod stress, followed by buffer stress, Mean C, and CW Mean C (Pearson's r<-0.60 for all variables). Hydroperiod stressors had stronger correlations with the hydrologic scores than water quality-related stressors for the montane ecoregion sites.

5.6.3 Physical Structure

We hypothesized that physical structure scores would strongly correlate with AA physical, hydroperiod, and water quality stressors and with FQA metrics. The physical stressor value is directly related to the AA attribute being evaluated in the category, and most hydroperiod and water quality structure disturbances within the AA were related to physical disturbance. We also anticipated that physical disturbance within the AA would modify the plant community and be correlated with heath of plant communities.

As hypothesized, physical structure was strongly correlated with physical, hydroperiod, and water quality stressors for all three groups of sites, except for hydroperiod stress for the mid-elevation montane sites. AA physical stress and AA overall stress were among the top three strongest correlations for all three groups (r≤-0.68 for both variables in all groups). The physical structure score was only correlated with Mean C in montane ecoregion sites and with CW Mean C in montane ecoregion and mid-elevation montane sites. Many other variables were correlated with physical structure scores including AA vegetation stress, overall AA plus buffer stress, total vegetation stress, and total water quality stress at all three groups of sites. Office hydroperiod and water quality stress and landscape stress model scores were not correlated with the physical structure score, except for office hydroperiod stress at the mid-elevation sites.

5.6.4 Vegetation Structure

Vegetation structure categorical scores were hypothesized to weakly correlate with AA vegetation stress, buffer vegetation stress, total vegetation stress, and with FQA metrics. We expected correlations to be weak because we assumed that many alterations to vegetation structure metrics (i.e., woody species regeneration, woody debris and litter accumulation, horizontal interspersion) would occur from long-term processes that would not easily be captured in our surveys. We expected the largest correlations in the basin and range ecoregion where non-native cover of *Phragmites australis* in the buffer (a vegetation stressor) was likely to be related to high *Phragmites australis* cover and associated litter accumulation in the AA.

Vegetation structure was not correlated with any variables in the mid-elevation montane sites, but was correlated with all five of the hypothesized variables in the two ecoregion groups, except for Mean C in the montane sites and AA vegetation stress in the basin and range sites (table 26). The strongest correlation in both groups was with total vegetation stress.

5.6.5 Vegetation Composition

Vegetation composition was hypothesized to strongly correlate with AA vegetation stress, buffer vegetation stress, total vegetation stress, and FQA metrics because the stressors directly affect vegetation and FQA metrics are calculated directly from vegetation composition data. Composition was correlated with all of the five hypothesized variables in the montane ecoregion, with all but AA vegetation stress in the mid-elevation montane group, and with only buffer vegetation stress and FQA metrics in the basin and range ecoregion. CW Mean C and Mean C had the highest correlations in all three groups ($r \geq 0.52$). Most tested variables in the montane ecoregion were correlated with vegetation composition.

5.6.6 Overall Score

Overall scores were hypothesized to strongly correlate with AA overall scores, buffer overall scores, and overall AA plus buffer stress because these variables all summarize overall stress to the site. We also hypothesized that overall scores would correlate with landscape stress model scores and with FQA metric values.

All six hypothesized variables were correlated with overall scores in all groups except for buffer overall stress in the mid-elevation montane sites and the landscape model score in the basin and range and mid-elevation montane sites. Over half of the variables in all groups, and almost 90% of the variables in the montane ecoregion group, were correlated with overall scores. In the basin and range, the strongest correlations were with total vegetation stress and buffer vegetation stress ($r=-0.78$ for both), followed by CW Mean C, which suggests the outsized effect of non-native *Phragmites australis* on overall site scores. In the other two groups, the strongest correlations were with the two FQA metrics ($r \geq 0.64$ for all variables).

5.6.7 Landscape Model Values

The strongest correlation between landscape stress model values and any URAP score was in the landscape category score; the landscape integrity value was the strongest correlation of any examined variables for this category for the two ecoregion groups ($r=-0.66$, $p<0.01$ for basin and range, $r=-0.76$, $p<0.01$ for montane). The model was weakly correlated with overall score in the basin and range ($r=-0.35$, $p=0.09$) and significantly correlated with overall score in the montane ecoregion ($r=-0.43$, $p<0.01$). The model was correlated with hydrologic and vegetation composition scores in the montane ecoregion, but not with physical structure or vegetation structure, which had very low Pearson correlation coefficient values ($0.03<r<0.10$). Similarly, the model had very weak correlations with vegetation structure and vegetation composition in the basin and range ecoregion ($0.02<r<-0.05$).

5.7 Results of Watershed-wide Landscape Analysis

5.7.1 Landscape Stress by Wetland Type

Mean landscape stress model scores assigned to individual polygons differed between strata, based on an ANOVA analysis ($p<0.01$). Post-hoc Tukey comparisons showed that all strata differed from one another except for Montane Zone versus Uintas strata and Wetlands versus Foothills strata. Footslopes and Valleys both had approximately 50% of wetland area in the highest landscape stress category, though Footslopes had more low stress wetland area than Valleys (table 27). Approximately 25% of Foothills wetland area was in the high stress category; all other strata had less than 5% of wetland area in the high stress category. Montane Zone sites had the most area in the low stress category, followed by sites in the Uintas, and then Foothills and Wetlands sites.

Strata exhibited strong differences in the amount and relative landscape stress level of each wetland type, based on the landscape analysis (figure 18). No woody wetlands or saturated wetlands are in the Wetlands. Most wetlands in the stratum were identified as riparian, though much of the wetland area is actually impounded with canals running through them. Wetlands in the strata were almost

Table 27. Percent of wetland area in each landscape stress category (obtained from entire sample frame) and estimated amount of area with grazing within sites and site buffers, for all grazing and moderate to heavy grazing only. Grazing estimates include any amount of grazed area, even for a very small proportion of AA or buffer.

Stratum	Landscape Stress Model Category			Percent of Area with Stressor			
	Low	Moderate	High	AA grazing, total	AA grazing, mod+	Buffer grazing, total	Buffer grazing, mod+
Wetlands	41.1%	54.6%	4.3%	18.8%	9.2%	48.0%	20.9%
Footslopes	6.6%	39.7%	53.7%	79.2%	66.7%	84.2%	58.3%
Valleys	0.6%	52.2%	47.3%	25.8%	25.8%	37.1%	27.1%
Foothills	36.4%	38.9%	24.7%	58.4%	45.4%	64.6%	18.8%
Montane Zone	87.5%	12.4%	0.1%	44.2%	13.3%	70.4%	16.7%
Uintas	61.7%	36.6%	1.7%	27.1%	25.0%	35.4%	16.7%

evenly split between the low and moderate landscape stress categories, relatively little area was mapped as severe. Wetlands in the Footslopes are predominantly mapped as temporarily or seasonally flooded emergent wetlands. A low proportion of wetlands were in the low stress category, and almost all woody and aquatic bed wetlands were categorized as severe stress.

In the montane ecoregion, most wetland types were not overly dominated by a single stress category, though saturated wetlands and semi-permanently flooded wetlands were predominantly low stress. Very little wetland area in the Valleys was modeled as having low landscape stress. Most wetlands in this stratum were emergent seasonally flooded wetlands. Almost all wetlands in the Foothills were associated with riparian areas. Seasonally flooded emergent wetlands were most abundant, but temporarily and seasonally flooded woody wetlands, temporarily flooded emergent wetlands, and aquatic beds were present as well. Almost all Montane Zone wetlands were in the low stress category and only the aquatic bed wetlands had any area categorized as severe stress. Most wetland area in the Montane Zone was aquatic bed, followed by saturated emergent and then seasonally flooded woody and emergent wetlands. Wetlands in the Uintas were of moderate or low severity landscape stress with a small proportion of wetland area in the severe landscape class. Aquatic bed, seasonally flooded woody wetlands, and seasonally flooded and saturated emergent wetlands were most common. Most woody wetlands were associated with riparian area, and most saturated emergent, semi-permanently flooded emergent, and aquatic bed wetlands were not riparian.

5.7.2 Land Ownership and Wetland Stress

Approximately 45% of wetland area in the Weber River watershed is privately owned outside the bounds of identified private management areas and CWMUs; the Valleys and Footslopes had the highest proportion of area in private ownership, 78% and 97% of area, respectively (table 28). A high proportion of wetland area in the Wetlands is in state wildlife areas or other state land, whereas these two categories never account for more than 2% of wetland area in any other strata. Wetlands in the Foothills and Montane Zone are predominantly divided between CWMUs and other private land ownership. In the Uintas, CWMUs are second only to Wasatch-Cache National Forest ownership.

