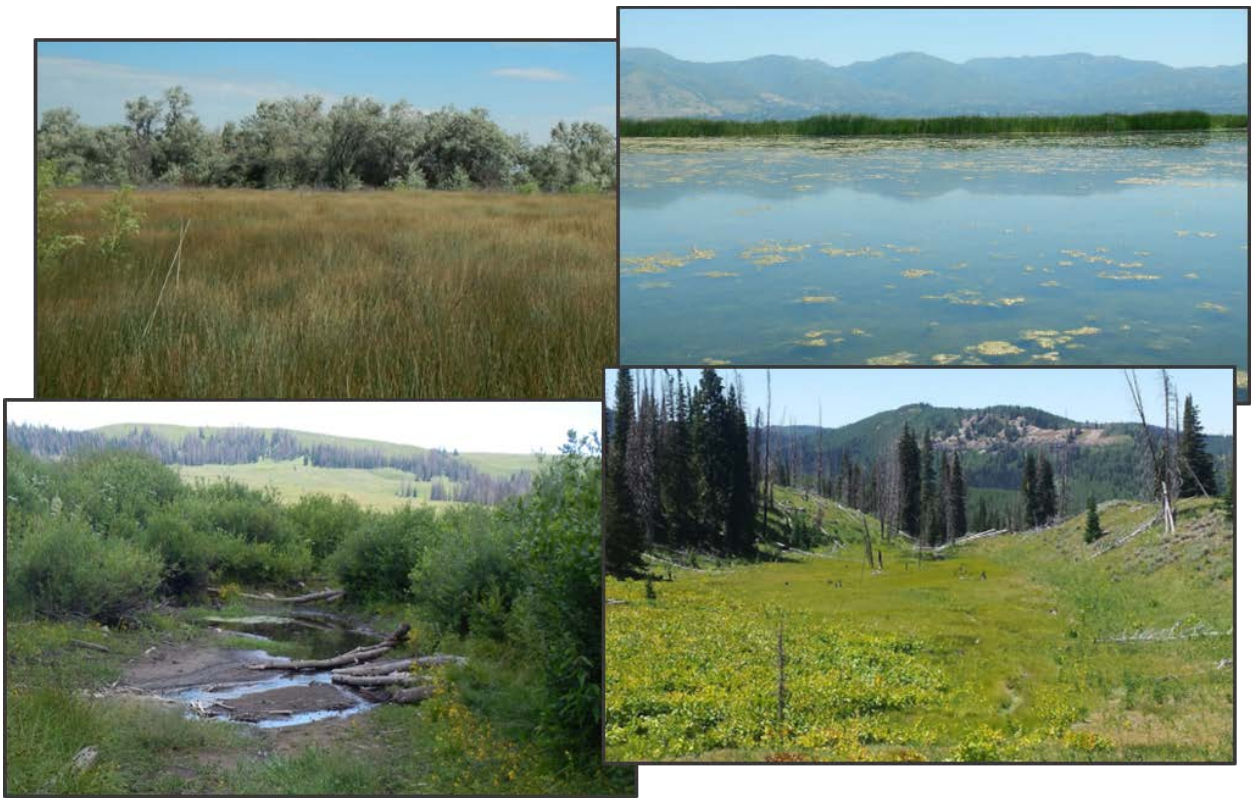
Jordan River Watershed
Wetland Assessment and Landscape Analysis



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Cover (clockwise from upper left): Alkaline depression in the floodplain of the Jordan River, submergent marsh in a managed impoundment at a privately owned duck hunting club near Great Salt Lake, wet meadow peatland in the Wasatch Montane Zone near the headwaters of the Little South Fork Provo River, and montane shrubland in the Wasatch Montane Zone near Lake Creek.

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Executive Summary

The Utah Geological Survey, with a grant from the U.S. Environmental Protection Agency and supplemental funding from the Uinta-Wasatch-Cache National Forest and the Utah Endangered Species Mitigation Fund, assessed wetlands in the Jordan River watershed in 2015 and 2016. The assessment project focused on wetlands and shallow waterbodies <1 m deep (e.g., playas, shallow impoundments, lake margins). The project had three main objectives, including:

1) obtaining baseline data on the types, common stressors, range of conditions, and potential functions of wetlands,
2) characterizing common Ecological Systems, including conducting an exploratory analysis to quantify reference condition for each System, and
3) creating a landscape profile by summarizing wetland spatial data.

To achieve the first two objectives, field surveys were conducted at 102 randomly selected and 7 subjectively selected wetland sites. Baseline data were analyzed for seven ecoregional strata, including three in the Central Basin ecoregion: Great Salt Lake, Jordan, and Utah Lake (from north to south), and four in the Wasatch Mountains ecoregion: Mountain Valleys, Semiarid Foothills, Wasatch Montane Zone, and Alpine Zone (from lowest to highest elevation).

Almost all wetland area in the watershed is surrounded by buffers of (semi-)natural land cover at least 50 m wide. Common stressors within 100 m of wetlands include non-native plant species (adjacent to 94% of wetland area), livestock grazing (38%), linear disturbances such as roads and power lines (37%), excessive filamentous algae (34%), and ditches (23%); these stressors are common across the watershed. Other stressors are only common in one ecoregion, including vegetation control and off-road vehicle tracks in the Central Basin and trails in the Wasatch Mountains.

Landscape-scale water quality stressors and hydrologic alteration are very common in the Jordan River watershed. Over 70% of wetlands in the Central Basin have a nearby hydrologic connection with point source dischargers or run-off from development and 50% have a nearby connection with agricultural run-off; these stressors were also present in the Wasatch Mountains ecoregion, particularly in the Mountain Valleys, but generally less prevalent. Water quality stressors often come from streams, lakes, or canals that directly provide water to wetlands instead of via overland runoff. All or almost all wetland area in the Great Salt Lake, Jordan, Utah Lake, and Mountain Valleys strata and half the wetland area in the Semiarid Foothills are estimated to have some degree of hydropattern alteration. Alteration was most pronounced in the Great Salt Lake, Jordan, and Mountain Valleys strata, due to management for wildlife habitat, urban run-off, and direct and indirect irrigation inputs, respectively. Control structures, berms, ditches, irrigation return flow, and impervious surface each affect over one-third of wetland area in the Central Basin ecoregion and in the Mountain Valleys.

Livestock grazing and excessive algae were common stressors within sites, estimated to occur in 37% and 31% of wetland area, respectively, and off-road vehicle tracks and vegetation control were found in 28% and 16% of Central Basin wetlands, respectively. However, soil disturbance from these activities was generally minor; 93% of wetland area is estimated to have good or excellent soil condition. Despite the prevalence of water quality stressors noted above, algae and turbidity conditions within

wetlands are generally good or were not evaluated due to lack of surface water; 22% of wetland area is estimated to be fair to poor for algae and 7% for turbidity.

Over one-third of wetland area has fair to poor litter accumulation, primarily in the Central Basin, and 15% has poor woody species regeneration or dominance by non-native woody species. Non-native plant species are extremely widespread in wetlands in the watershed. Almost 40% of all wetland plant cover in the Central Basin and 25% in the Wasatch Mountains is estimated to be comprised of non-native species. Eleven noxious weed species were documented during the study; most had fairly low cover in wetlands except for *Phragmites australis* (common reed) and *Tamarix* (tamarisk) in the Central Basin and *Cirsium arvense* (Canada thistle) in the Wasatch Mountains. *Phragmites australis* is the most widespread noxious weed species, with an estimated 13.6% cover across wetlands in the Central Basin.

Wetlands in the Jordan River watershed provide many functions, including wildlife habitat, recreational use, and water quality improvement. We documented over 45 species of birds, mammals, amphibians, and fishes at study sites, despite not conducting focused wildlife surveys, including three state sensitive species: American white pelican, boreal toad, and Columbia spotted frog. We collected data on habitat features for boreal toad and Columbia spotted frog; between one-third and one half of wetland area within the species' respective ranges in the Wasatch Mountains may be suitable for breeding. However, threats related to turbidity and recreational use are relatively common at potential boreal toad breeding sites and threats related to fragmentation and water quality stress from roads were common near potential Columbia spotted frog breeding sites. Wetland recreational use can be inferred from the landscape profile which shows that about 15% of wetland area in the watershed is privately or publicly managed for duck hunting and just under half the wetland area is on state or federal land, much of which is located near hiking trails. Most wetlands in the Jordan River watershed are estimated to currently provide some water quality improvement function, with both capacity and landscape need for improvement. Wetlands in the Semiarid Foothills, Wasatch Montane Zone, and Alpine Zone frequently did not show a landscape need for water quality improvement but had capacity that could be important in the face of future landscape changes such as fires or new development.

We documented nine Ecological Systems, including three Systems surveyed at one site each. We characterized the remaining Systems, including alkaline depressions, playas, and basin marshes in the Central Basin and wet meadows, foothill shrublands, and montane shrublands in the Wasatch Mountains, by summarizing hydrology, water chemistry, and plant community metrics. We screened for low disturbance reference sites in each System using data on site and surrounding stressors and plant community composition; we had to relax the screen for alkaline depressions, playas, and basin marshes to obtain at least four reference sites per System. Almost 47% of montane shrublands, about 11% of wet meadows, and between 16% and 23% of sites in other Systems had both condition scores and mean C values (a vegetation metric) above the 25th percentile of reference site scores.

