TRAIT DATA FOR UTAH'S CENTRAL BASIN AND RANGE WETLAND PLANTS

by

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ABSTRACT

Wetlands are important refuges in Utah's Central Basin and Range ecoregion ("Central Basin"), providing water and food in an otherwise harsh and arid landscape, but unfortunately data on their current condition and functions are lacking. As part of our wetland surveys, the Utah Geological Survey has been collecting plant community data which can be used to further our understanding of the state of Central Basin wetlands. Different plant species have different values for functions such as wildlife habitat, water quality improvement, and flood containment. They also have different sensitivities to disturbances such as cattle grazing, nutrient inputs, and soil disturbance. By assigning scores to plant species related to their functional or disturbance-sensitivity traits and then calculating site-wide scores for those traits, we can make inferences about a wetland's value for certain functions or what stressors the wetland is currently experiencing. This study focuses on 1) compiling data to assign scores to common Central Basin species for different traits and 2) testing if nutrient tolerance wetland scores appear to align with nutrient input data collected in the field. We found several databases that contributed most of the information for the data compilation component. Between 31% and 61% of plant species documented in the Central Basin were assigned trait values for most of our focal traits. We also found that sites rated as having high water quality stress in field data had higher nutrient tolerance scores derived from plant trait data than sites with lower water quality stress. Further analysis is needed to determine whether water quality stressors are driving plant community composition towards nutrient-tolerant species or whether other factors influence both water quality stress and plant communities.

INTRODUCTION

Wetlands are important refuges in Utah's Central Basin and Range ecoregion ("Central Basin"), providing water and food in an otherwise harsh and arid landscape (figure 1). Unfortunately, Central Basin wetlands face many threats, including declining groundwater and surface water levels due to a long history of diversions and groundwater pumping, disturbance from livestock and feral animals, impaired source water, and development pressure along the Wasatch Front. Overarching these threats is the fact that basic information on Utah's Central Basin wetlands is lacking, which creates gaps in our understanding of their current conditions and functionality.

The Utah Geological Survey (UGS) has been working to address these data gaps by conducting field studies on Utah's Central Basin wetlands using the Utah Rapid Assessment Protocol (URAP). URAP initially focused only on evaluating wetland condition, but the UGS later added components to evaluate wetland function as well. The protocol relies on qualitative measures of condition and function, requiring surveyors to make many subjective evaluations to score sites. The UGS has conducted wetland assessment surveys across almost the entire Central Basin region in Utah (Menuz and others, 2014; Menuz and others, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019; McCoy-Sulentic and others, 2021).

Plant composition data are another valuable tool for evaluating wetlands and have also been collected as a part of URAP. Plant species respond to both recent and ongoing disturbances, even those that are not visible during field surveys (e.g., water quality disturbances, late season grazing), and plant communities can often be evaluated at a single point in time, rather than requiring repeat visits. The UGS has already used plant community composition data from URAP surveys to validate wetland condition scores and to separate low- and high-quality wetlands by calculating plant metrics from traits such as nativity, growth form, duration, and coefficient of conservatism value (e.g., McCoy-Sulentic and others, 2021). Those traits, however, are just the start of how plant species information can help us understand more about Utah's wetlands. Assigning additional trait values to species found in the Central Basin would help the UGS validate other components of URAP, such as wetland function and stressor data.

The goal of this project was to assign values to Central Basin plants for traits such as sensitivity to disturbances (e.g., drought, cattle grazing, nutrient increase) and for functions such as bank stability or wildlife habitat use. We then used data from one of the traits, tolerance to nutrients, to evaluate how well those data performed against other measures of site water quality.

METHODS

Focal Traits

We developed a list of 35 traits to populate for each species. Information on traits such as root depth, root type, and stem diameter are helpful for assessing a plant's value for erosion control potential if pre-determined erosion control potential information is not directly available. Other values, such as cover and food values for different groups of fauna, can give information about a species' value for wildlife. Tolerance to excess nutrients and tolerance to grazing were also included for measures of resiliency to human induced stressors. A full list of focal traits and their description, category, sources, and data type can be found in table 1.