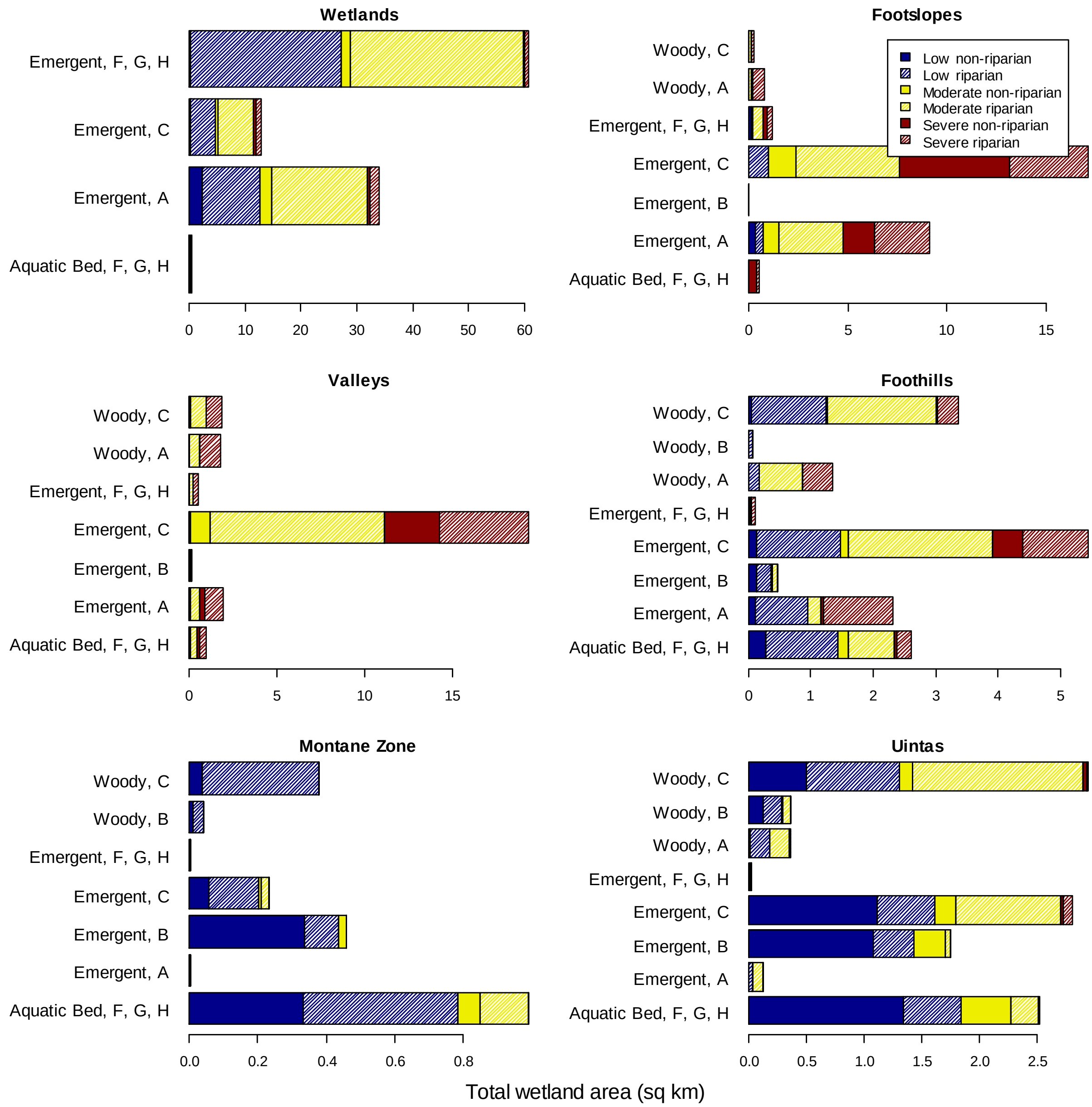

Figure 18. Palustrine wetland area by landscape stress class (low, moderate, or severe) and wetland type and water regime for each strata.

The highest proportion of land in the severe landscape category was almost always found in the non-managed private land ownership class (figure 19). Privately owned land may frequently be embedded in a fragmented landscape; by way of comparison, landowners must have at least 5000 contiguous acres of land to be enrolled in the CWMU program (http://wildlife.utah.gov/about-the-cwmu-program.html). The Montane Zone and Uintas have the highest proportion of wetland area in the

Table 28. Percent of wetland area in each ownership class, by strata.

Ownership Type	Wetlands	Footslopes	Valleys	Foothills	Montane Zone	Uintas	Total
State wildlife area	50.4%	0.7%	0.9%	1.1%	1.2%	0.8%	**28.7%**
Other state land	17.5%	1.7%	0.5%	0.8%	0.0%	0.0%	**10.3%**
Wasatch-Cache N.F.	0.0%	0.0%	0.0%	2.4%	5.2%	41.0%	**2.6%**
Other federal land	0.0%	0.0%	1.3%	0.3%	0.0%	0.0%	**0.2%**
Private managed area	7.2%	19.2%	0.0%	0.0%	0.0%	0.0%	**7.0%**
Private CWMU	0.0%	0.0%	0.0%	40.9%	72.5%	35.2%	**6.1%**
Other private land	24.8%	78.2%	97.3%	54.5%	21.1%	23.0%	**45.1%**
Wetland area (km^2)	**108.1**	**29.0**	**26.5**	**15.7**	**2.1**	**10.9**	**192.3**

low landscape stress category, but livestock grazing, not included in the landscape model, was prevalent in the Montane Zone.

5.7.3 Wetlands and Water Quality

Of the 4 reservoirs and 27 stream assessment units with impaired water quality, four had no riparian wetlands mapped within the assessment unit (table 29). Impairments for these included copper at three sites, temperature at two sites, and dissolved oxygen and total phosphorus at one site. Twelve impaired assessment units had 45% or more of their wetland area in the severe landscape stress class, whereas all other assessment units had 26% or less in this class. These units included Pineview, Rockport, and Echo Reservoirs and four units of the Weber River, three units of Chalk Creek and one unit each of Mill Creek and Middle Fork Ogden River. In seven units, over 50% of the wetlands were in the low landscape stress category; four of these units were impaired for copper and the other three for a variety of impairments. The four most common impairments included dissolved oxygen, water temperature, copper, and invertebrate bioassessment. Of these, assessment units impaired for dissolved oxygen had the most wetland area with high landscape stress and the least wetland area with low landscape stress (table 30). Assessment units with copper impairment had relatively low landscape stress whereas assessment units with bioassessment impairments frequently had landscape stress similar to all impaired sites.

6.0 Discussion

6.1 Wetland Condition and Common Wetland Stressors

6.1.1 Target Population and Limitations of Sample Frame

Generalizations about wetland condition and other study findings only pertain to the target population, palustrine vegetated wetlands. Accordingly, we cannot make inference about playas and emergent marshes (particularly those composed of aquatic bed) because these Ecological Systems were largely excluded from the sample frame. Furthermore, wetlands mapped by the National Wetland Inventory, from which our sample frame was composed, often did not meet the strict U.S. Army Corps of Engineers definition of wetland, though all sites had at least one of the three wetland indicators and evidence of at least historical wetland hydrology. We recommend continuing to maintain an inclusive target population because this is the simplest approach given the constraints of the existing mapped