Wetlands in most of the watershed were mapped using imagery from 1998, though some were mapped using imagery from the 1980s. An estimated 17% of the mapped area does not appear to be wetland based on 2015 imagery, though only 3% overlaps new development; the remaining may have been incorrectly mapped or lost to hydrologic changes. We updated spatial data in a portion of Salt Lake County; we mapped approximately one-third less wetland area than was in the original dataset. We used the wetland spatial data to profile wetlands in the watershed. Meadows, marshes, shallow lakes, and unconsolidated shores (i.e., playas, mudflats) each comprise between 20% and 28% of the wetland area in the Central Basins (where 90% of all mapped wetlands occur), whereas meadows comprise over half the wetland area in the Wasatch Mountains. Wetland polygons frequently overlapped land mapped as irrigated in two strata, with 46% overlap in the Mountain Valleys and 18% overlap in the Semiarid Foothills. According to an aquatic resource stress model, forested, scrub shrub, and pond wetlands in the Central Basin and marshes and meadows in the Wasatch Mountains face the most local stress. Local stress is highest in the Jordan and Mountain Valleys strata and lowest in the Wasatch Montane Zone and Alpine Zone.

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Introduction

Project Background

Wetlands in the Jordan 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 and Utah Lake. These wetlands have the potential to provide important ecological services including wildlife habitat, water quality improvement, and flood attenuation. Wetlands in the watershed support millions of migrating and nesting birds and two state sensitive amphibian species, Columbia spotted frog and boreal toad. 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 on the Provo River Blue Ribbon Fishery.

Anthropogenic disturbances have the potential to affect wetland condition and their ability to provide ecological services. In the Jordan river watershed, about 30% of the land cover in the Central Basin and Range ecoregion and 3% of the land cover in the Wasatch and Uinta Mountains ecoregion is developed, and approximately 7% of the entire watershed is used for agriculture. Livestock grazing is common across much of the watershed, and wastewater treatment plants discharge to waterbodies that supply many of the wetlands in the watershed. Many reservoirs and streams in the watershed are not meeting water quality standards (Utah Division of Water Quality, 2016b) and hydrologic modifications such as reservoirs, groundwater withdrawal, and diversions are common. However, little work has been done 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) and supplemental funding from the Uinta-Wasatch-Cache National Forest, conducted a field assessment of wetlands in the Jordan River watershed to provide data on the type, condition, and potential function of wetlands in the watershed. Our project had three major objectives, including obtaining baseline data on the condition and potential function of wetlands, describing common Ecological Systems, and creating a landscape profile using mapped wetland data and ancillary information to better understand the landscape setting of wetlands in the watershed.

Overview of Wetland Assessments

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 moderately detailed, often relying on qualitative rather than quantitative evaluation. These assessments maximize the amount of field sites that can be surveyed and thus 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. For this project, we created a Level I landscape profile, collected primarily qualitative Level II wetland condition and function data, and collected more intensive Level III water chemistry and plant community composition data.

Condition Versus Function Assessments

The assessments conducted for this project evaluate wetland condition and some aspects of wetland function. 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 others, 2016). 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 the condition assessment, wetlands are evaluated to determine the degree to which they deviate from a reference standard, or anthropogenically unaltered, wetland. In contrast, functional assessments 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.

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, playa). The reference standard condition can refer to the expected state prior to any anthropogenic disturbance or at a specified historical 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). For the condition assessment, we used a reference standard 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 others, 2016). While reference standard condition is ideally determined from field observations of undisturbed or minimally disturbed wetlands (i.e., reference standard sites), there can be too few undisturbed sites in some highly altered landscapes to determine the natural range of variability. Because of this, reference standards for the condition assessment 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. In contrast, we used the least disturbed condition as the reference standard for our exploratory analysis of wetland condition by Ecological System.

Wetland Classification

We used three wetland classification methods in this study: Cowardin, hydrogeomorphic (HGM), and Ecological System. The only currently available spatial data for wetlands in Utah is the National Wetlands Inventory (NWI). NWI classifies wetlands using the U.S. Fish and Wildlife Service's Cowardin classification system, 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). We used the Cowardin classification system 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 and function of wetlands during field assessments. The HGM system classifies wetlands as one of seven types based on water source, hydrodynamics, and geomorphology (Brinson, 1993). HGM classes are useful for determining the expected condition of hydrologic attributes, such as water retention time, nutrient cycling capacity, and hydroperiod, and for functional potential, such as water quality improvement and floodwater storage. For this study, wetlands were either classified as lacustrine fringe, riverine, slope, or depressional (four of the original HGM classes) or as one of three novel classes predominantly found around Great Salt Lake, impoundment release, depressional impoundment, and depressional impoundment fringe. These novel classes were developed by the UGS to improve description of highly managed wetlands around Great Salt Lake. *Impoundment release* wetlands receive horizontally spreading water when water is released from an upgradient impoundment, typically occur on mudflats around Great Salt Lake, and lack major channels. *Depressional impoundments* are wetlands that occur within artificial impoundments >8 ha in size and <2 m deep with primary water fluctuations that are vertical with rising and falling water levels due to steep impoundment sides. *Depressional impoundment fringe* wetlands occur on the edge of impoundments and receive water that spreads and recedes horizontally with changing water levels.

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); 15 wetland and riparian Ecological Systems have been described for the state of Utah. Ecological Systems generally describe classes of wetlands that may be recognized by non-specialists, such as marshes and montane shrublands. 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.

Project Objectives

Objective 1: Baseline data by ecoregional strata

Our first objective was to obtain baseline data on wetlands in the Jordan River watershed, including estimates of the types, range of conditions, potential functions, and common stressors. These data can provide information for conservation and management planning and serve as a baseline for future studies. We used the Utah Rapid Assessment Procedure (URAP) to collect field data at over 100 wetlands in the Jordan River watershed. We present results for each of the two Omernik Level III ecoregions in our project area, the Central Basin and Range (“Central Basin”) and the Wasatch and Uinta Mountains (“Wasatch Mountains”) and for seven strata nested within the ecoregions. We also produced estimates specific to wetlands on the lower elevation portions of the Uinta-Wasatch-Cache National Forest (National Forest).

Objective 2: Ecological System characterization

Our second objective was to characterize common Ecological Systems in Utah. Ecological Systems are a useful classification system for determining vegetation targets (e.g., cover, richness, etc.)

for restoration or mitigation projects and may be used in the development of quantitative reference standards for Utah's wetlands. We summarized data on attributes related to elevation, depth and extent of surface flooding, water quality parameters, and richness and cover of plant species within each common Ecological System in the watershed. We also conducted an exploratory analysis to quantify reference condition by Ecological System based on a wetland condition score and on mean C, an index of plant quality. The exploratory analysis was used to determine the strengths and weaknesses of classifying wetlands by Ecological System when developing reference standards and to identify data gaps.

Objective 3: Landscape analysis

Our third objective was to create a landscape profile of wetlands in the watershed. The landscape profile combined information on wetland location, wetland type, and wetland stress to highlight uncommon, unprotected, or threatened wetland types. The landscape profile can be used to identify areas and wetland types with the most need for restoration, creation, or mitigation. However, the landscape profile depends on existing mapped wetland data, which is out-of-date. We undertook two actions to provide better context for the mapped data. First, we estimated the accuracy of the available mapped wetland data in the watershed and provided potential explanations for changes in wetland area based on examination of randomly selected points. Second, we remapped a portion of the watershed and compared the old mapping data with the new.

Study Area

Geographic and Ecoregional Setting

The study area for this project was the Jordan River 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 is entirely in Utah and has an area of approximately 9855 km^2. The watershed is bordered by the Wasatch Range to the east, the East Tintic and Oquirrh mountains to the west, the Levan Ridge to the south, and Great Salt Lake to the northwest. Most of the watershed drains to Utah Lake from the Wasatch Range and small ranges to the south and west and then flows via the Jordan River to Great Salt Lake, though some areas drain directly to Great Salt Lake or the Jordan River.

The Central Basin and Wasatch Mountains ecoregions comprise 45.5% and 54.5% of the area of the Jordan River watershed, respectively (Omernik, 1987). Though occupying about half the watershed area, the Central Basin ecoregion contains just over 90% of the watershed's wetland acreage. Most wetlands occur along the shallow edges of Utah Lake or along the southeastern shore of Great Salt Lake. Wetland extent and type along both waterbodies fluctuate with changes in water levels, though the highly managed systems of canals, control structures, and impoundments along Great Salt Lake dampen some of this fluctuation. 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),* spikerushes (*Eleocharis* spp.), and mixtures of native and non-native grasses are common 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*