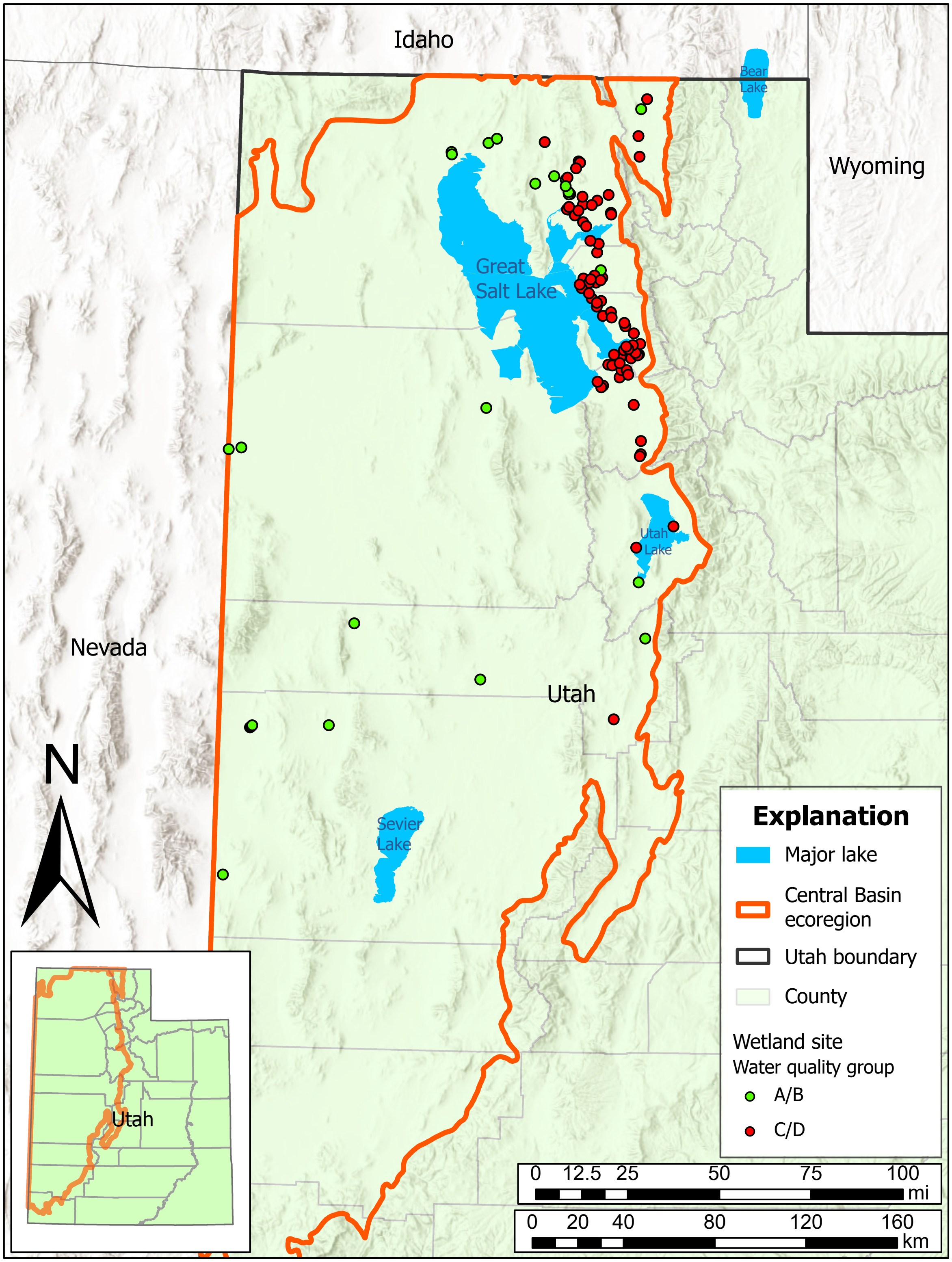

Figure 1. *Central Basin and Range ecoregion boundary and the wetland sites included in analysis of site water quality rating versus plant nutrient tolerance scores. Water quality groups are based on water quality condition rating assigned to sites in the field using ranks defined in table 2.*

Table 1. *List of plant species traits with descriptions, sources, data types, and number of records compiled.*