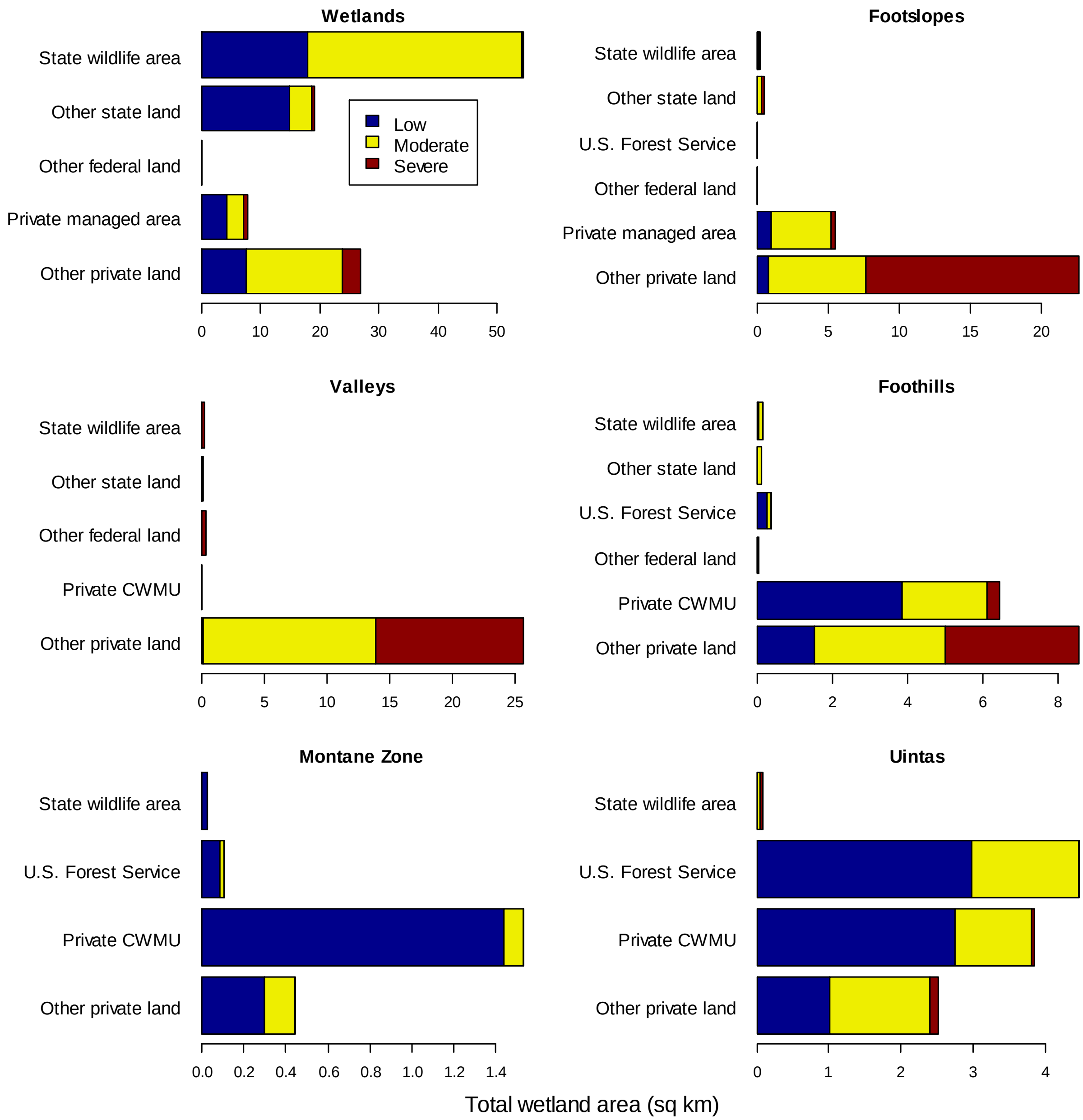

Figure 19. Wetland area by ownership class and landscape stress class (low, moderate, or severe), by strata. “State wildlife area” includes waterfowl management areas and “other state land” includes land parks and recreation, state sovereign land, and state trust land. “Other federal land” includes Bureau of Land Management and Bureau of Reclamation land. “Private managed areas” include privately owned duck clubs, Great Salt Lake Shorelands Preserve, and Legacy Nature Preserve.

wetland data and doing so is much more field efficient than conducting a rigorous Army Corps delineation.

Despite using a more relaxed wetland definition, we found that 10% of the sample frame was non-target population, including almost half of the wetland area in the Montane Zone. Wetlands that

Table 29. Percent of riparian wetland area in each landscape stress class per water quality assessment unit, for those assessment units that are listed as category 5, impaired for one or more designated uses. See text of report for description on riparian designation, which should be considered only an approximation. Assessment data is from the draft 2014 integrated report and should not be considered final.

Assessment Unit Name	Assessment ID	Cause of Impairment	% Area in Each Landscape Class			Wetland area (m^2)	Wetland Area Per Assessment United Area (%)
			Low	Mod.	Severe		
Pineview Reservoir	UT-L-16020102-014	Dissolved Oxygen, Total Phosphorus, Water Temperature	0%	44%	56%	1,202,912	9.88%
Rockport Reservoir	UT-L-16020101-002	Dissolved Oxygen, Water Temperature	0%	8%	92%	62,347	1.46%
East Canyon Reservoir	UT-L-16020102-020	Dissolved Oxygen, Total Phosphorus, Water Temperature				0	0.00%
Echo Reservoir	UT-L-16020101-001	Dissolved Oxygen, Total Phosphorus, Water Temperature	0%	0%	100%	94,198	1.74%
Barnard Creek	UT16020102-043	Copper, Dissolved Oxygen	100%	0%	0%	1,535	0.03%
Chalk Creek-1	UT16020101-010	OE Bioassessment	1%	7%	92%	94,578	0.21%
Chalk Creek-2	UT16020101-012	OE Bioassessment	2%	19%	79%	315,612	1.00%
Chalk Creek-3	UT16020101-014	pH	20%	34%	46%	778,016	1.16%
East Canyon Creek-2	UT16020102-026	OE Bioassessment, Temperature, Total Dissolved Solids	14%	86%	0%	3,450,224	1.47%
East Fork Chalk Creek	UT16020101-015	OE Bioassessment, pH	78%	22%	0%	558,042	0.63%
Echo Creek	UT16020101-007	OE Bioassessment, Total Dissolved Solids	26%	71%	3%	2,950,955	0.79%
Farmington Creek-1	UT16020102-039	Copper, E. coli	0%	74%	26%	225,864	5.78%
Farmington Creek-2	UT16020102-038	Copper	91%	9%	0%	143,358	0.53%
Hardscrabble Creek	UT16020102-023	Temperature	55%	38%	6%	292,199	0.32%
Holmes Creek-1	UT16020102-035	Copper, E. coli	0%	90%	10%	137,759	1.03%
Holmes Creek-2	UT16020102-034	Copper				0	0.00%
Kays Creek	UT16020102-031	E. coli	6%	77%	17%	719,257	2.89%
Kays Creek South and Middle Fork	UT16020102-032	Copper				0	0.00%
Kimball Creek	UT16020102-027	Arsenic, OE Bioassessment	0%	85%	15%	742,090	1.28%
Middle Fork Ogden River	UT16020102-009	Dissolved Oxygen	13%	19%	69%	1,330,735	0.85%
Mill Creek-1	UT16020102-050	Copper, Total Dissolved Solids	0%	30%	70%	355,390	3.49%
Mill Creek-2	UT16020102-049	Copper	100%	0%	0%	7,186	0.03%
Parrish Creek	UT16020102-044	Copper	100%	0%	0%	4,567	0.08%
Silver Creek [1]	UT16020101-020	Arsenic, Cadmium, Dissolved Oxygen, Nitrate, OE Bioassessment, pH, Total Dissolved Solids, Zinc	14%	77%	9%	769,271	0.62%
Stone Creek-1	UT16020102-046	Copper, Temperature				0	0.00%
Stone Creek-2	UT16020102-045	Copper	100%	0%	0%	5,464	0.04%
Weber River-1	UT16020102-001	OE Bioassessment, Total Ammonia	40%	55%	4%	34,478,845	19.21%
Weber River-3	UT16020102-002	OE Bioassessment	0%	55%	45%	513,513	4.24%
Weber River-6	UT16020102-022	OE Bioassessment	0%	51%	49%	286,633	5.25%
Weber River-7	UT16020101-004	OE Bioassessment	0%	20%	80%	405,412	6.46%
Weber River-8	UT16020101-017	Dissolved Oxygen	0%	0%	100%	1,050,581	20.86%

[1]Assessment unit listed as categories 4A, 4B, and 5, meaning that site is impaired for multiple pollutants, but some individual pollutants have been addressed through the development of a total daily maximum load plan and others have been addressed through other pollution controls.

Table 30. Median, 25th and 75th percentile of the percent of wetland area in each landscape stress category within water quality assessment unit with the indicated impairment, or all impaired assessment units. Assessment units with no mapped wetlands are not included in the percentile calculations.

Assessment Unit Impairment	Percentile	Landscape Stress Category		
		Low	Moderate	High
Dissolved oxygen (n=11, 1 with no wetlands)	25th	0.0%	2.0%	4.5%
	50th	6.5%	24.5%	62.5%
	75th	14.0%	64.3%	86.5%
Water temperature (n=7, 2 with no wetlands)	25th	0.0%	8.0%	6.0%
	50th	0.0%	38.0%	56.0%
	75th	14.0%	44.0%	92.0%
Copper (n=11, 3 with no wetlands)	25th	0.0%	0.0%	0.0%
	50th	95.5%	4.5%	0.0%
	75th	100.0%	41.0%	14.0%
Invertebrate bioassessment (n=11, 0 with no wetlands)	25th	0.0%	21.0%	3.5%
	50th	2.0%	55.0%	15.0%
	75th	20.0%	74.0%	64.0%
All impaired assessment units (n=31, 4 with no wetlands)	25th	0.0%	7.5%	1.5%
	50th	6.0%	30.0%	17.0%
	75th	47.5%	63.0%	69.5%

were too small, had a temporarily flooded water regime, or were incorrectly mapping produced the most non-target population area, rather than land use conversion or hydrologic modifications removing the wetland from the landscape. Wetland loss from anthropogenic reasons appeared greatest in the Footslopes. While we can estimate the amount of *mapped* palustrine vegetated wetland that is not in fact wetland, we cannot estimate the amount of unmapped or incorrectly classified target wetland that was left out of the sample frame (i.e., there may be more wetland area than estimated in this report). Excluded wetlands may include small or otherwise difficult to detect wetlands, newly created wetlands, and wetlands with fluctuating vegetation cover. If excluded wetlands are similar in characteristic to included wetlands, then target population condition estimates may still be robust. However, a large area of recently exposed mudflat along Great Salt Lake that was mapped as unvegetated lacustrine wetland is now predominantly covered by *Phragmites australis*. Study results likely underestimate the cover of emergent wetlands and of *Phragmites australis* in Great Salt Lake wetlands because this mudflat area was not included in the sample frame. Beaver-modified wetlands may also be under-mapped since beavers move around the landscape and can turn non-wetland riparian areas into mosaics of ponds and wet meadows, though this is likely to have a smaller effect on condition estimates. We support efforts to update wetland maps for Utah and we recommend conducting an accuracy assessment of mapped data for future projects to better estimate the amount of lost wetland area and the amount of unmapped wetland area so that extent estimates can be appropriately adjusted.