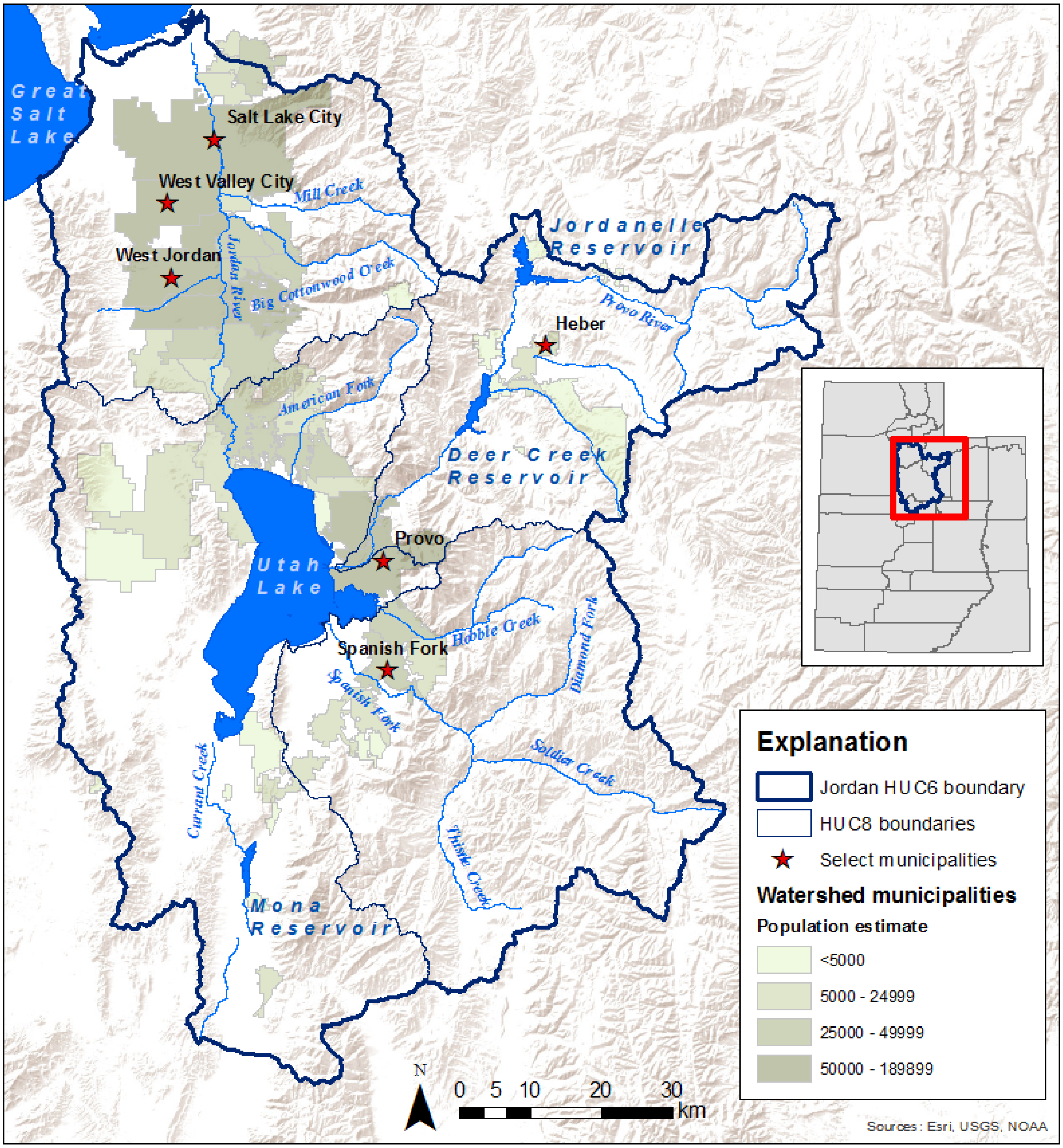

Figure 1. Overview of the Jordan River watershed, including municipalities, major streams and waterbodies, and HUC8 boundaries.

spp.). Other wetland types found in the Central Basin ecoregion include spring complexes, retention ponds, and riparian wetlands along the Jordan River.

The Wasatch Mountains ecoregion is composed of high, glaciated and partially glaciated mountains, dissected plateaus, foothills, and high elevation valleys (Woods and others, 2001). Wetlands within the ecoregion include headwater meadows and shrublands formed from groundwater and snowmelt, lower-elevation riparian areas, springs and seeps, and small and typically excavated depressions used for watering livestock. Irrigated cropland and pastureland have replaced native shrub communities in much of the mountain valleys, leading to wetlands that receive a mixture of natural and altered hydrologic inputs.

Climate and Hydrology

Most precipitation in the Jordan River watershed falls as snow in the higher elevation mountain valleys, foothills, and mountains, which receive between 51 and 88 cm of precipitation per year (Daly and others, 2008). The Central Basin ecoregion receives between 40 and 51 cm of precipitation. Mean annual temperatures in the study area range from 3.2°C in the Uinta Mountains and alpine areas to between 5.2 and 7.5°C in the mid-elevation mountains and mountain valleys and between 10 and 11.8°C in the Central Basin ecoregion.

Most of the watershed drains to Great Salt Lake via the Jordan River and canals off the river or directly to Great Salt Lake, except for a small internally draining basin to the west of Utah Lake. About three-quarters of the watershed first drains to Utah Lake via several rivers from the Wasatch and Uinta Mountains and smaller tributaries and springs to the south and west, before exiting Utah Lake to the Jordan River. The Jordan River accounts for approximately 17% of the surface flow and 12% of the overall inflow to Great Salt Lake (Utah Division of Forestry, Fire, and State Lands, 2013).

Major dams and reservoirs in the Jordan River watershed provide a total storage capacity of over 1.3 million acre-feet of water, almost all of which is in the Utah Lake portion of the watershed (Utah Division of Water Resources, 2014a). Utah Lake was dammed in 1872 to provide water to Utah and Salt Lake counties and additional reservoirs were built in the early 1900s, including Mona Reservoir and more than a dozen small reservoirs in the Uinta Mountains. More recently, the Bureau of Reclamation has invested in several large water projects in the region, including the construction of Deer Creek and Jordanelle Reservoirs along the Provo River and transbasin diversion projects bringing water from the Duchesne and Weber basins.

Wildlife

The most well-known and extensive wetland habitat in the Jordan River watershed occurs around Great Salt Lake and Utah Lake. Great Salt Lake wetlands support millions of migratory birds, including two-thirds of all Wilson's phalaropes (*Phalaropus tricolor*) and half of all eared grebes (*Podiceps nigricollis*) (Jehl Jr., 1988) as well as large populations of breeding birds, including several species of gull, heron, and egret (Paul and Manning, 2002). Two species that utilize Great Salt Lake and Utah Lake wetlands, American white pelicans (*Pelecanus erythrorhynchos*) and long-billed curlew (*Numenius americanus*), have been designated as 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).

The rivers, streams, lakes, and reservoirs in the Jordan River watershed provide habitat for several native fish species, although non-native fish are also abundant and often dominate the larger streams and lakes. The June sucker, a federally endangered native fish, is endemic to Utah Lake (June Sucker Recovery Team, 1999). Two other native fish species known to occur in the watershed, the bluehead sucker (*Catostomus discobolu*s) and Bonneville cutthroat trout (*Oncorhynchus clarkia utah*), receive special management in Utah under a state Conservation Agreement (Utah Division of Wildlife Resources, 2017). A third Conservation Agreement species, the least chub (*Iotichthys phlegethontis*), has been extirpated from the Jordan River watershed, though is extant in other parts of the state (Bailey and others, 2005).

Wetland habitats are important for a number of amphibian and mammal species in the Jordan River watershed. Common native amphibian species include the western chorus frog (*Pseudacris maculate*), northern leopard frog (*Lithobates pipiens*), and tiger salamander (*Ambystoma tigrinum*) as well as the non-native American bullfrog (*Rana catesbeiana*). Small populations of both the Columbia spotted frog (*Rana luteiventris*), a Conservation Agreement species, and boreal toad (*Bufo boreas*), a Utah Species of Concern, also occur in the watershed (Bailey and others, 2006). The American beaver (*Castor canadensis*) and the less common northern river otter (*Lontra canadensis*) both occur along creeks, rivers, and ponds, primarily in the upper portions of the watershed.

Land Ownership and Land Use

Land ownership within the Jordan River watershed is 50% private, 39% federal, and 11% state, according to GIS calculations using data from the Automated Geographic Reference Center (http://gis.utah.gov/data/sgid-cadastre/land-ownership). Government land managers in the Central Basin ecoregion include the U.S. Bureau of Land Management and the Utah School and Institutional Trust Lands Administration south and west of Utah Lake, the Utah Division of Wildlife Resources at Farmington Bay Waterfowl Management area on the shore of Great Salt Lake, and the Utah Division of Forestry, Fire, and State Lands on the lakebeds of Utah Lake and Great Salt Lake. About 25% of land in the watershed adjacent to Great Salt Lake is privately managed for duck hunting or avian conservation. Private land ownership decreases, and U.S. Forest Service ownership increases, with increasing elevation in the Wasatch Mountains ecoregion, ranging from 78% private ownership in the mountain valleys and about 55% in the lower montane areas to <1% in the highest elevation montane areas. The State owns about 7% of the land in the Wasatch Mountains ecoregion, much of it as state parks or wildlife management areas. About 4% of the 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.

The population in the Jordan River watershed is predominantly located in the Central Basin ecoregion, and over 1.5 million people can be found in the band of development extending from Bountiful to the north to Spanish Fork and smaller municipalities to the south. Populations are continuing to grow, with some of the highest rates of anticipated growth on the northwestern side of Utah Lake, southern Utah County, and Wasatch County (Utah Governor's Office of Management and Budget, 2012). Salt Lake City, West Jordan, West Valley, and Provo all have over 100,000 people as of 2010. Heber, along the middle Provo River, has the largest population in the Wasatch Mountains ecoregion with more than 11,000 people. The adjacent town of Midway has a population of almost 4,000, and the remaining towns have populations less than 1000. Overall, development accounts for 30% of the land cover in the Central Basin ecoregion and 3% in the Wasatch Mountains ecoregion, including 19% in the mountain valleys (Landfire, 2014). Approximately 7% of the watershed is used for agriculture, of which about 61% is irrigated and the remainder is sub-irrigated, idle, or dry farmed (Utah Division of Water Resources, 2014b and c). Alfalfa and pasture are the most common agricultural uses on irrigated land, followed by corn, grain, and grass or hay. The remaining land cover in the watershed is a mixture of open water, grassland, shrubland, and forested areas in the Central Basin ecoregion and forest with a smaller component of shrubland in the Wasatch Mountains ecoregion. Much of the non-agricultural, non-developed land is used as rangeland.