Trait Category	Trait	Trait Description	# Species with Data	Data Type	Data Options	Primary Source
Erosion Control	Erosion control potential	Potential for the species' presence to help control erosion	244	String	Low, Medium, High	PIN, Riparian Plant List
Livestock	Livestock use- average	Average use by all livestock (cattle, horses and sheep), particularly for forage	179	Numeric	Between 1 (Poor) and 3 (Good)	Calculated from PIN
Livestock	Livestock use- cattle	Use by cattle, particularly for forage	179	String	Good, Fair, Poor	PIN
Livestock	Livestock use- horse	Use by horses, particularly for forage	179	String	Good, Fair, Poor	PIN
Livestock	Livestock use- sheep	Use by sheep, particularly for forage	179	String	Good, Fair, Poor	PIN
Livestock	Poisonous to livestock	Whether the species is known to be poisonous or mechanically dangerous to livestock	188	String	Major, Mechanical, Minor, No, Suspected	PIN
Plant trait	Height[1]	Species' height, listed as "base age" or "mature" for data for USDA Plants	169	Numeric	Numeric	USDA Plants
Plant trait	Root depth	Depth of rooting structure	167	Numeric	Numeric	USDA Plants
Plant trait	Root type	Type of rooting structure	11	String	Rhizomes, Taproot, etc.	A Utah Flora
Plant trait	Stem diameter	Diameter of the species' stem	4	Numeric	Numeric	A Utah Flora
Stressor tolerance	Drought tolerance	Tolerance to drought conditions	170	String	None, Low, Medium, High	USDA Plants
Stressor tolerance	Flood tolerance	Tolerance to increased inundation depth or duration	173	String	None, Low, Medium, High	USDA Plants
Stressor tolerance	Hydrologic stress indicator	Whether species presence or an increase in presence can indicate hydrologic stress	3	String	Increases, Yes	None
Stressor tolerance	Soil disturbance indicator	Whether the species is an indicator of soil disturbance, and, if so, what type	182	String	Decreases, Mechanical, No, Other, Overgrazing	PIN
Stressor tolerance	Tolerance to cattle grazing	Ability of species to continue to thrive after being grazed by cattle	9	String	Low, Medium, High	None
Stressor tolerance	Tolerance to nutrients	Ability to tolerate excess nutrients from pollutants such as agricultural runoff, cow manure, lawn fertilizer, etc.	128	String	Low, Medium, High	Nutrient Database
Wildlife use	Palatable Browse Animal	Palatability to browsing animals (USDA Plants rating only)	125	String	Low, Medium, High	USDA Plants
Wildlife use	Palatable Graze Animal	Palatability to grazing animals (USDA Plants rating only)	127	String	Low, Medium, High	USDA Plants
Wildlife use	Small mammal cover	Value for small mammal shelter	180	String	Good, Fair, Poor	PIN
Wildlife use	Small mammal food	Value for small mammal food	181	String	Good, Fair, Poor	PIN
Wildlife use	Small non-game bird cover	Value for small non-game bird shelter	180	String	Good, Fair, Poor	PIN
Wildlife use	Small non-game bird food	Value for small non-game bird food	182	String	Good, Fair, Poor	PIN

Table 1. *Continued.*

Trait Category	Trait	Trait Description	# Species with Data	Data Type	Data Options	Primary Source
Wildlife use	Upland game bird cover	Value for upland game bird shelter	181	String	Good, Fair, Poor	PIN
Wildlife use	Upland game bird food	Value for upland game bird food	180	String	Good, Fair, Poor	PIN
Wildlife use	Waterfowl cover	Value for waterfowl shelter	177	String	Good, Fair, Poor	PIN
Wildlife use	Waterfowl food	Value for waterfowl food	177	String	Good, Fair, Poor	PIN
Wildlife use	Wild ungulate cover- antelope	Value for wild antelope shelter	176	String	Good, Fair, Poor	PIN
Wildlife use	Wild ungulate cover- average	Average shelter value for wild ungulates (antelope, mule deer, elk)	181	Numeric	Between 1 (Poor) and 3 (Good)	Calculated from PIN
Wildlife use	Wild ungulate cover- elk	Value for wild elk shelter	179	String	Good, Fair, Poor	PIN
Wildlife use	Wild ungulate cover- mule deer	Value for mule deer shelter	180	String	Good, Fair, Poor	PIN
Wildlife use	Wild ungulate food- antelope	Value for antelope food	165	String	Good, Fair, Poor	PIN
Wildlife use	Wild ungulate food- average	Average food value for wild ungulates (antelope, mule deer, elk)	183	Numeric	Between 1 (Poor) and 3 (Good)	Calculated from PIN
Wildlife use	Wild ungulate food- elk	Value for wild elk food	181	String	Good, Fair, Poor	PIN
Wildlife use	Wild ungulate food- mule deer	Value for wild mule deer food	182	String	Good, Fair, Poor	PIN

[1]Height listed in three different ways in the database: height, height (base age), and height (mature)

Focal Species

We compiled a list of plant species recorded during UGS surveys in the Central Basin conducted between 2013 and 2020 (Menuz and others, 2014, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019; McCoy-Sulentic and others, 2021) and data from partner organizations, including data from Utah Division of Water Quality wetland surveys (Utah Division of Water Quality, 2016, 2018), unpublished data from the Environmental Protection Agency's (EPA) 2016 National Wetland Condition Assessment, the Bureau of Land Management's (BLM) 2019 lentic AIM data, and research from a graduate student at Utah State University. We used USDA PLANTS as the taxonomic standard and created a list of synonyms for cross-reference. Our full plant list included 399 unique species, including about 45% that occurred at one or two sites and just over 25% that occurred at 10 or more sites. We were interested in obtaining trait data for as many species as possible, but also wanted to look for more detailed data for common species in one focal wetland type. We chose marshes as our focal wetland type because they were among the most common types that we surveyed and because we postulated they could have a higher likelihood of having available information for our traits of interest. We defined common marsh species as those plants that were in the upper 75th quartile for both their estimated cover per site and the number of sites where they were found, among all sites classified as marsh. The result was 12 focal marsh species for which a more thorough literature review was performed.