Survey results could be skewed by our inability to access a large percent of sites if, for example, owners of poorly managed sites were less likely to grant permission for surveys than owners of better managed sites. However, lack of access usually occurred because we were unable to get in touch with landowners, which is more likely to be a random process than landowner rejection. Results may be skewed towards a particular landowner when that landowner owned several survey sites in a stratum and other landowners in the stratum are not able to be contacted. We recommend starting the landowner contact process earlier in the year and sending letters to problematic landowners to increase landowner participation for future monitoring projects.

6.1.2 Wetland Condition by Strata

The majority of wetland area in the Weber River watershed is estimated to be slightly deviated from reference condition, indicating almost natural functioning. However, it is probably more useful to consider categorical and individual metrics scores than overall scores to understand wetland condition because these are more indicative of the particular characteristics that are healthy or stressed. For example, it is clear that vegetation composition is a greater issue across all sites than the surrounding landscape based on the categorical URAP scores. Furthermore, URAP scoring was calibrated through correlation with other measures of wetland condition, which does not necessarily lead to sensible cut-offs between the different ranks. The following paragraphs is a summary of the general findings, key threats, and management recommendations for each stratum based on survey results and landscape data, presented with the caveat that sample sizes per stratum were too small to allow for anything but observational trend detection.

We surveyed alkaline depressions, emergent marshes, and playas in the Wetlands stratum, though, as discussed above, the sample frame predominantly excluded much of the latter two Ecological Systems. Most wetlands in the stratum are embedded within large wetland complexes and thus AAs frequently had few stressors immediately adjacent to them, with the exception of cover of the invasive grass *Phragmites australis*. Many potential water quality stressors, such as urban run-off and point source dischargers, are located considerably upstream from sites, and, using a rapid assessment approach, the degree to which stressors may be tempered before water reaches particular sites is difficult to evaluate. Hydrology at most sites is controlled by management practices via impoundments, ditches, and control structures, either directly within impoundments or indirectly due to overflow or release from impoundments. Management activities, including hydrologic manipulation and management of *Phragmites australis* through grazing, herbicides, or mechanical control, are both common stressors at sites and also vitally important for maintaining wetland function. Condition of wetlands in the stratum is constrained by structural limitations, but also benefits from the fact that wetlands are largely managed for wildlife. We recommend developing an appropriate classification for these wetlands so that condition estimates and management recommendations are made in the context of both anthropogenic and natural limitations. Site types include natural riverine and depressional wetlands and large, shallow impoundments, impoundment overflow sites, and impoundment release sites. Natural variation in water regime and salinity also play a role in determining management needs and expected site attributes. Great Salt Lake wetlands have been and will continue to be the focus of numerous research studies due to their importance for wildlife and recreational opportunities. It is important for researchers to use a common language when classifying these wetlands and to standardize some measurement parameters to create a larger body of data from which to make inference. Furthermore, sites that receive less polluted water, have a relatively natural hydroperiod (even if obtained due to management), and are not invaded by *Phragmites australis* should be identified. These sites should be prioritized for long-term monitoring to define the least disturbed condition and should also be prioritized for management and conservation actions so that their relatively undisturbed status is maintained.

We surveyed alkaline depressions and a single greasewood and Great Basin shrubland in the Footslopes. Wetlands in the Footslopes appear to be in poorer condition than wetlands anywhere else in the Weber River watershed. The Footslopes had the most sites with low landscape, physical substrate, hydrologic, and overall URAP scores and the lowest distribution of Mean C values. The Footslopes also had sites with the highest values for many potential problematic water quality constituents, such as ammonium, nitrate plus nitrite, and total phosphorus. Footslopes wetlands are subject to similar levels of hydrologic modification and water quality stressors as found in the Wetlands, but usually without the benefit of management focused on preserving wetland functions. In fact, most sites in the stratum received water incidentally from irrigation via tail water run-off, subjecting wetlands to unnaturally timed and potentially polluted waters and making wetlands dependent on agricultural water sources that may not be dependable in an urbanizing environment. Much of the wetland area has been used as pastureland and evidence of moderate or high severity grazing was very common in the Footslopes. Non-native species are widespread and abundant throughout the stratum, perhaps due to high levels of landscape fragmentation and grazing pressure, though sites are not as heavily invaded by *Phragmites australis* as the adjacent Wetlands. Wetlands in the Footslopes are predominantly privately owned and often either may not meet the technical Army Corps definition of wetland or are subject to agricultural practices that exempt them from some regulatory restrictions. It is important to work with landowners to support grazing practices in a manner that also maximizes wetland condition. Wetland conservation through land purchases or easements may be crucial for wetland preservation in the Footslopes because there is little managed wetland area, wetlands are highly stressed, and wetland loss may be higher than in other strata. Potential conservation targets could include woody wetlands, which are rare in the basin and range ecoregion and only found in high stress landscape settings, wetlands with intact native plant communities, or wetlands with secure water rights and less artificial sources of hydrology.

Surveyed wetlands in the Valleys included wet meadows and emergent marshes; the latter included two periodically drying aquatic beds on the edge of Pineview Reservoir and one aquatic bed in a slough. Valleys wetlands are located in more confined landscape settings than other Weber River watershed wetlands. They often had small buffers intersected by roads and were usually located in a fragmented landscape; no wetlands in this stratum received an A for the URAP landscape category score. Valleys wetlands were similar to the Footslopes in that both were commonly located in a landscape that is predominantly a mixture of agriculture and development, though the Valleys had much less direct disturbance from grazing and off-road vehicles within wetlands. Valley wetlands received water from a mixture of natural and unnatural sources, including groundwater discharge, subsurface floodplain flow, and irrigation return flows, and tended to have more natural hydrology than Footslopes sites. In the Valleys, non-natives species and noxious weeds were more abundant in wet meadows than in aquatic bed sites. Four of nine wet meadow sites had over 30% non-native cover and only one of nine wet meadow sites scoring above C for the vegetation composition metric. Most of the abundant non-native species found in Valleys wetlands are grasses frequently planted in hayfields. Three non-native species are of particular concern in the Valleys. *Phalaris arundinacea* was found at over half of the Valleys sites, had between 10 and 30% cover at four sites, and is considered a highly aggressive wetland invader in the eastern United States. Both European and North American genotypes of the species exist, though research suggests that most extant populations are of European origin. *Phragmites australis* and *Elymus repens* were found at only one and two sites, respectively, but each had 25% absolute cover at one site and both are considered noxious weeds in Utah or individual Utah counties. Unfortunately, issues with subspecies or species identification make it difficult to ascertain the true nature of these threats. Wetlands in the Valleys are almost entirely privately owned, so regulations (such as establishing wetland buffer requirements) and incentives (such as funding for wetland easements and for noxious weed programs) may be essential for protecting these wetlands.

Wetlands surveyed in the Foothills included wet meadow, lower montane woodland, and upper montane shrubland sites. These sites predominantly received water from natural sources including groundwater discharge, subsurface floodplain flow, and direct precipitation and snowmelt, though a quarter of sites also received some water from irrigation return flows. Foothills wetlands were second only to the Footslopes in the proportion of wetlands surrounded by a fragmented landscape, though fragmentation was often caused by roads rather than the presence of larger-scale land transformations such as agriculture or development. Foothills wetlands were more frequently located in watersheds with oil and gas wells than wetlands in other strata. Of the montane ecoregion strata, Foothills wetlands had the lowest mean values for physical substrate, vegetation composition, and vegetation structure, and overall URAP scores, which could be due to the presence of intense grazing at many sites. Though grazing was common both within wetlands and in surrounding buffers, the Foothills stratum was the only one that had a much higher rate of intensive grazing concentrated in wetlands rather than in the surrounding landscape. Livestock grazing could be more intensely concentrated in the Foothills due to lack of water availability in the surrounding landscape or due to differences in land management at the predominantly privately owned wetlands, though the actual reason is uncertain. Non-native pasture grasses and clovers often had high cover at sites, including the non-native *Poa pratensis*, which was found at three sites with 10% or more cover. *Poa pratensis* is highly resistant to grazing, often comes to dominate areas that are overgrazed, and may persist as a dominant species even after grazing pressure is removed (Uchytil, 1993). The species is commonly found in wet meadows that experience a lower water table during the drier part of the summer. Noxious weeds were in all but one of the Foothills sites and were particularly abundant at the lower montane woodlands sites. A reduction in wetland grazing pressure may improve plant community composition and structure. Non-native species, once established, are unlikely to be extirpated. Foothills wetlands of the montane ecoregion wetlands were also the most likely to be subject to off-road vehicle disturbance within the wetlands. Foothills wetlands may benefit from decreased stress from grazing and other substrate disturbance. This could potentially be accomplished through fencing and construction of water troughs, though water diversion could create new hydrologic stressors. Most of the wetland area in the watershed is privately owned, but CWMU operators, who own about 40% of the land, are likely to work with biologist to manage their land and may be open to new management suggestions, particularly if accompanied by funding support. Much of the Foothills wetland area is in a relatively natural landscape position; wetlands with low levels of landscape stress that have intact plant communities and a negligible grazing history appear to be rare and are potential targets for preservation.