Mining is an important part of the current and historical landscape of the watershed. Rio Tinto's Bingham Canyon Mine, the largest human excavation on earth, and associated mining infrastructure, including large tailings ponds, occur in the northern Oquirrh Mountains and adjacent to Great Salt Lake. Rock quarries are common, including several large operations on the eastern bench of the Central Basin ecoregion. The largest concentration of historical mineral mining operations recorded in Utah Division of Oil, Gas, and Mining's database of abandoned mines are found in the drainages for Big and Little Cottonwood Creeks, American Fork, just east of Park City, and the southern edge of the Oquirrh Mountains (R. Williams, Utah Division of Oil, Gas, and Mining, unpublished information, 2015).

Recreation is another important land use in the watershed. The Jordan River watershed supports Blue Ribbon Fisheries at Jordanelle Reservoir and the lower and middle Provo River, meaning that these waterbodies have met criteria for high quality fishing, outdoor experience, fish habitat, and economic benefits (https://wildlife.utah.gov/hotspots/blueribbon.php). Waterfowl hunting and bird watching are popular along Great Salt Lake. Other recreational opportunities include big game hunting, boating in lakes and reservoirs, skiing, and hiking.

Water Quantity and Water Quality

The combined population of the three counties that make up the majority of the Jordan River watershed—Salt Lake, Utah, and Wasatch—is projected to more than double between 2010 and 2060 (Utah Governor's Office of Management and Budget, 2012) and current water supplies are not expected to be able to meet the anticipated need (Utah Division of Water Resources, 2010 and 2014a). Water demand is already too high to be met by existing supply during drought years in parts of Utah County (Utah Division of Water Resources, 2014a). The additional demand may be met through transfers of existing agricultural water rights to municipal rights, increased water conservation, and new water development projects. Diminished irrigation return flows, declining groundwater levels, and increased water demand are all likely to impact water availability in aquatic and wetland systems.

Water quality in the Jordan River watershed has been affected by factors including urban run-off, industrial dischargers, agricultural, and resource extraction (Toole, 2011). Seven of the 15 lakes assessed by the Utah Division of Water Quality in the watershed are listed as impaired (Utah Division of Water Quality, 2016b). Only 11 of the 119 water quality stream assessment units in the watershed were designated as fully meeting water quality standards, whereas 47 were designated as impaired and 2 have water quality plans designed to address impairments; the remaining units did not have enough data to evaluate all uses. The most common impairments were *E. coli* and impaired macroinvertebrate communities, followed by dissolved oxygen, total dissolved solids, and temperature. Sixteen assessment units are impaired for selenium, cadmium, arsenic, or other elements commonly associated with mining legacies.

Field Study Design and Survey Methods

Site Selection

Target Population and Sample Frame

The target population for this study was wetlands within the Jordan 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 wetland hydrology indicators, hydric soil indicators, and a predominance of hydrophytic plant species (Cowardin and others, 1979; U.S. Army Corps of Engineers, 2008; U.S. Army Corps of Engineers, 2010). For this study, a site was considered part of the target population if it had an indicator of wetland hydrology and if it had hydrophytic plants and hydric soils if vegetation or soils were present. We did not include areas we termed dry mudflats as part of the target population. These were areas along the shore of Great Salt Lake and, less frequently, Utah Lake, that never appeared wet across all the years of imagery available in Google Earth, though they are likely inundated during years with high water levels.

The U.S. Fish and Wildlife Service's NWI program maps wetlands and deepwater habitat throughout the United States using the Cowardin classification system. We obtained NWI data for the state of Utah from the U.S. Fish and Wildlife Service website (http://www.fws.gov/wetlands/data/State-Downloads.html) on March 30, 2015; the file was last updated on October 6, 2014. The urban Wasatch Front portion of the study area was mapped using imagery from 1998 and the rest of the study area was mapped using imagery from between 1981 and 1985. For the Jordan River watershed project, we focused our sampling effort on areas with water <1 m deep for the safety of field crews and because different sampling methods are more appropriate for deepwater areas. We removed deepwater areas from the NWI data by removing all polygons mapped as lacustrine limnetic (L1); these are deepwater areas with water ≥2.5 m deep. We kept polygons mapped as lacustrine littoral (L2), which includes open water <2.5 m in depth, lakeshore edges, playas, and mudflats and impoundments around Great Salt Lake. In the Cowardin classification system, riverine systems include wetlands and deepwater habitat in channels, unless the wetlands are dominated by persistent vegetation or mosses and lichens (https://www.fgdc.gov/standards/projects/FGDC-standards-projects/wetlands/nvcs-2013). We wanted to include oxbows and backwaters in our sample frame, but not perennially flowing streams or stream washes that only occasionally contained water. We eliminated all riverine polygons from the sample frame that were in the unconsolidated bottom or streambed classes. Based on visual inspection in ArcGIS, features mapped as unconsolidated bottom were mainstem river channels and features mapped as streambed were channels associated with intermittent streams. We kept riverine unconsolidated shore features in the sample frame because these were often on the edges of streams in areas that received frequent overbank flooding.

Wetlands were included in the sample frame if most of the polygon was located in the Jordan HUC6. Twenty-six polygons crossed the Jordan HUC6 boundary; most of these crossings were minor, but one feature extended over 6 km into the adjacent HUC6 at Farmington Bay Wildlife Management Area. We kept this entire feature in our sample frame for the sake of consistency and to ensure that the polygon would not be excluded from future assessments.

Strata and Selection of Study Sites

We selected wetland sites using six strata. In the Central Basin ecoregion, 20 sites were allocated to the Great Salt Lake stratum (Salt Deserts, Shadscale-Dominated Saline Basins, and Wetlands Level IV Ecoregions), 10 sites to the Jordan stratum (the remaining area of the Jordan HUC8), and 20 sites to the Utah Lake stratum (the remainder of the Central basin ecoregion). In the Wasatch Mountains ecoregion, 6 sites were allocated to the Alpine zone (Alpine Zone, Uinta Subalpine Forests, and Mid-Elevation Uinta Mountains Level IV ecoregions), 24 sites to the National Forest stratum (Uinta-Wasatch-Cache National Forest land outside of the Alpine Zone), and 20 sites to the remainder of the ecoregion. For data analysis, we analyzed results for the National Forest and Alpine Zone strata and for three additional Level IV ecoregional strata, the Mountain Valleys, Semiarid Foothills, and Wasatch Montane Zone. All sites outside the Alpine Zone stratum were classified into one of these latter three strata and analyzed with weights appropriate to their selection probability in the original data selection (figure 2). A summary of characteristics of the ecoregional strata used for data analysis can be found in table 1.

We used the spsurvey package (Tom and others, 2012) in R 3.2.0 (R Core Team, 2015) to select survey sites using a Generalized Random Tessellation Stratified (GRTS) survey design. GRTS is a statistical method to select random sample locations that are spatially balanced and ordered so that any consecutive sets of sample 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. We used a stratified equal weight selection design, so all wetland area within each stratum had equal probability of selection, and we selected between 25 and 50 oversample points per stratum. Oversample points were used to replace the primary sample points that could not be surveyed due to lack of permission from landowners or absence of target wetland.

Selection of Reference Sites

We wanted to survey at least one low and one high quality site in each stratum to capture the full range of wetland conditions in the watershed. We used field data from the first year of surveys and the Landscape Integrity Model (Menuz, 2015) to evaluate whether each survey stratum had randomly selected low and high quality sites. We then used two methods to develop a list of potential low and high quality reference sites to survey in addition to the randomly selected sites. First, we asked land managers, watershed specialists, and Utah Geological Survey employees for site recommendations. Second, we screened sites with low and high scores in the Landscape Integrity Model. Ten subjectively selected sites were visited in 2010, though not all were surveyed due to lack of target wetland.

Site Office Evaluation and Landowner Permission

Sample sites were screened to determine whether they were located near target wetland using true color and infrared aerial imagery, digital elevation data, data on water-related land use, the USA Soil Survey layer in ArcGIS online, and NWI polygons (Menuz and others, 2015; Appendix A). Survey points were moved up to 100 m from the original point to account for inaccuracies in the NWI mapping. We attempted to contact landowners through phone calls and a mailer. We rejected all sample points where access was denied or where we were unable to obtain permission.