Data Sources

We used four existing databases to populate plant trait values for large numbers of our focal species, including the Plant Information Network (PIN), USDA PLANTS, National Database of Wetland Plant Tolerances ("Nutrient Database"), and a list of plants associated with the BLM's Multiple Indicator Monitoring (MIM) protocol ("Riparian Plant List").

The PIN database contains information on vascular plants in Colorado, Montana, North Dakota, Utah, and Wyoming (United States Department of the Interior, 1983). The database was previously computerized, but due to lack of funding is now only available as a PDF of a type-written document. We manually entered data from the document for traits related to plant use by different animal groups as well as soil disturbance indicators and erosion control potential. Values for most traits were listed as good, fair, or poor.

The USDA PLANTS database contains information on the distribution, growth habit, duration, and nativity of vascular plants in the United States and territories (USDA and NRCS, 2021). The database also contains more detailed data on morphology, physiology, growth requirements, reproduction, and use characteristics for some species. We extracted seven fields from the database to add to our compilation, including Drought Tolerance, Flood Tolerance, Height at Base Age, Mature Height, Palatable Browse Animal, Palatable Graze Animal, and Minimum Root Depth. The USDA PLANTS database also occasionally has detailed species factsheets. We used available factsheets when conducting the more thorough review of the focal marsh species.

The Nutrient Database contains data on wetland plant species' response to excessive nutrient and altered hydrologic regimes, based on a review of literature from the 1980s and 1990s (Adamus and Gonyaw, 2001). The database includes information from over 200 sources on 2234 species that occur in the United States. Species can be listed multiple times to capture responses specific to different life stages (e.g., seed, tuber, seedling, adult), response variables (e.g., germination, survival, growth, dominance), and trait (e.g., response to general pollutants, nitrogen, phosphorous, changes in water regime). Response values were reported as decrease, increase, unaffected, or as degree of tolerance consisting of intolerant, somewhat tolerant, tolerant, moderately tolerant, or very tolerant. We evaluated four traits from the database for this study, including unspecified nutrient increase, nitrogen increase, phosphorus increase, and unspecified nutrient decrease. Most species were classified as somewhat tolerant or tolerant. We classified species as low tolerance if their response to any increase in nutrient was "decrease," "intolerant," or "somewhat tolerant," or if their response to a nutrient decrease was "increase." We classified species as moderate tolerance if their response to any nutrient increase was "increase." For species with more than one value in the database, which only occurred for a few species, we evaluated all available data and made a judgement call on the final tolerance value or left the data as unknown if there was conflicting information.

The Riparian Plant List was obtained by downloading the Arid West and Western Mountains and Valleys data entry modules for the BLM's MIM protocol (Bureau of Land Management, 2021). These modules include species lists with data on the Winward stability rating of each species. Winward (2000) assigned greenline stability ratings to vegetation communities in the Intermountain Region based on their ability to buffer the forces of moving water. The stability ratings in the MIM plant list have been modified from Winward's original values and are used to calculate the Winward greenline stability rating, a long-term indicator used to monitor riparian condition. All species on the list were assigned just one of three numeric values: 2, 5, or 8.5.

We used the stability ratings from the Riparian Plant List as proxies for erosion control by converting the numeric values to low, medium, and high potential for erosion control. If a species had a different rating on each region's list, which happened rarely, we left the final value as "Uncertain."

We used additional sources to compile more detailed data for the focal marsh species. These sources were typically narrative descriptions that we read through and interpreted to fit our existing data structure. The Fire Effects Information System (FEIS) is an online tool that contains species reviews summarizing scientific literature on the distribution, ecological characteristics, fire ecology, fire effects, and management considerations for select species in the United States (USDA and USFS, 2021). The reviews often contain information on species' tolerance to disturbance, livestock and wildlife use, and other traits relevant to our study. FEIS data were available for eight of our focal marsh species. Other sources that we frequently used included *A Utah Flora 5th Edition* for plant structural information (Welsh and others, 2015) (e.g., root depth, root type, stem diameter, height), *Invasive Species Compendium* for information on non-native species (CABI, 2021), and *American Wildlife & Plants*, a book describing plant-animal associations (Martin and others, 1961). We used additional sources and articles as needed to fill in information not found elsewhere and to obtain greater confidence for our assigned values for some of the traits.

Data Structure

We created a uniform data structure for our database consisting of eight fields. The first two fields were the species scientific name and the name of the trait. The field "value" contains the trait value when only a single value was present, whereas the fields "value_low" and "value_high" contain numeric data when a range of values were listed. The "units" value lists the units for numeric values. "Sources" contains a list of one or more sources used to obtain the value and "notes" contains any additional notes about the value.