Wetlands surveyed in the Montane Zone included wet meadow and upper montane shrubland that obtained water via subsurface floodplain flow, groundwater discharge, and direct snowmelt, and rarely received water from unnatural sources. Montane Zone wetlands were second only to the Uintas in terms of wetland condition, based on cumulative distribution functions, individual metrics scores, and the lack of largescale landscape stressors, with the exception of livestock grazing. Only Montane Zone and Uintas wetlands had no sites that scored below B for landscape, vegetation structure, and hydrologic category scores and overall URAP scores. Local stressors in the Montane Zone include livestock grazing and occasional local hydrologic manipulations such as dredging or diking of ponds for livestock. However, despite widespread livestock grazing in the landscape surrounding sites, little wetland area was subject to high intensity grazing. Half of the Montane Zone sites, compared to only one Valleys and Foothills site, had over 90% relative cover of native plant species, including three sites with no noxious weeds present. However, four Montane Zone sites scored as C- or D for relative cover of non-natives; these sites were usually dominated by the same pasture grasses and clover species found in the Foothills, including *Poa pratensis*. Wetlands are predominantly privately owned but often part of the CWMU program, which suggests that many land owners may already have a working relationship with wildlife biologists. The Montane Zone likely contains many high functioning and high condition wetlands, though some wetlands are impacted by non-native species, minor hydrologic stressors, or intense grazing.

Uintas wetlands included wet meadow and upper montane shrubland sites with natural hydrologic inputs including subsurface floodplain flow, natural surface flow, and groundwater discharge. Uintas wetlands had the most sites scored as A, and generally the least C and D sites, in every URAP category and for the overall URAP score. Sites were rarely influenced by land cover alterations with the exception of occasional roads, and site hydrology was predominantly natural except for, rare, minor ditches and dikes. Uintas wetlands also had the most intact plant communities, having high FQA metric values and only one site below 90% relative native species cover. Noxious weeds were also less common and less abundant than in other strata. Livestock grazing was not as prevalent as in the Foothills and Montane Zone, but was moderate or high severity when present. Wetlands in the Uintas were subject to one novel stressor, excessive tree herbivory related to mountain pine beetle kill, which was recorded as a stressor in two site buffers. Mountain pine beetle kill can lead to excessive woody debris accumulation at sites. The impacts of beetle kill to water quantity and quality are difficult to predict, inconsistent across studies, and may vary regionally. Some studies have found that beetle kill is related to increases in dissolved organic carbon, total phosphorus, total nitrogen, and/or nitrate in nearby seepage water or stream water (Mikkelson and others, 2013). Most wetland area in the Uintas is managed by the Uinta-Wasatch-Cache National Forest or as private CWMUs. In general, management strategies appear effective, though managers should be vigilant for impacts from beetle kill and increases in non-native species cover.

6.1.3 Non-Native Plant Species

Altered plant communities are one of the most common issues across the Weber River watershed. At one quarter of sites, including at least one site per stratum, half or more of the total plant cover was composed of non-native species. Non-native plant species can dramatically alter ecosystems; for example, non-native species can decrease native plant and invertebrate species diversity (Gerber and others, 2008), change nutrient availability (Ehrenfeld, 2003), alter disturbance regimes (Mack and

D'Antonio, 1998), and threaten imperiled species (Wilcove and others, 1998). Non-native species can also serve as indicators of past or on-going disturbance, such as described above for *Poa pratensis*, and thus may be correlated with other site stressors such as nutrient enrichment or hydrologic alteration. At the same time, many non-native species are considered desirable and are intentionally planted; most of the high-cover non-natives documented in this study are recommended for planting for erosion control and livestock forage (Jensen and others, date unknown). Non-native species are pervasive and often perform important ecological roles in areas where native plant communities have been severely altered; complete elimination of non-native species is not a realistic management goal.

One way to assess the threat of non-natives species is by evaluating their pervasiveness on the landscape. Wetlands with little non-native species cover may be worth protecting simply because they are unique in some areas and rare examples of intact wetland plant communities. Some of these wetlands may also have been shielded from other historical stressors, making them good reference examples of fully functioning systems. Wetlands with very little non-native plant cover (<10% relative cover) were common in the Uintas, occasional in the Montane Zone, and very rare in other strata. Protection of wetlands with intact plant communities may be especially desirable in wetland types and regions where few high quality examples exist.

A second way to assess the threat of non-native species is by evaluating the threat posed by individual species. The first question to consider is how likely the species is to reach wetlands. Species' spread is influenced by dispersal ability, which was not assessed in this study, and by species' prevalence on the landscape. Second, how likely is a species to establish and spread within a wetland? We assume species that are found at least occasionally with high abundance and species more strongly associated with wetlands (i.e., not species that have wetland indicator ratings of facultative upland and upland) are more likely to invade wetlands. Third, how likely is a species to cause either social or ecological impacts? Species listed as noxious weeds are often perceived to cause economic, ecological, or other harm and are subject to regulation and management (Skinner and others, 2000). Many of Utah's listed noxious weeds negatively impact livestock grazing because they are toxic, such as *Leucanthemum vulgare* and *Cynoglossum officinale*, or are not preferred forage for most livestock, such as *Cirsium arvense* and *Carduus nutans*. Some listed species are known to have severe ecological impacts, such as *Tamarix* spp. and *Phragmites australis*. Species trait information could also be used to predict potential for impact. For example, species with nitrogen-fixing bacterium in their roots may alter nutrient dynamics at sites and strongly rhizomatous species may have a high potential to crowd out other species.

In the basin and range ecoregion, *Bassia hyssopifolia* (fivehorn smootherweed), *Phragmites australis,* and *Trifolium fragiferum* are the only species that are both widespread (found at 25% or more sites) and sometimes abundant where found (found at least once with 5% or more cover). Of these, *Phragmites australis* is already a species of upmost management concern due to both ecological and social threats caused by its aggressive invasion. *Trifolium fragiferum*, often used as a pasture species, could impact wetland nutrient dynamics as a nitrogen-fixing species, but may be limited to drier wetlands since it is a facultative upland species. *Bassia hyssopifolia*, a facultative species, can be toxic to livestock in large amounts, though considered good forage in small quantities (DiTomaso and others, 2013b). Toxicity could be an issue in wetland pastures or areas with managed grazing for *Phragmites australis* control, but would only be an issue where the species was dominant.

Several other potentially problematic species were found in the basin and range ecoregion. *Lepidium latifolium* is a Utah noxious weed that can form dense stands, reduce forage quality, and increase both soil salinity and streambank erosion (DiTomaso and others, 2013c). This facultative species is widespread in the ecoregion, but was never found with more than 2% cover at survey sites. This suggests that, while the species is an overall threat on the landscape, it may not come to dominate wetlands. *Elaeagnus angustifolia* (Russian olive) is a noxious weed in several southern Utah counties that can displace native willow and cottonwood stands and is sometimes associated with nitrogen-fixing bacteria (DiTomaso and others, 2013d). This species was only found at three sites, including one with 5% cover. The species is facultative and may be more widespread in non-wetland areas. The facultative wetland species *Echinochloa crus-galli* was only found at two sites, but with 15% cover at one. This annual species is listed as a noxious weed in Arkansas; it can remove high amounts of phosphorus and nitrogen from the soil and can sometimes accumulate levels of nitrate high enough to be toxic to livestock (http://extension.psu.edu/pests/weeds/weed-id/barnyardgrass).