We conducted an office evaluation for each site before the field survey. We used either the Web Soil Survey (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) or the USA Soil Survey layer in

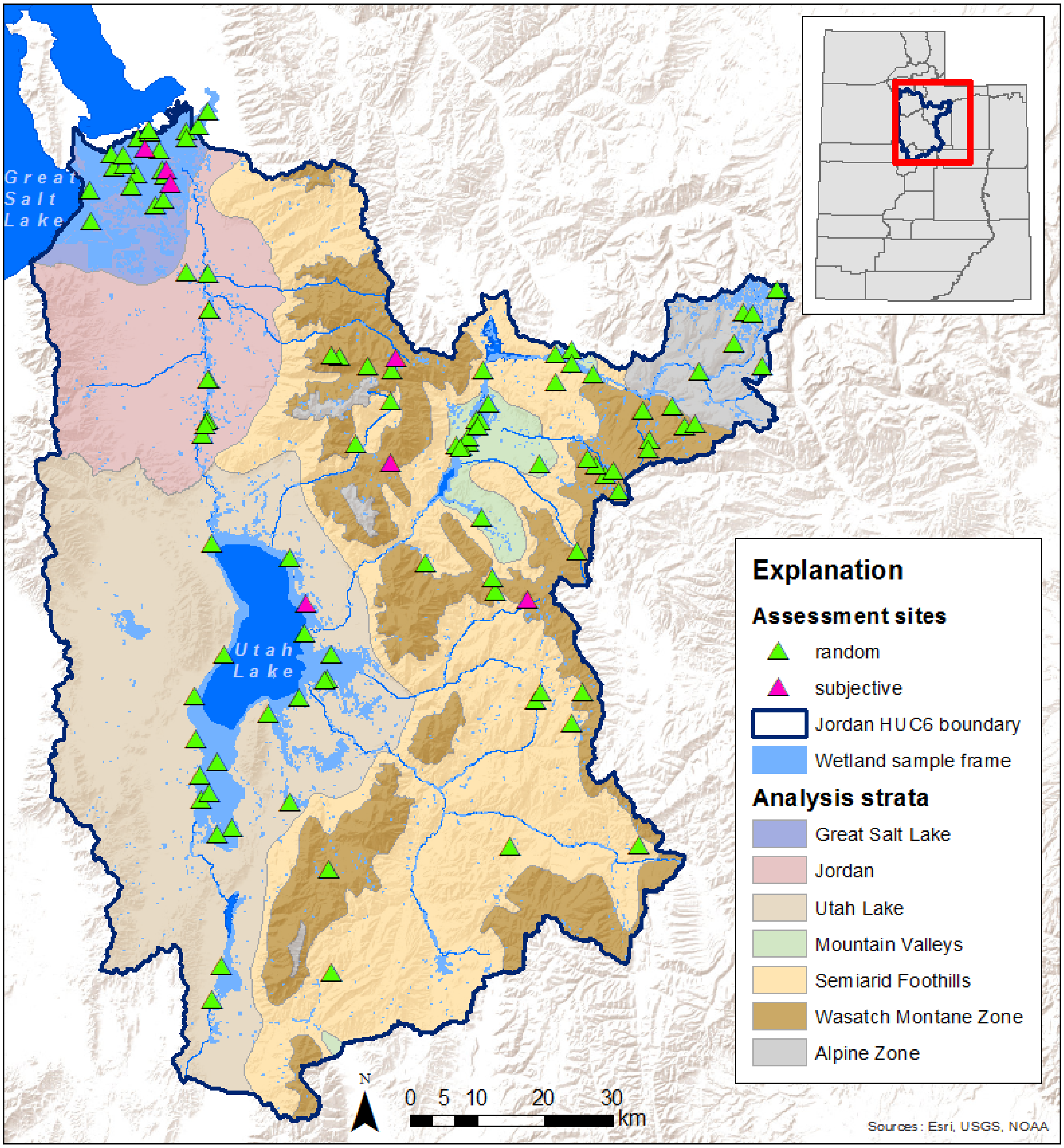

Figure 2. Strata used in data analysis and surveyed randomly and subjectively selected wetland sites. The Great Salt Lake, Jordan, and Utah Lake strata are part of the Central Basin ecoregion and the remaining strata are part of the Wasatch Mountains ecoregion

ArcGIS online to determine the soil 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 and visible hydrologic stressors, such as dams, water control structures, and irrigation return flows. We evaluated stressors with potential to degrade water quality including development, agriculture, rangeland, point source dischargers, oil and

Table 1. Characteristics of analysis strata including extent and abundance of wetlands in the sample frame, climatic and elevational means (Daly and others, 2008), land ownership (http://gis.utah.gov/data/sgid-cadastre/land-ownership), and land cover (Landfire, 2014).

Stratum		Great Salt Lake	Jordan	Utah Lake	Mountain Valleys	Semiarid Foothills	Wasatch Montane Zone	Alpine Zone
Area (km^2) (% of total)		384 (3.9)	1069 (10.8)	3028 (30.7)	252 (2.6)	2989 (30.3)	1741 (17.7)	392 (4.0)
# of wetlands (% of total)		1609 (14.3)	1065 (9.5)	2916 (25.9)	624 (5.5)	2108 (18.7)	1213 (10.8)	1716 (15.3)
wetland area (ha) (% of total)		17,152 (37.5)	693 (1.5)	23,572 (51.5)	1,696 (3.7)	1,262 (2.8)	457 (1.0)	946 (2.1)
30 year climate data (from mean monthly values)	Max. temperature (°C) (Standard deviation)	33.6 (0.5)	32.2 (2.1)	32.7 (1.5)	30.2 (1)	28.6 (1.9)	24.7 (1.8)	23.6 (1.8)
	Mean temperature (°C) (Standard deviation)	11.8 (0.3)	10.6 (1.5)	10.2 -1.0	7.5 (0.4)	7.4 (1.3)	5.2 (1.3)	3.2 (1.1)
	Min. Temp (°C) (Standard deviation)	-6.5 (0.2)	-7.2 (0.7)	-8.8 (1)	-11.3 (0.6)	-10.3 (1.6)	-10.8 (1.4)	-13.5 (1)
	Daily precip. (mm) (Standard deviation)	1.2 (0.1)	1.4 (0.3)	1.1 (0.2)	1.4 (0.2)	1.6 (0.4)	2.3 (0.5)	2.4 (0.4)
Mean elevation (m) (Standard deviation)		1289 (13.5)	1540 (279.6)	1561 (238.4)	1816 (130.4)	2050 (245.5)	2531 (249.5)	2833 (272)
Land ownership, by percentage	Federal	0.0%	5.5%	64.3%	20.3%	42.6%	44.3%	99.4%
	Private	55.3%	94.3%	31.6%	77.6%	55.0%	54.3%	0.6%
	State	44.7%	0.2%	4.1%	2.1%	2.4%	1.4%	0.0%
Land cover, by percentage	Developed (including mines)	29.5%	63.8%	18.8%	19.1%	3.2%	0.9%	1.3%
	Agricultural	7.7%	9.2%	22.9%	25.2%	0.9%	0.0%	0.0%
	Forested (including all	0.2%	11.1%	13.5%	9.6%	55.8%	84.8%	75.4%
	Shrubland	27.1%	11.6%	22.7%	40.5%	31.2%	9.8%	7.5%
	Grassland	1.8%	3.1%	9.3%	1.6%	7.8%	1.3%	3.9%
	Open water	26.5%	0.1%	12.5%	3.6%	0.5%	0.1%	0.8%
	Snow, barren, sparsely vegetated	7.1%	1.0%	0.4%	0.2%	0.6%	3.2%	11.1%

gas wells, and mines. We also determined whether contributing streams or lakes were listed as impaired in the draft 2014 integrated report (Utah Division of Water Quality, 2014a and 2014b). Information from the office evaluation was verified by observations in the field whenever possible. A full description of the office evaluation procedure can be found in appendix A.

Field Methods

Training

Four seasonal technicians conducted most field surveys, with a team of one botanist and one soil and water quality technician working each summer. Technicians were trained by experienced UGS employees and then conducted six surveys accompanied by an experienced UGS employee before surveying on their own. The experienced UGS employee also periodically checked in with the technicians throughout the field season, accompanying each crew on seven or eight additional surveys.

Establishment of Assessment Area

We used a combination of best professional judgement and easily observable hydrologic, soil, and vegetation indicators to determine whether sites were within the target population, loosely following standards from the U.S. Army Corps of Engineers (USACE) wetland delineation guides (U.S. Army Corps of Engineers, 2008; U.S. Army Corps of Engineers, 2010). Wetland determination was conducted rapidly using traits such as redoximorphic features or gleying in augured soil samples rather than full soil profiles, as well as readily apparent hydrology indicators. We assessed sites for the presence of hydrophytic vegetation if plant species were known and otherwise only keyed out dominant plant species when site status was uncertain. Wetland determinations done for this project should not be considered USACE delineations due to the limited time spent on each determination and the broader definition of wetland used in this study.

If a site contained target wetland, we next set up an assessment area (AA). AAs were 40-m radius circular survey plots centered on the randomly selected sample point where possible, though to avoid inclusion of non-target areas, AAs can also be 40-m radius plots with shifted centers or rectangular or free form plots between 0.1 and 0.5 ha and at least 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 >1 m in depth. AAs were also shifted to avoid features that would divide the hydrology of the wetland, such as dikes and bermed ditches. AAs were generally placed in a single Ecological System.

Wetland Soils and Water Quality Samples

Surveyors used a handheld auger to dig at least one soil pit at a representative location within the dominant vegetation type at each site. An additional pit was sometimes 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 depth whenever possible. For each soil layer, surveyors recorded the layer depth, color of the matrix and any dominant and secondary redox features (based on a Munsell Soil Color Chart), soil texture, and percent coarse (>2mm) material. Hydric soil indicators were recorded based on the USACE regional 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.