We assigned most non-numerical traits to values of "good, fair, poor" or "none, low, medium, high," based on the ratings used by the primary source where the data were extracted from (table 1). We averaged fields found in the PIN database to create three new fields, including the average livestock use values (from the cattle, horse, and sheep fields) and average wildlife ungulate cover and food (from the respective antelope, mule deer, and elk fields). For each of these fields, we translated values of good, fair, and poor to 3, 2, and 1 and then calculated the mean. We fit information we found from other sources, such as FEIS and journal articles, into our standard values using best professional judgement.

Nutrient Analysis

Nutrient Tolerance Scores

We assigned nutrient tolerance scores to sites by first converting the nutrient tolerance ratings of low, medium, and high to values of 1, 2, and 3, respectively. We then calculated the cover-weighted mean nutrient tolerance score by multiplying each species' nutrient tolerance rating by the species' cover estimate, summing those values across the site, and dividing by the total cover at the site, excluding species without assigned nutrient tolerance scores from the calculation. We only included sites in our analysis when at least 80% of the plant cover had an assigned nutrient tolerance score. We also limited our analysis to the four most common wetland types, which were fresh meadow, saline meadow, marsh, and mudflat.

URAP Field Data

We compared site nutrient tolerance scores with relevant field data collected by the UGS between 2013 and 2020 to assess the relationship between the two data sources. Detailed descriptions of URAP survey methods can be found in reports for each study (Menuz and others, 2014, 2016; Menuz and Sempler, 2018; Menuz and McCoy-Sulentic, 2019; McCoy-Sulentic and others, 2021), but methods were fairly consistent across years. Each study site consisted of a 40-m-radius circular plot when possible or a variable shape plot if necessary based on wetland dimensions. Surveyors recorded all plant species observed in the plot along with a corresponding cover estimate. In 2018 and subsequent years, surveyors used a progressive meander method where the amount of time the surveyor spent looking for new plant species depended on how complex the site was and how many new species had been found in the last period of the survey (McCoy-Sulentic and others, 2021). We used the plant composition data to assign nutrient tolerance scores to sites.

We compared the nutrient tolerance score data to two other types of data collected in the field, water samples and condition scores. Starting in 2014, surveyors collected water quality samples when surface water was present for general chemistry, total metals, and total non-filtered nutrients using sample containers obtained from the Utah Public Health Laboratory Chemical and Environmental Services Laboratory (Utah Public Health Laboratory).

Samples were analyzed at the Utah Public Health Laboratory following procedures outlined in the Client Services Manual (Utah Public Health Laboratory, 2013). We analyzed five parameters from the water quality samples, including total phosphate, ammonia, nitrate plus nitrite, total Kjeldahl nitrogen, and total nitrogen. All values were based on unfiltered water samples.

Surveyors also recorded data on wetland condition using a series of qualitative metrics. The water quality metric consisted of a series of statements that describe the degree to which a site has stressors that may impact water quality (table 2). Surveyors considered the distance to and degree of connectivity with stressors such as cattle manure, agriculture, stormwater runoff, and large point-source dischargers. Sites were given a rating of A, B, C, or D, with A indicating a site not likely to experience water quality stressors and D indicating a site likely to receive substantial and frequent inputs of water quality stressors. Of note, stressors were not limited to nutrient inputs.

Table 2. *Ratings for the URAP water quality condition metric.*

Rank	State
A	**There are no water quality stressors likely to impact site.** *All sites:* Within the AA, soils are intact with no evidence of damaging soil disturbance or excessive manure inputs. Any anthropogenic stressors within 500 m up-gradient from the AA must be minor (e.g., small areas with unnatural bare ground or lightly grazed pasture, a few fertilized lawns, etc.) and unlikely to impact the site (e.g., separated from site by at least 50 m of thick vegetation and on a shallow slope from site). *For sites receiving most water from channels:* The land cover of the contributing area for any channels reaching sites is predominantly natural with no point source dischargers that are likely to impact the site's water quality.
B	**Site likely to receive infrequent or minor inputs of water quality stressors.** *All sites:* Within the AA, some minor dung and soil disturbance from livestock (if grazing impacts very light, may be an A); up-gradient stressors within 500 m of site are minor, somewhat buffered from site, or well-buffered if more severe (e.g., runoff from dirt road with narrow buffer or expansive area of exposed sediment with 100-m vegetated buffer). *For sites receiving most water from channels:* The entire contributing area has <20% development or cropland; entire contributing area has a few minor point source dischargers; streams and lakes that contribute directly to the site are not on the 303d list.
C	**Site likely to receive moderate input of water quality stressors.** *All sites:* Within the AA, moderate dung and soil disturbance from livestock or up-gradient stressors that occur within 500 m of the site that are more moderate in extent or severity and less well-buffered from site (e.g., runoff from low-density development directly reaching site or nutrient input from a farm; consider both the slope leading to the site and the land cover between the stressor and the site; vegetated very low slope may be B and unvegetated very steep slope may be D). *For sites receiving most water from channels:* The entire contributing area has ~20%–60% development or cropland, or has point source dischargers that are distant from site or only a few that are closer; streams and lakes that contribute to the site are not listed on the 303d or are listed, but water quality is likely to be attenuated or improved before reaching the wetland by passing through reservoirs or emergent vegetation.
D	**Site likely to receive substantial water quality stressors.** *All sites:* Stressors may include: high levels of dung and soil disturbance from livestock within AA or, up-gradient stressors such as irrigation return flow water, fertilizer and pesticide application, and erosion from fires, construction, off-road vehicles, and dirt roads *discharging directly into sites*. May be considered C if run-off from the features is likely to occur infrequently, if slope is shallow, or if only a small area of the AA receives these stressors. Stressors may occur immediately adjacent or within sites or may be minimally buffered from sites (e.g., up a steep hill with very narrow or unvegetated buffer). *For sites receiving most water from channels:* The entire contributing area has >60% development or cropland, a high number of point source dischargers; or streams and lakes that directly contribute to the site are listed as impaired on the 303d list with no attenuation.