In the montane ecoregion, several widespread and at least occasionally abundant non-native species were facultative species planted for erosion control or livestock forage, including *Poa pratensis* and *Trifolium repens*. *Poa pratensis* is a grass species that spreads via rhizome, often out-competes native species, and can be associated with livestock grazing (Uchytil, 1993). *Trifolium repens* is a perennial nitrogen-fixing species that can potentially alter soil nutrient dynamics and displace native species (Klein, 2011). Noxious weeds of potential concern include the facultative species *Cirsium arvense, Elymus repens*, and *Phragmites australis*, all occasionally found with high cover at sites, though the identification of the latter two species was somewhat uncertain. *Cirsium arvense* was very common in wetlands and can reduce pasture productivity due to livestock avoidance and can cause infectious abrasions in grazing animals (DiTomaso and others, 2013a). *Phalaris arundinacea*, though sometimes considered a native species and planted for erosion control, should also be a species of concern. *Phalaris arundinacea* is listed as a noxious weed in several states and can alter plant and insect communities and change sedimentation patterns and hydrologic processes of invaded streams and wetlands (Lavergne and Molofsky, 2004). This species was common and sometimes very abundant in the Valleys and Foothills and, as a facultative wetland species, is more likely to be problematic in wetlands than other common non-native species.

6.1.4 Livestock Grazing

Livestock grazing was the most frequently recorded stressor within surveyed wetlands and second only to non-native species cover in surrounding buffers. Grazing impacts were usually recorded as low severity and very rarely recorded as high severity, though it is difficult to determine the true impact of livestock grazing on wetlands during a single site visit. Grazing intensity often varies through time, particularly when grazing is managed on a rotational basis. Surveyors assess sites based on the visible appearance of the site at the time that a site is surveyed. Surveyors may overestimate actual stress levels if they visit sites during the peak of grazing intensity, particularly if livestock are rotated away from the site after a limited time. Surveyors may underestimate actual stress levels or neglect to record grazing as a stressor if livestock graze sites after surveys take place. Changes to hydroperiod and physical substrate, such as stream entrenchment, soil compaction, pugging, and unnatural bare areas, are often visibly apparent and attributable to grazing even if sites are not being actively grazed whereas changes to water quality (and more generally to nutrient dynamics) and vegetation are more difficult to evaluate. Long-term grazing can change plant community composition through a shift towards less palatable and more disturbance tolerant species, which can sometimes also alter wetland structure by decreasing shrub cover, decreasing litter cover, and increasing forb cover (Zhou and others, 2006). Long-term nutrient addition in wetlands can shift plant communities towards fast-growing plant species better able to take advantage of the increase in nutrients and can also alter nutrient dynamics, sometimes increasing rates of nutrient cycling and nutrient leeching (Verhoeven and others, 2006).

Severe impacts of livestock grazing to hydroperiod and physical substrate were rare in the Weber River watershed, but the extent to which grazing has altered nutrient dynamics and plant community composition is uncertain. Water quality stress from livestock was not directly evaluated, though the algae and water quality metrics may in part capture the impacts of such stress. Few sites scored below B for the algae metric and most sites that scored below B for the water quality metric were affected by point source dischargers and agricultural and development stressors instead of, or in addition to, livestock grazing pressure. Wetlands may go from having very little response to having a drastic change in plant communities and ecosystem functions when annual anthropogenic nutrient critical loads exceed 10 kg phosphorus and/or 25 kg nitrogen per hectare, though critical load values may vary based on wetland type and other local factors (Verhoeven and others, 2006). Whenever possible, grazing rates should be adjusted so that manure contributions are below these critical values.

Plant community composition changes from long-term grazing may be captured by the woody species regeneration and relative cover of native species metrics. Most sites received high scores or no scores for the woody regeneration metric, though it can be difficult to gauge baseline expectations for the metric, particularly if grazing has removed all signs of woody species from a site. Sites frequently received low scores for relative cover of native species. The low scores could be indicative of a history of grazing stress, though non-native species along roads or associated with agriculture and development could also invade sites after natural disturbances, such as flooding, open up bare ground within wetlands. The Colorado Natural Heritage Program uses Mean C values to help evaluate the condition of plant communities, and have stricter thresholds between Mean C classes for fens, riparian areas, and wet meadows and less strict thresholds for marshes, playas, and saline wetlands (Lemly and Gilligan, 2013). Mean C is an evaluation of the degree of disturbance tolerance of species at a site. Almost 80% of sites in the Weber River watershed would score as C- or D for the Mean C metric, and only about 5.5% as A or B, based on Colorado's thresholds, though an important note is that thresholds and species' C-values were not developed or calibrated for use in Utah. As with non-native cover, many factors could alter the Mean C values of plant communities, though livestock grazing was by far the most common stressor in and adjacent to sites in the Foothills, Montane Zone, and Uintas. A more thorough analysis of the effect of livestock grazing on plant communities should be undertaken through comparison with reference sites with no known or very light grazing histories (determined through discussion with land owners).

6.1.5 Water Quality

Most wetlands in the Wetlands, Footslopes, and Valleys are subject to high water quality stress levels which are often due to landscape issues such as impaired water sources or heavy agricultural and urban development, sometimes in combination with intense local grazing pressure. Some very heavily grazed pastures and some wetlands may receive water from point source dischargers that exceed the critical values for nitrogen and phosphorus discussed above (Verhoeven and others, 2006), though regionally specific critical values must be developed. Footslopes also have the lowest scores for the turbidity and pollutants and algae metrics and the most recorded water quality stressors per site. In contrast, sites in the Foothills, Montane Zone, and Uintas generally scored as A or B for the water quality metric; the main source of water quality stress to these wetlands was livestock grazing. Buffers at all but three sites in the watershed were wide enough to remove most sediment, nitrogen, phosphorus, and pesticides before reaching wetlands, based on widths cited in several literature reviews (McElfish and others, 2008, Zhang and others, 2010), though almost 20% of site buffers had significant soil disturbance at sites that may render buffers less effective. Furthermore, water quality stressors were often present directly within buffers or sites themselves, or water quality stressors came from streams, lakes, or canals that directly provided water to sites, bypassing buffers entirely. At least eleven of the surveyed wetland sites were hydrologically connected to impaired waterbodies, including five in the Wetlands and three in the Valleys. Impacts to wetlands depend on the actual loadings of nutrients, sediment, and contaminants to sites and the assimilative capacity of different wetlands, which is difficult to determine from rapid assessment results.

We recommend three actions to ensure protection of wetland water quality in the study area. First, efforts should address impaired waterbodies to improve the quality of wetland water sources. Second, land managers and private land owners should be encouraged to sustainably manage grazing, off-road vehicle use, and other activities within and adjacent to sites and to use appropriate buffers to protect wetlands from adjacent runoff. Effective buffers are especially critical in the Footslopes and Valleys where the landscape is already very fragmented by permanent structural stressors such as roads and other land cover conversion. Third, water quality data should continue to be collected across a range of geographic areas and wetland types to better quantify natural and impaired water quality parameter values. Water quality stress to wetlands is difficult to rigorously evaluate in the absence of wetland-specific water quality standards, with so few sites per stratum and per wetland type, and so few samples per site. By comparison, the Utah Division of Water Quality requires at least 10 samples from a site before declaring a stream or lake impaired for certain constituents (Utah Division of Water Quality, 2014a). Water quality data from the Weber River watershed will be combined with data from adjacent watersheds in the future to provide a more comprehensive understanding of baseline levels of water quality constituents and potential responses to stress across an environmental gradient.

Wetlands can play an important role in protecting adjacent waterbodies from non-point source water quality stressors. Some common impairments in the Weber River watershed, such as copper and *E. coli*, can be directly filtered by wetlands. Other common impairments, such as dissolved oxygen, pH, temperature and impaired macroinvertebrate communities, may be indirectly improved as a result of nutrient filtration, streambank shading, or improvement of other water quality parameters (Knox and others, 2008, Sheoran and Sheoran, 2006). Wetlands are likely to be most effective at improving water quality in impaired waterbodies if three conditions are met. First, water quality stressors must pass through wetlands before reaching sites, typically meaning that non-point stressors should play a significant role in causing impairment. Each impaired water quality assessment unit needs to be analyzed to determine major drivers of impairment, though data from the landscape stress model can approximate landscape stress potential. In many water quality assessment units, a large percent of wetlands have high landscape stress model values, indicating that they are likely adjacent to sources of water quality stress. Second, assessment units must have an adequate density of wetlands for significant improvements to occur; most research has found between 2 and 7% of the land cover of a catchment must be wetland before significant improvements in water quality are detected (Verhoeven and others, 2006). We analyzed riparian wetland area within assessment units (that do not necessarily correspond to catchments) instead of all wetland area within catchments. Nonetheless, the results of our landscape analysis can help suggest which assessment units would benefit the most from wetland restoration and creation. Assessment units with less than 2% wetland area may benefit from additional wetland acreage if the overall acreage can be increased to at least to 2%. Any additional wetland acreage in assessment units with over 2% wetland area is likely to improve water quality, particularly in those units with less than 7% wetland area. Third, wetlands will have the highest impact on water quality if they are relatively intact, with minimally degraded soils, adequate vegetation cover, and pollutant loadings below critical values. Few sites in the Weber River watershed had extremely degraded soils or vegetation cover; sites with the highest stress levels for these factors were typically located in the Footslopes and Foothills strata. Wetlands, Footslopes, and Valleys wetlands may be most at-risk for exceeding assimilative capacity on pollutants. Decreasing within-wetland stress and increasing wetland area in places with the most water quality stress may help address issues water quality impairments.