Groundwater and surface water chemistry data were collected with a handheld Hanna Instruments Combo meter (HI98129 and HI98130); meters were tested at least weekly and calibrated as needed. We measured pH, EC, and temperature of water samples from channels and pools, at points of groundwater discharge, and at the surface of flooded wetlands. We collected surface water samples for laboratory analysis from one location at sites when surface water was available and likely to reflect the dominant water source at the site. Samples were generally not taken when water depth was very low (<10 cm) due to the high probability of contamination from soil sediments. Water sample containers for general chemistry, total metals, and total non-filtered nutrients were prepped with the necessary preservatives by the Utah Public Health Laboratory Chemical and Environmental Services Laboratory (Utah Public Health Laboratory). 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).

Rapid Assessment Metrics and Stressor Data

We collected wetland condition data using the metrics on the 2016 field forms and associated user's manual (appendices B and C). Each metric is composed of a series of potential states, ranked from A through D, to denote wetland condition ranging from pristine or reference condition to severely altered wetlands that may have little conservation value and be extremely difficult to restore. 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. Observers used office evaluation data, maps, and information obtained from walking around AAs and the surrounding area to score the remaining metrics. Photos and notes were frequently taken to better capture condition, especially when sites were difficult to evaluate.

Surveyors also recorded data on stressors observed in the field. Stressor data included information about features within 100 m of each AA (buffer) 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 downstream stressor may be less likely to affect the water quality of a wetland than an upstream stressor but may still impact the hydroperiod.

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. We also collected data on the percent cover of ground cover features within the AA including bare ground, litter, water, bryophytes, lichens, algae, and various classes of woody debris. 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), Grasses of the Intermountain West (Anderton and Barkworth, 2000), Field Guide to Intermountain Sedges (Hurd and others, 1998), and Flora of North America (http://floranorthamerica.org). We used species scientific names as listed in U.S. Natural Resources Conservation Service's Plants Database (http://plants.usda.gov).

Functional Data

Data on boreal toad habitat were collected using metrics derived from the Ecological Integrity Table for the species (Oliver, 2006a) and adjusted based on a brief literature review. Final habitat metrics included types of breeding waterbodies present, presence of north shore, waterbody slope and depth, daytime summer temperature, abundance of hibernation features, and shrub cover. In 2016, the shrub metric was modified to account for the potential positive role of shading by understory-forming tall forbs and for the potential negative role of overabundance of shrubs. Water temperature data collected in the field were used to assign ranks to sites for the temperature metric.

Data on Columbia spotted frog habitat were collected using metrics derived from the Ecological Integrity Table for the species (Oliver, 2006b) and adjusted based on a brief literature review. Final habitat metrics included types of breeding waterbodies present, waterbody substrate, vegetation growing in waterbody, and overwintering waterbodies. Two boreal toad metrics, waterbody slope and

Table 2. Condition 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	Percentage 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]	Percentage 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]Excluded from scoring for emergent marsh, alkaline depression, and playa 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

depth and presence of north shore, were also included as habitat metrics for Columbia spotted frog, though were only collected at sites in the Wasatch Mountains ecoregion. We also collected two stress-related metrics for the Columbia spotted frog, livestock grazing and distance to impervious surface.

Metrics were developed and collected in the field in 2016; values for 2015 sites were estimated using site data, except for the waterbody substrate metric, which was left null for the 2015 sites.

We collected data on wetland potential for water quality improvement using a presence/absence checklist of site indicators adapted from the Washington State's wetland rating system (Hruby, 2014a and b). Indicators were grouped into three categories, site potential to improve water quality, landscape potential to need improvement, and societal value. Most indicators were evaluated in the field, though some were evaluated in the office using ArcGIS. The water quality checklist was developed for the 2016 field season and applied retrospectively to 2015 field sites using site data and best professional judgement.

Data Summarization and Analysis

Weight Adjustment, Population Estimation, and Data Summaries

Sites were assigned a weight when they were originally selected by the R package spsurvey to represent the amount of area represented by the site relative to the total wetland area in the watershed. For example, Great Salt Lake wetlands were assigned higher weights than sites in the Alpine Zone because the Great Salt Lake stratum has much more total wetland area. Weights allow for accurate estimation within a stratum, where all weights may be the same, and across the whole watershed, where weights differ. We adjusted the assigned weights based on the total number of sites evaluated in each selection stratum by dividing the total stratum area by the 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 cat.analysis and cont.analysis in the spsurvey package in R to estimate parameters for categorical and continuous variables. We used spsurvey to create cumulative density functions for some metrics. 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 parameters using spsurvey for most wetland assessment data, including wetland stressors, condition, and function. However, in some cases we present raw, unweighted data. Data used for ordination analysis and for Ecological Systems descriptions are presented as raw data, which limits our ability to make inference to the whole watershed from these results. For example, if the raw mean native plant cover for wet meadows in our study is 70%, we cannot expect that the average cover of all wet meadows in the Jordan River watershed is also 70%. Usually, results obtained from weighted data are referred to as estimates of the percent of wetland area or total wetland area and include a measure of uncertainty. Results obtained from raw data are typically presented as a number or percent of sites. All statistical analysis was conducted in R 3.2.1 statistical software (R Core Development Team, 2013).

Wetland Condition

Stressors Data

We calculated stressor indices for buffer stress, AA stress by stress category, and water quality and hydroperiod stress recorded during the office evaluation. To calculate stressor indices, we first converted low, medium, and high severity stressors to values of 1, 2, and 4, respectively. 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, 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 within each category to obtain an estimate of stress, obtaining separate values for the buffer and each of the three categories of AA stress—vegetation, physical, and hydroperiod. Only severity, not extent, was recorded for stressors identified in the office evaluation. For these stressors, we summed the total stress by category—water quality and hydroperiod. We only evaluated water quality stressors within 2 km of the site rather than all water quality stressors. We excluded livestock grazing from the office evaluation stressors because we could not consistently evaluate the presence or severity of livestock grazing in GIS.

We calculated overall office, AA, and site stress indices as follows. Overall office stress was calculated as the sum of office hydroperiod and office water quality stress. Overall AA stress was calculated as the sum of the three categories of AA stress. Overall site stress was calculated as the sum of the overall office stress divided by 3, then added to buffer stress and overall AA stress. The weight of office stress was reduced when combining the three indices of stress together because the office evaluation method did not take into account the area affected by each stressor.

Rapid Assessment Condition Results

Wetland condition results are primarily presented at the level of the individual metric rather than for categories or as an overall site score. We used the following standard to refer to metric rankings: A—excellent, B—good, C—fair, D—poor. Rankings for the relative cover of native species and absolute cover of noxious species metrics were obtained by calculating cover estimates using plant composition data and then converting estimates to ranks using the thresholds shown in appendix B. We considered all recorded *Phragmites australis* to be the non-native, noxious subspecies of *Phragmites australis* when subspecies was not recorded.

We calculated categorical and overall condition scores for ordination analysis and overall scores for use in a cumulative density function plot and for evaluating reference sites by Ecological Systems. We converted metric ranks to point values based on the following: A or AB—5, A—4.5, B—4, C—3, C-—2, D—1. 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:

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

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. Overall condition scores were obtained by taking the mean value across all categorical scores.

Plant Coefficient of Conservatism Values

We report on two vegetation metrics that rely on coefficient of conservatism values (C-values), mean C and covered-weighted mean C. 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.

C-values are often developed for individual states or regions to capture regional variability in how species respond to disturbance, but C-values have not been 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), Wyoming (Washkoviak and others, 2015), and Idaho, which uses C-values from eastern Washington's Columbia Basin region (Rocchio and Crawford, 2013). We assigned Utah species the mean C-value of the four states' lists. We then made sure that every non-native species, and no native species, had a C-value of 0. Twenty-six species were recorded during field surveys that were not assigned C-values.

We calculated mean C by taking the average C-value for all species at a site and cover-weighted mean C by multiplying the C-value for each species by its cover at the site, summing up the result for all species, and dividing by the cover of all species at the site. Both mean C and cover-weighted mean C range from 0 to 10.

Functional Assessment Data

Boreal Toad

Boreal toad habitat estimates were made for two habitat strata in the Wasatch Mountains, prime and non-prime habitat. Wetlands in the Wasatch Montane, Mid-Elevation Uinta, and Uinta Subalpine Level IV ecoregions were considered prime habitat and wetlands in the Mountain Valleys and Semiarid Foothills were considered non-prime habitat based on the known range of climatic conditions at sites occupied by the species in Utah, outside of the lower-elevation boreal toad population in northwestern Utah. We obtained a final vegetation metric score by combining the shrub cover metric and tall forb cover metric. Sites were assigned the lower of the two metric scores if overabundance was an issue for either forbs or shrubs and otherwise assigned the highest value of the two scores. We calculated the mean metric value across the six boreal toad metrics for each site and compared values with a metric threshold developed in previous studies (Menuz, 2016a; Menuz, 2017). Both studies found that a threshold of around 3.8 was useful for separating known breeding locations from other wetland locations.

Columbia Spotted Frog

Columbia spotted frog habitat estimates were made for three separate habitat strata to differentiate between areas with different likelihood of supporting populations and suitability for introductions. We analyzed all the Central Basin ecoregion sites as one stratum and divided the Wasatch Mountains sites into prime and non-prime montane habitat. Montane Columbia spotted frog populations are only known from alongside perennial streams in Utah (K. Wilson, Utah Division of Wildlife Resources, personal communication, 2016) and tend not to move more than about 500 m from breeding areas (U.S. Fish and Wildlife Service, 2002). Therefore, wetlands in the Wasatch Mountains ecoregion within 500 m of perennial streams and <8000 ft in elevation were designated as prime habitat and wetlands in the remainder of the ecoregion as non-prime.