Data Analysis

We performed a two-way analysis of variance (ANOVA) to analyze the effect of wetland type and the water quality metric score on site nutrient tolerance scores and used Tukey's honestly significant difference test to determine differences among factors. We then conducted separate analyses for marsh and saline meadow sites, the two wetland types with the largest sample sizes. For this analysis, we combined the A and B ratings into a "low stress" category and C and D ratings into a "high stress" category (figure 1), based on the results of the initial analysis, and then used t-tests to test for differences in nutrient tolerance scores within each wetland type. Lastly, we used the Pearson correlation coefficient to test the relationship between site nutrient tolerance scores and individual water quality parameters. All analysis was done using base packages in the statical program R (R Core Team, 2021).

RESULTS

Data Compilation

We found data for between 3 and 244 unique Central Basin species for each trait (table 1). Traits with the fewest records were those that lacked a compiled source of information and thus were only populated for the focal marsh species, including root type, stem diameter, hydrologic stress indicator, and tolerance to cattle grazing. Of those four traits, tolerance to cattle grazing and root type were found for most of the 12 marsh species, whereas the other two were found for one-fourth or fewer of the species. All other traits were present for at least 125 species.

Some species-trait combinations were listed more than once due to difficulty in resolving conflicting data. This occurred either when additional research into one of the marsh species conflicted with compiled data or when two sources of compiled data conflicted with one another. We evaluated data from PIN to determine how frequently the PIN data conflicted with other sources of information, removing species-trait combinations where PIN data agreed with some sources and disagreed with others (three total records were dropped). We first looked at erosion control potential, a trait where we had values from both PIN and the Riparian Plant List. Of the 88 species rated by both data sources, only 38 had the same rating; 39 differed by one rank and 11 differed by two (i.e., "Low" versus "High"). We also evaluated wildlife and livestock use traits that were rated both by PIN and through focused research for the focal marsh species. Sixty unique species-trait combinations were rated by multiple sources for wildlife traits and 15 for livestock use traits. PIN data agreed with other sources of data 93.3% of the time for livestock use traits and 85.0% of the time for wildlife traits. Disagreements were never more than one unit (i.e., "Low" to "Medium" but not "Low" to "High").

Nutrient Analysis

We calculated nutrient tolerance scores for 280 wetland sites in the Central Basin, though only 111 sites had enough data to include in subsequent analysis. After dropping uncommon wetland types, 102 sites remained, including 8 fresh meadow, 15 mudflat, 24 saline meadow, and 55 marsh sites. These sites represented 15.7% of fresh meadow, 68.2% of mudflat, 58.5% of saline meadow, and 77.5% of marsh sites in the full dataset and included 17 sites rated as A for the water quality metric, 8 as B, 36 as C, and 41 as D. We found a statistically significant difference in nutrient tolerance scores by both wetland type ($F(3) = 17.61$, $p < 0.001$) and water quality rating ($F(3) = 9.79$, $p < 0.001$, figure 2). Mudflats had significantly higher nutrient tolerance scores than fresh meadows ($p < 0.001$) and saline meadows ($p < 0.001$), and marshes had significantly higher mean nutrient tolerance scores than fresh meadows ($p = 0.01$) and saline meadows ($p < 0.001$). Sites rated as A had significantly lower nutrient tolerance scores than sites rated as C or D ($p < 0.001$); no other comparisons were significant. Analysis of individual wetland types with grouped water quality metrics showed similar results. The six saline meadow sites classified as low water quality stress had lower nutrient tolerance scores than the six sites classified as high stress ($t(13.6) = -2.58$, $p = 0.022$, figure 3) and the 11 marsh sites classified as low water quality stress had lower nutrient tolerance scores than the 44 sites classified as high stress ($t(20.9) = -5.58$, $p < 0.001$, figure 3).