6.1.6 Wetland Hydropattern

Wetland hydropattern, including the frequency and duration of flooding (hydroperiod) and timing of inundation, is a fundamental system characteristic that plays a large role in determining nutrient cycling (Tanner and others, 1999) and the types of plant, invertebrate, and amphibian communities that a wetland can support (Snodgrass and others, 2000; Tarr and others, 2005; Webb and others, 2012). Hydropattern stressors were common throughout the Weber River watershed in all but the Montane Zone and Uintas strata. Sites in the Wetlands and Footslopes had the highest rates of hydropattern alteration, though usually due to different causes. Sites in the Wetlands typically either directly receive water managed for the benefit of wildlife or water that results from overflow or impoundment release as a consequence of the management, whereas Sites in the Footslopes either receive irrigation return flows or managed water to maintain pastureland. In many cases restoration of hydropattern to a natural condition is impossible because hydrologic modifications are permanent fixtures on the landscape, though water management can likely be optimized to support natural functioning. Many wetlands with altered hydrology provide important wildlife and water quality benefits, and some, such as passively managed stock ponds, may mimic the hydrology of natural wetlands.

One important component of wetland hydropattern not evaluated by the study is the impact of surface and groundwater withdrawal. We did not document obvious impacts from water withdrawal, which would be difficult to assess without long-term water level monitoring data or interviews with land owners. We did observe upland plant encroachment at 8 to 25% of sites per strata, but this could be driven by either normal climatic variation or by longer term reduction in water levels. We recommend installing a network of wetland piezometers to monitor water levels in least disturbed sites to characterize natural hydropatterns and determine whether trends in water level data are climatically or anthropogenically driven.

6.1.7 Rare and Threatened Wetland Types

In the basin and range ecoregion, woody wetlands and emergent saturated wetlands are rare and typically surrounded by high levels of landscape stress. Palustrine aquatic bed wetlands are also relatively uncommon, though aquatic beds are common in lacustrine wetlands that we excluded from the sample frame. The Great Basin shrubland and greasewood flat Ecological Systems occupy the least amount of wetland area in the ecoregion, though both systems may occupy area that is not mapped as wetland. The greatest land conservation opportunities are in the Footslopes, where the majority of uncommon wetland types are found and the majority of land is privately owned.

In the montane ecoregion, emergent wetlands with semi-permanently flooded or wetter water regimes are very rare in all four strata. These wetlands likely correspond to cattail or bulrush-dominated marshes as opposed to aquatic bed-dominated marshes, which are relatively common in the Foothills, Montane Zone, and Uintas strata. All wetlands in the Valleys are subject to high levels of landscape stress and all but seasonally flooded emergent wetlands are relatively uncommon. Wetlands with saturated water regimes, particularly those with woody vegetation, are uncommon in the Foothills. These may correspond with wetlands that receive water from groundwater or subsurface floodplain flow. Wetlands in the Valleys and Foothills have the least amount of protection based on ownership patterns.

Minimally altered wetlands are also relatively rare in the Weber River watershed, particularly wetlands protected from water quality and hydropattern stressors in the Wetlands, Footslopes, and Valleys strata and wetlands with undisturbed, predominantly native (>95% relative native species cover) plant communities in all strata except the Uintas. Least disturbed wetlands across the geographic range are worth protecting to provide baseline expectations for natural wetland condition and function, which can be used to detect impacts in other wetlands. In addition, these best-condition wetlands represent a unique piece of biodiversity that cannot easily be recreated once lost.

6.2 Method Verification and Potential Improvements

We verified the URAP method quantitatively through correlation analysis and qualitatively through discussion of strengths and weaknesses of individual metrics with field surveyors. All URAP category scores for the ecoregions, and most for the mid-elevation montane site group, were at least weakly (Pearson correlation coefficient >|0.40|) and usually strongly (Pearson correlation coefficient >|0.60|) correlated with at least one of the hypothesized alternative measures of wetland condition. Correlations were as strong as or stronger than those used to validate the well-established California Rapid Assessment Method (CRAM, [Stein and others, 2009]), though CRAM used completely independent data for their validation. Overall field and total stressor indices and FQA metrics were used to calibrate the calculation of the overall score, which makes those values particularly problematic for method validation. However, URAP category scores were minimally or not calibrated against any stressor values, so correlations with these scores are a better test of the URAP method. Vegetation structure scores in the ecoregions were significantly correlated with almost all of the hypothesized alternative measures of condition even though many of the metrics that make up this category were particularly challenging to evaluate in the field. These correlations suggest that vegetation stress does lead to detectable alterations in vegetation structure. The hydrologic category scores were inconsistently correlated with alternative measures of condition in the basin and range ecoregion. Water quality and hydropattern metrics could be separated into two categories; this could increase the strength of correlations when water quality and hydropattern stressors are not operating in tandem and could lead to better assessment of each component of wetland condition. Despite strong correlations with other measures, the method for developing an overall score may need to be further developed because site ranks do not correspond well with the definition of the ranks found in table 1. Alternative thresholds could be developed for the overall score through the examination of reference sites, or overall score could be calculated from the average of the lowest three or four category scores rather than all scores. Individual metric results are probably more useful than the overall score for understanding the condition of Weber River watershed wetlands.

Field surveyors founds that some metrics were more difficult to evaluate than others. Landscape category scores were straightforward to evaluate, several metrics were evaluated quantitatively rather than qualitatively. Buffer vegetation condition was probably the most challenging metric to measure in this category because the nativity of buffer species was sometimes unknown. Many measures in the vegetation structure category were difficult to evaluate because the expected reference state was not always known. This was particularly true for the woody debris and woody species regeneration metrics at sites with little woody species cover; it was not always clear whether woody species and debris were naturally absent or absent due to site and upstream stressors. Plant species composition metrics were time-consuming to evaluate because they relied on identifying all species within sites, but were based on qualitative measures and thus easy to evaluate once plant species were identified. The hydroperiod, timing of inundation, and water quality metrics were relatively easy to evaluate, but it was difficult to determine whether thresholds between ranks were appropriate without more comprehensive hydrologic data from sites. Some changes to URAP metric wording was made based on survey results.

One potential improvement to URAP would be changing how stressors are measured in the field and tabulated into indices. It may be useful to develop a more rigorous method to quantify stressors into low, medium, and high severity categories, particularly for stressors that are most prevalent on the landscape, such as livestock grazing. Surveyors could look for livestock grazing impacts along transects or in plots rather than estimating impacts across the entire buffer or AA. Livestock impact could also be assessed at a subset of sites multiple times in a year to determine which components of grazing stress are most susceptible to seasonal variation. The calculation of stressor indices could also be changed to not rely solely on the severity and extent of the stressor. Stressors could be assigned different coefficients based on their perceived impact to sites so that, for example, a factory was weighted more heavily than a suburban housing development. We may be able to use coefficients, such as those adopted by Keate (2005), to relate land cover types to their relative degree of contribution to runoff, nutrient and sediment loading, and habitat quality. Values would still need to be modified based on stressor landscape position and, at least in some cases, degree of severity (e.g., hydrologically connected severely degraded rangeland would be weighted more heavily than hydrologically disconnected, lightly grazed rangeland). Weights for land cover classes could still be multiplied by their extent; weights for hydrologic manipulations may need to be multiplied by either the extent of the wetland that they impact or by another modifier related to the degree of severity. Another change that could be made to stressor tabulation is that very high non-native cover within wetlands could be considered a stressor instead of just a response to stress. Currently, non-native cover stress is only recorded in the buffer. Non-native stress could be measured based on overall non-native cover or on cover of dominant aggressive species, such as *Phragmites australis* and *Elymus repens*. Improved tabulation of stressor information will make it easier to calibrate and validate the URAP method and to connect stressors with site impacts.

Despite data limitations, survey results provide useful information for management decisions and land use planning in the Weber River watershed, as summarized above in *6.1 Wetland Condition and Common Wetland Stressors*. Most previous wetland surveys in Utah have focused on Great Salt Lake wetlands or wetlands managed by a particular entity such as the U.S. Forest Service rather than using a watershed-wide approach. Confidence intervals for survey results tended to be wide, making it difficult to test for differences in wetland condition among strata or wetland types and limiting the power to detect change over time. Nonetheless, this survey represents a step towards obtaining useful watershed-wide information; imperfect data is better to support management decisions than no data at all. We now have the necessary baseline data to detect at least relatively large changes in wetland condition in the watershed. We can increase the strength of inference in future watershed surveys by focusing monitoring efforts in areas of concern, such as areas with sensitive wildlife species or with water quality impairment issues. We could also increase the strength of inference by collaborating with other agencies or with volunteer monitors to collect at least a subset of the URAP data.