We dropped the waterbody substrate metric from analysis because we only had data for one year; >80% of Central Basin and >95% of Wasatch Mountains sites with at least some surface water were scored as good or excellent for this metric. We took the mean value of the remaining five habitat metrics at sites in the Wasatch Mountains sites and three metrics in the Central Basin sites to obtain an estimate of overall habitat suitability (Central Basin sites lacked estimates of north shore and slope and water depth). We did not have an established threshold at the time of analysis, so we arbitrarily considered sites with scores ≥4.5 to have excellent habitat and ≥3.5 and <4.5 to have good habitat.

Water Quality Improvement

Two of the indicators on the checklist were dropped from analysis, microtopography and riverine surface depressions. We summarized information on the most common indicators, the total number of indicators per category, and the most vulnerable sites– those with high landscape potential for water quality stress. All checklist items were weighted equally except for in the following cases. First, sites could not receive more than two credits in the capacity category for any of the three indicators related to vegetation. Second, sites could not receive more than one credit in the landscape category for any of the two indicators related to stressors in the broader contributing area. Third, sites received two credits rather than just one in the societal value category if they were in a watershed rated as impaired (category 4 or 5) in the Utah Division of Water Quality's 2014 integrated report (Utah Division of Water Quality, 2014a; Utah Division of Water Quality, 2014b).

Plant Community Ordination

We used non-metric multidimensional scaling (NMDS) with the vegan package (Oksanen and others, 2013) in R to explore plant community composition data within Level III ecoregions and within common Ecological Systems. 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 were interested in exploring relationships between plant community composition and measures of wetland condition, wetland stress, natural variation, and sampling effort.

We excluded from analysis most species only identified to genus, but did include the genera *Atriplex* (saltbush), *Carex* (sedge), *Chenopodium* (goosefoot), *Eleocharis, Epilobium* (willowherb), and *Viola* (violet). We grouped all species within the genera *Abies* (fir), *Lemna* (duckweed), *Tamarix* (tamarisk), and *Typha* (cattail) into their respective genera rather than considering these species independently. We did not include subspecies or varieties in the analysis. 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 fit site attribute and species data to the 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 10,000 permutations. We analyzed a broad variety of site attributes, including categorical and overall URAP condition scores, mean C and cover-weighted mean C, and both local and watershed stress from landscape stress models (Menuz, 2015; Menuz, 2016b). We also looked at site attribute data related to natural variation among sites, including climate data, surface water cover, HGM class, strata, and Ecological System. For the climate data, we 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. 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 then reduced the climate data to uncorrelated axes using principal components analysis (PCA) with the function princomp. We also used PCA to reduce field estimates of current and potential cover of shallow (<20 cm) and deep surface water to fewer axes. We used the first two axes of each PCA in the analysis. We evaluated three variables related to sampling effort, the day of year, survey year, and observer team. Observer team was 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.

Ecological System Attributes

Reference Site Screening

We screened for high quality reference sites within common Ecological Systems using stressor indices and the relative cover of native vegetation. We set an initial screen of ≥80% relative native plant cover, ≤2 for buffer stress, ≤1 for any single aspect of AA stress, ≤4 for water quality stress, and ≤4 for hydroperiod stress (the latter two variables are from the office evaluation stressors). These values are the equivalent of one moderate severity stressor across the entire buffer, one low severity stressor across the entire AA, and one high severity hydroperiod or water quality stressor in the contributing basin. We loosened the screens as needed to obtain at least four reference sites per Ecological System.

We evaluated two metrics in the population of reference sites, mean C and overall URAP score, using a method adapted from the EPA’s National Wetland Condition Assessment (U.S. Environmental Protection Agency, 2016). EPA used the bottom 25th and 5th percentiles of vegetation multi-metric index values within their population of reference sites to set thresholds of good versus fair versus poor wetlands. We classified sites as good if they scored above the bottom 25th percentile value for the references sites but did not distinguish between fair and poor due to the limited number of reference sites within each Ecological System.

Landscape Analysis

GIS Analysis of Mapping Accuracy

We used aerial imagery in ArcGIS and Google Earth, supplemented by field data when available, to evaluate the accuracy of NWI mapping at all the randomly selected points evaluated for wetland surveys. Since we focused specifically on the random points, some sites that were surveyed were classified as non-wetland *at the point* (because the AA was shifted from the original point). We also classified points that fell on inaccessible private property using best professional judgement, though many such points were classified as “unknown.” Points were classified as wetland (even if smaller than our target site size), non-wetland, unclear, or non-target aquatic feature, with the latter further classified as dry mudflats, streambeds, waterbodies >1 m deep, and industrial and sewage treatment ponds. We used the spsurvey package to obtain estimates of the percent of each stratum with each class of wetland.

Updated Wetland Mapping

We updated wetland spatial data for a section of the study area that was predominantly in the Central Basin ecoregion of Salt Lake County, with small sections of Davis and Tooele counties (figure 3). Most of this area was mapped using imagery from 1998, with small portions mapped in the early 1980s; some of the latter had a partial update in 2005. Wetlands and riparian areas were mapped following the guidance of the Federal Geographic Data Committee (2009, 2013) and the U.S. Fish and Wildlife Service (2009). Field reconnaissance was conducted in the summer of 2016, and features were delineated using heads-up digitization in ArcGIS 10.5 over 2014 NAIP imagery.

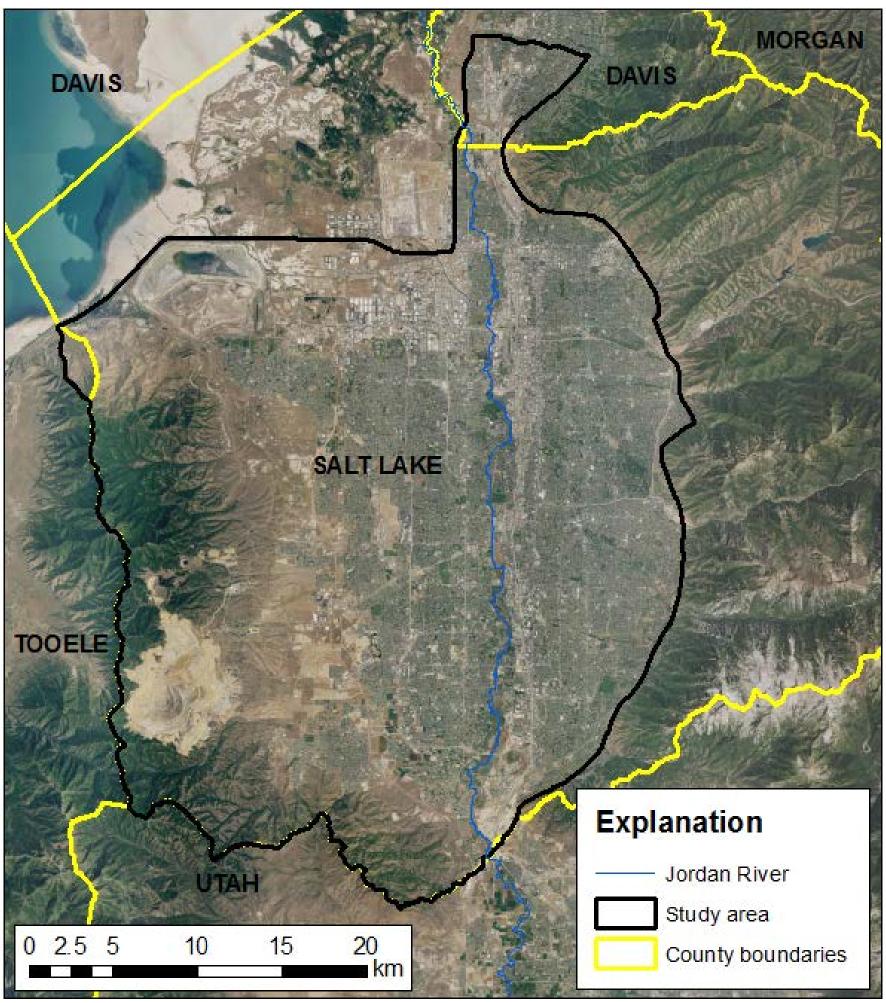

Figure 3. Overview of study area for wetland and riparian mapping project.

We compared the UGS mapping data to the original NWI data. We used the second draft of the UGS mapping data dated September 17, 2018 for the comparison, which included changes that resulted from feedback from personnel with the NWI program. We converted the Cowardin classifications into nine wetland types for ease of use, including lake, pond, riverine, scrub shrub, forested, emergent marsh, emergent meadow, palustrine unconsolidated shore, and lacustrine unconsolidated shore. Lacustrine and palustrine wetlands with an unconsolidated bottom or aquatic bed class were classified as lake and pond, respectively. Palustrine scrub shrub and palustrine forested wetlands were classified as scrub shrub and forested. Palustrine emergent wetlands were divided into two types based on water regime. Those with semi-permanently flooded regimes were classified as emergent marsh and the remainder classified as emergent meadow. The remaining wetlands were all classified as either lacustrine or palustrine unconsolidated shore. Unconsolidated shore wetlands are wetlands with <30% vegetation cover that lack surface water for at least part of the growing season. In the Central Basin, most unconsolidated shore wetlands are playas or mudflats along Great Salt Lake and Utah Lake. Seasonal ponds and unvegetated shores along streams or lakes are also classified as unconsolidated shores. Only the first class and the first water regime were used for wetland polygons with split classification.