Only 30 sites had water quality data, including 2 fresh meadow, 4 saline meadow, 4 mudflat, and 20 marsh sites. We were not able to analyze total Kjeldahl nitrogen due to low sample size ($n = 8$) and only 25 sites, including 16 marsh sites, had total nitrogen data. None of the correlations between water quality parameters and site nutrient tolerance scores were significant for either all sites or marsh sites.

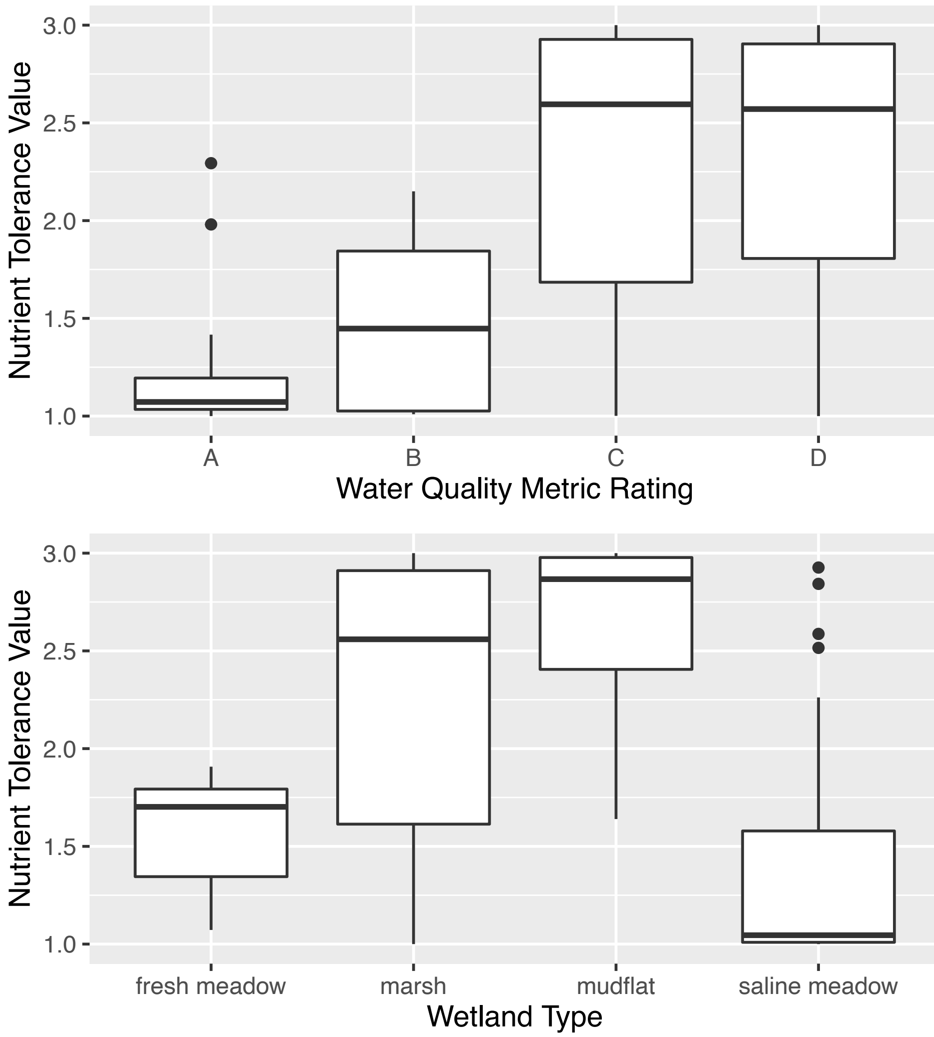

Figure 2. *Site nutrient tolerance values by water quality metric rating and wetland type.*