Additional discussion of the use of this survey data for method verification and calibration can be found in appendix A and in the report on the development of the landscape stress model (Menuz, 2015b).

6.3 Multi-Metric Index Development and Grouping of Sites

The multi-metric index developed for the mid-elevation montane sites reliably separates the least disturbed sites from the most disturbed sites with greater strength than any single tested metric. The index also serves as a separate evaluation of the URAP method since least and most disturbed sites were not selected based on URAP metric scores. For every category except the landscape category, there was either a statistically significant difference or a strong trend indicating that high disturbance sites had lower scores than least disturbed sites. However, least disturbed sites received overall URAP ranks of A or B and most disturbed sites were all ranked as B. The overall scoring method used for URAP may need further calibration to develop more useful thresholds, as discussed above. Furthermore, the most disturbed sites in the mid-elevation montane may not have been extremely altered. Only one of the four most disturbed sites had any of the 19 metrics rated as D, indicating significant deviation from reference, and one site had only one metric rated below B. Since thresholds to distinguish between good, fair, and poor categories are often developed from the range of values found in reference sites rather than in most disturbed sites (U.S. Environmental Protection Agency, in review), the lack of extreme disturbance may not be consequential. Nonetheless, subjective selection of some highly disturbed survey sites could improve the breadth of data available for multi-metric index development.

The multi-metric index captured information on both the relative richness of non-native plant species and the degree to which disturbance-tolerant species were found at sites. Two of the included variables are similar, the relative percent of species with C-values between 6 and 10 and the number of species with C-values between 8 and 10. These metrics differ in that the former metric evaluates the proportion of species at sites that have low to moderate disturbance tolerance whereas the latter metric determines how many extremely disturbance intolerant species are at sites. Unfortunately, the latter metric, because it evaluates an absolute rather than relative number, is more sensitive to differences in AA size. A metric evaluating whether *any* most sensitive species are present may be more appropriate, though still subject to area-based restrictions. Only one of the four most disturbed sites had any species with a C-value above 8, versus all of the least disturbed sites.

Based on this pilot work, we have identified four important challenges for future development of multi-metric indices. First, subjective site selection needs to supplement random sampling to obtain an appropriate sample of least and most disturbed sites. The random selection of sites included no highly disturbed sites in the mid-elevation montane group and almost exclusively highly disturbed sites in the basin and range ecoregion. Sites could be selected based on land manager or researcher recommendations or based on site scores from the landscape stress model. All selected sites would still need to pass a screen of stress thresholds to be considered most or least disturbed. Least disturbed condition could also be described from sites outside of the region, though this may lead to an unobtainable reference standard. Second, a statistical method of dividing sites into good, fair, poor categories should be developed for ease of interpretation of results. A variety of methods, including those used by the EPA for the National Wetland Condition Assessment, should be reviewed and tested once a larger number of sites are sampled. Thresholds could also be dependent on individual project needs. Third, a broader range of variables should be considered for index development. Invertebrate community data and water chemistry parameters are frequently used to evaluate streams and rivers. Invertebrate data has rarely been successfully used to evaluate wetlands, potentially because interactions between invertebrates and disturbances can be very complex (Batzer, 2013). Water chemistry data can vary considerably within different areas of a wetland and throughout the year; it may be expensive to obtain an adequate number of samples at each site. In addition, many sites lack water for much of the year, and some sites that are highly stressed may still have natural water chemistry. Soil nutrient and plant isotope data may be more readily available and may help capture wetland stress information, though both methods would be expensive to develop. Fourth, we must decide how to group sites. More inclusive groupings make it easier to obtain adequate sample sizes and to identify low and high condition sites within groups. However, it may be difficult to limit the natural heterogeneity of large groups; differences between least and most disturbed sites for many attributes may be minimal if water sources, vegetation communities, and other key components naturally differ among all sites. Groupings that only include closely related wetland types are also more useful for setting expectations for restoration or mitigation projects for attributes other than those measured in the multi-metric index. Regionally-specific groupings are helpful for obtaining the best data on condition in an area (realistic project goals) rather than actual condition based on reference sites in other parts of the state. The implications of different groupings will be more apparent as we incorporate additional site data into the analysis.

Different factors appear important for grouping sites in each ecoregion. In the montane ecoregion, vegetation composition occasionally differed by HGM class and water regime, though slope and riverine wetlands and all but the driest water regime had similar composition in the mid-elevation montane group. Too little data were available to analyze most Ecological Systems in the montane ecoregion, though the two Rocky Mountain Foothill Woodland/Shrubland sites and three emergent marsh sites appeared to cluster by system. There were no clear differences in plant species composition between upper montane shrubland and wet meadow sites, and sites of both Ecological Systems clustered together in the mid-elevation montane group even when woody species and water cover were included in the cluster analysis. These two sites types likely exist along a continuum; for example, over

60% of wet meadow sites in the Weber River watershed had at least some shrub cover. In the basin and range ecoregion, plant community composition differed by HGM class, water regimes, and Ecological System, though classes had substantial overlap. For example, several riverine HGM sites grouped closest with the majority of depressional sites and three high salinity emergent marshes formed a distinct cluster apart from other marsh sites. Classification based on hydropattern and salinity may be most appropriate for the majority of basin and range wetlands. A method to estimate wetland salinity class around Great Salt Lake in the absence of water should be developed, potentially through use of soil salinity samples and/or analysis of position on the landscape, so that sites can be grouped into salinity classes that may better explain plant composition patterns or water quality parameter values. Hydrologic classifications could be based on either natural or both natural and artificial components of hydrology. The best obtainable condition for many wetlands around Great Salt Lake is strongly determined by the structural limitations of the wetland location, such as whether a site is within an impoundment or an area of impoundment release. It may be useful to determine the condition of wetlands in different anthropogenic hydrologic classes as well as the least disturbed condition of wetlands within broader hydrologic classes.

6.4 Landscape Analysis

The landscape analysis revealed some strengths and weaknesses of the landscape stress model. The model did a good job predicting URAP landscape category scores, which was expected given the similarity in the type of information assessed by both measures. However, the model was not able to predict physical or vegetation structure scores. These attributes are likely highly dependent on local stressors not captured by the model, such as livestock pugging, off-road vehicle use, beetle kill, small-scale anthropogenic vegetation removal, and excessive browse by livestock. Vegetation composition was weakly correlated with model values in the montane ecoregion and not at all correlated in the basin and range ecoregion. The distribution of the major compositional stressor in the basin and range, *Phragmites australis*, is driven by factors such as salinity and inundation period (Long, 2014) that were not captured in the landscape stress model. Hydrologic category scores were also only related to the landscape stress model in the montane ecoregion, where wetlands often were isolated or had relatively small watersheds. The model did a poor job capturing hydrologic condition in basin and range wetlands, where water quality and hydroperiod are frequently located far from wetlands. Without using a watershed-based approach, it is not surprising that the model performs poorly on systems with large watersheds and many important distant stressors.

Given the inadequacies in the landscape stress model, how can model results be used to better understand wetland condition? In the montane ecoregion, it may be adequate to adjust the landscape stress model scores to take into account the prevalence of key stressors since the model correlates well with many components of wetland condition. For example, it might be assumed that a certain percent of low stress sites (based on the landscape stress model score) actually have moderate stress based on the prevalence of soil disturbance and other local stressors on the landscape. In the basin and range, the model is inadequate to capture most components of wetland condition as measured by field data. This is likely due to the high degree of connectivity between wetlands and upstream stressors, the commonness of management effects that help counteract negative impacts of hydroperiod stressors, and the presence of a highly invasive grass species whose spread is not dependent upon factors captured in the model. The Utah Department of Natural Resources' Endangered Species Mitigation Fund has funded the UGS to incorporate watershed-based stressor data in the landscape model in winter 2015 (Menuz, 2015a). This will only be a pilot project developed for a portion of Utah, but will serve as a template for similar work. The current landscape stress model and the new watershed-based model may be used concurrently, with the former model applied to more isolated wetlands and the latter model applied to wetlands that receive water from streams and lakes with larger watersheds. The riparian designation may help determine which model should be applied to which wetlands, but may need to be refined by water regime or other classification to distinguish between wetlands that predominantly receive water from versus contribute water to adjacent waterbodies.

While the landscape stress model is limited in its ability to predict wetland condition, the landscape analysis was useful for understanding the distribution of different wetland types and potential conservation opportunities. Conservation priorities could focus on rare wetland types, wetland types subject to the highest stress levels, or both, and may vary depending on ownership class. Regions with very little wetland ownership in managed ownership classes, such as the Footslopes and Valleys, may benefit from direct wetland preservation and wetland easements. In other regions, it may be easier to communicate management recommendations to large groups of owners because much of the land is either managed by a public entity or by land owners with large CWMU holdings.

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