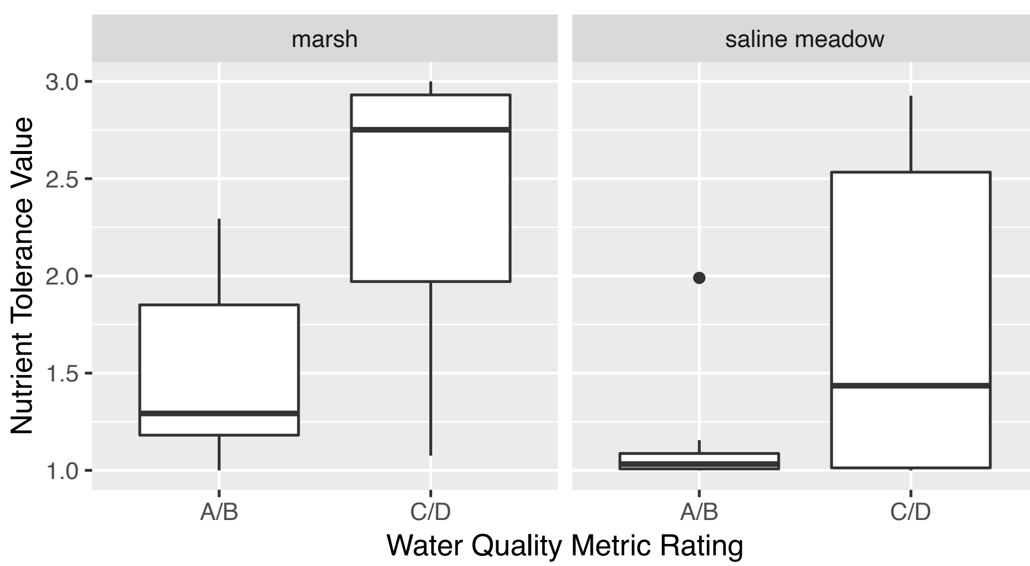

Figure 3. *Site nutrient tolerance values for marsh and saline meadow wetlands by grouped water quality metric rating.*

DISCUSSION

Data Compilation

We found trait data for between 31% and 61% of the plant species documented in Central Basin wetlands for all but four traits, mostly by using existing compiled trait lists. Many of the species for which we found data were amongst the most common species in the Central Basin. For example, for the waterfowl food trait, we found data for 16 of the 20 species with the highest cover and 31 of the 50 most frequently found species. Continuing to fill in data gaps by targeting these abundant species would be the most efficient way to build the plant trait database. In cases where data cannot be found for target species, we may be able to infer ratings based on similar species by, for example, assuming that certain ratings will be the same across all members of a genus.

Obtaining data for the four traits with very few values will require more effort. For two of the traits, stem diameter and root type, we obtained values for many species using floristic keys such as *A Utah Flora* with minimal effort. We would likely need to conduct focused literature reviews to obtain data for the other two traits, tolerance to cattle grazing and hydrologic stress indicator, which would require substantially more effort. We found little hydrology stress indicator data when we reviewed literature for the marsh review, suggesting that this trait may not be worth evaluating due to the limited availability of information.

Agreement among different data sources varied, though we did find good agreement between PIN wildlife and livestock trait values and other sources of data. In some cases, we kept multiple values for a single species-trait combination in the database because of the high degree of disagreement. These duplicates will need to be resolved before analysis can be conducted on those traits. Although disagreement was rare for most traits, we found large differences in values between PIN and other data sources (primarily the Riparian Plant List) for the erosion control potential trait. Additional investigation into these data sources could perhaps help elucidate how the information was obtained and the best way to handle these large discrepancies.

In addition to managing duplicate values, additional work could be done to combine similar traits together or construct new traits from existing values. For example, data on root type, root depth, height, and stem diameter could be used to assign values for traits such as erosion control and floodwater control. The palatable browse animal and palatable graze animal traits from USDA Plants could potentially be combined with livestock and wildlife use traits from PIN to increase the number of species with data for associated traits.

Nutrient Analysis

We consistently found that sites rated as having high water quality stress had higher nutrient tolerance scores than sites with lower water quality stress. One interpretation of this finding is that water quality stressors such as nitrogen and phosphorus additions alter plant community composition to favor species that are tolerant of nutrient inputs, as has been found in many studies (Soons and others, 2017; Goodwillie and others, 2020). However, it is also possible that areas with high water quality stress frequently have other characteristics that drive plant community composition, particularly since relatively few species drove most of the differences between sites. In our data, high-stress saline meadows and marshes tended to have higher cover of *Phragmites australis* and *Typha* ssp. than low stress sites, and low stress sites tended to have higher cover of *Schoenoplectus americanus* and *Juncus arcticus* (in addition to other species that were specific to a particular wetland type), though all four species were found in all four site types. Furthermore, the majority of our high-stress sites were located along the east shore of Great Salt Lake whereas many of the low stress sites were located elsewhere in the Central Basin (figure 1). Multiple factors besides nutrient inputs may lead to the abundance of *P. australis* and *Typha* ssp. around Great Salt Lake. For example, the spread of *P. australis* around Great Salt Lake is commonly attributed to flooding on the lake in the 1980s that left behind bare soil and high-light conditions that allowed seeds and seedlings to thrive (Kettenring and others, 2020).

Despite these limitations, the consistent results found in the nutrient tolerance analysis support the idea of using plant trait data to assess wetlands. We recommend rerunning the nutrient tolerance analysis after assigning nutrient tolerance ratings to additional species, since we had to eliminate over half of the Central Basin wetland sites due to lack of data. This second analysis would hopefully allow us to analyze data for additional wetland types and across a wider geographic area. We also recommend conducting similar analyses for other traits to evaluate how well they correspond with data such as wildlife observations and functional ratings.

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