Landscape Profile

We attributed data in the original sample frame of wetlands with land ownership, riparian status, landscape and watershed stress model values, land use, and irrigation class. This attribution allowed us to summarize information on the types, protection status, and potential vulnerability of wetlands within the watershed. Since the attribution was applied only to the sample frame, summarized information does not pertain to deepwater habitats (lacustrine limnetic) or riverine streambeds (riverine systems with unconsolidated bottom or streambed classes).

We used a modified version of the nine wetland types described above to summarize the wetland data, combining riverine, lacustrine, and palustrine unconsolidated shore into a single class for a total of seven wetland types, including lake, pond, scrub shrub, forested, emergent marsh, emergent meadow, and unconsolidated shore. We attributed wetland polygons as riparian or non-riparian based on proximity to stream and lake features in the 1:24,000-scale USGS's National Hydrography Database. 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 is an inexact designation. No set distance captures all riparian features and excludes non-riparian features. Features designated as riparian 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 were obtained from the Utah Automated Geographic Reference Center ([AGRC], http://gis.utah.gov/data/sgid-cadastre/land-ownership, accessed on January 2016). The AGRC ownership data include information on the ownership type (private, state, federal, tribal) as well as the managing agency and property name. We used the AGRC layer in combination with an internal layer of management areas digitized by the UGS in 2013 to classify wetlands into ownership categories. The UGS management areas layer was created from a combination of parcel data and boundary data obtained from individual land managers and includes boundaries of 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. We used the combination of the two ownership layers to classify wetlands as one of twelve land ownership categories. Categories of privately-owned land included private duck hunting reserves, private conservation and mitigation land, CWMUs, and other private land (which include land owned by local government entities). Categories of State-owned land included sovereign land (primarily the lakebeds of Great Salt Lake and Utah Lake), Farmington Bay Waterfowl Management Area, other wildlife areas, parks, and other State-owned land, which includes trust lands. Categories of federal-owned land included wilderness and non-wilderness U.S. National Forest and other federal land, which includes U.S. Bureau of Land Management and U.S. Department of Defense.

We classified wetland polygons as having low, moderate, or high levels of local and watershed stress based on values from two GIS-based aquatic resource stress models (Menuz, 2015, Menuz, 2016b). The local landscape stress model is a 30-m resolution raster of 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. The watershed stress model estimates stress at the local catchment scale for catchments delineated by NHDPlus Version 2 (http://www.horizon-systems.com/NHDPlus/index.php) based on cumulative upstream stress (e.g., total upgradient development). Predictor variables were log transformed and normalized to range from 0 to 1 and then assigned weights based on their probable severity. The selection of final weights and a final method for combining predictors into an overall stress score was calibrated with existing wetland and, for the watershed model, other aquatic resource data. For the landscape profile, we obtained the mean stress value for each wetland polygon. We converted values to low, moderate, and high stress categories using the thresholds of ≤200 and ≤800 for the local stress model and thresholds of ≤600 and ≤1300 for the watershed stress model. The models include data only on stressors with readily available geospatial data; data on stressors such as livestock grazing intensity, off-road vehicle use, and non-native species cover are not included in the models.

Land use and irrigation data were extracted from Water Related Land Use data (Utah Division of Water Resources, 2014b and 2014c), an effort to map all agricultural areas in the state as well as other lands that consume or evaporate water other than natural precipitation (which generally excludes deserts, rangeland, and forested areas). Urban areas, open water, and riparian features are only mapped if they are near irrigated lands, so these land use classes are likely underrepresented in the data. The basins in our study area were mapped in 2014. We combined the land use categories into six categories based on their similarity to one another and prevalence in the study area, including agriculture (irrigated and unirrigated crops), hay, pasture, urban (including sewage lagoons and urban grass), riparian and aquatic (including riparian, open water, mudflats, and playas), and unmapped. We calculated the percentage of wetland area in each land use class as well as the percentage in one of two irrigation classes−irrigated and subirrigated. Subirrigated lands are naturally irrigated agricultural lands that usually have a high water table, though they sometimes also receive direct or indirect irrigation water.

Results

Survey Site Characteristics

Surveyed Sites

We evaluated 188 of the randomly selected sites to obtain 102 sampleable sites. We were unable to obtain access to 11 sites and 75 sites were non-target, including both non-wetland sites and aquatic sites that did not fall within our target population (table 3). Points in the Jordan stratum had the highest percent non-target wetland, and points in the Semiarid Foothills and Mountain Valleys had the highest percent of sites with no landowner permission to access property.

We conducted surveys at 50 randomly select sites in 2015 and 52 randomly and 7 subjectively selected sites in 2016. The subjectively selected sites included three potential high-quality Great Salt Lake sites, one potential low-quality Utah Lake site, and two potential low quality and one potential high quality site in the Wasatch Montane Zone. Surveys were conducted between June 9 and September 20 each year. Surveyed sites included 52 40-m radius circular plots, 56 freeform plots, and 1 rectangular plot. All circular plots had an area of 5010 m^2; the remaining plots ranged in area from 812 to 7496 m^2, with a median area of 3058 m^2. Sites were frequently moved in the field away from the original sample point, usually due to large inclusions of upland or water or the presence of multiple Ecological Systems; only 23 sites were not moved.

Wetland Indicators

We used wetland vegetation data collected in the field to determine whether sites met the USACE definition of hydrophytic vegetation (U.S. Army Corps of Engineers, 2008; U.S. Army Corps of Engineers, 2010). Species from sites in the Central Basin ecoregion were assigned the Arid West

Table 3. Number of sites evaluated in each stratum and estimates of the percentage of wetland area in each survey category, including surveyed, no access, and no target wetland, with standard error in parentheses.

Strata	# Sites Evaluated	Percent Surveyed	Percent No Access	Percent No Target Wetland
Central Basin Ecoregion	**106**	**57.2 (4.8)**	**3.0 (1.7)**	**39.8 (4.8)**
Great Salt Lake	30	66.7 (6.5)	0	33.3 (6.5)
Jordan	37	27.0 (6)	2.7 (2.4)	70.3 (5.9)
Utah Lake	39	51.3 (7)	5.1 (3)	43.6 (7)
Wasatch Mountains Ecoregion	**82**	**65.1 (4.2)**	**14.2 (3.4)**	**20.7 (3.6)**
Mountain Valleys	21	61.9 (9)	19 (7.3)	19 (5.3)
Semiarid Foothills	27	41.8 (8.9)	26.7 (8.3)	31.4 (10)
Wasatch Montane Zone	28	63.7 (9.9)	0	36.3 (9.9)
Alpine Zone	6	100 (0)	0	0
National Forest	*37*	*67.6 (6.7)*	*0*	*32.4 (6.7)*

indicator ratings and species from sites in the Wasatch Mountains ecoregion were assigned the Western Mountains, Valleys, and Coast indicator ratings. We used a conservative approach in this evaluation by classifying all dominant species that were not assigned wetland indicator values as upland species, unless the unidentified dominant species was a genus that was almost always wetland-associated (e.g., *Eleocharis, Tamarix*). Five sites had <5% vegetation cover and were not evaluated for this indicator. All but four of the remaining sites met the USACE definition of hydrophytic vegetation based on the dominance test, meaning the majority of the most abundant species were obligate wetland, facultative wetland, or facultative species. Two of the four sites that did not pass the dominance test met the definition of hydrophytic vegetation based on the prevalence index, meaning that sites had a majority of obligate wetland, facultative wetland, or facultative species when all species were considered. The two sites that did not meet the USACE definition of hydrophytic vegetation were both depressions that pond with water at least some years and had hydrology and hydric soil indicators.

USACE hydrology indicators were evaluated in the field except the FAC-neutral test (D5) and inundation on aerial imagery (B7), which were only evaluated in the office (using vegetation data or aerial imagery) at sites that did not otherwise have an indicator of wetland hydrology. All surveyed sites had at least one primary or two secondary indicators of wetland hydrology. The most common indicators in the Central Basin ecoregion were surface soil cracks (B6, n=22), saturation (A3, n=20), surface water (A1, n=18), and salt crusts (B11, n=14). In the Wasatch Mountains ecoregion, the most common indicators were saturation (A3, n=37), surface water (A1, n=23), oxidized rhizospheres (C3, n=14), geomorphic position (D2, n=14), drainage patterns (B10, n=12), and high water table (A2, n=11).

In the Central Basin ecoregion, soil pits were dug at 51 of the 54 sites, including 2 pits at 11 sites and no pits at 3 fully inundated marsh sites. Three pits had no indicators present, including two pits in Goshen Valley and one pit along the Jordan River. The most common indicators in the Central Basin ecoregion was depleted matrix (F3, n=39), hydrogen sulfide odor (A4, n=11), and depleted below dark surface (A11, n=9). In the Wasatch Mountains ecoregion, soil pits were dug at all 56 sites, with two pits at 8 sites. Seven soil pits had no hydric soil indicators present, including four pits in the Semiarid Foothills, two in the Mountain Valleys, and one in the Wasatch Montane Zone; one of the pits was located at a site where a second pit had indicators. The most common indicators in the Wasatch Mountains ecoregion were redox dark surface (F6, n=34), depleted matrix (F3, n=9), depleted below dark surface (A11, n=9), and histic epipedon (A2, n=8).

Hydrogeomorphic and Ecological System Classification

Sites were assigned HGM classes based on their dominant class, though some contained more than one class. Depressional and lacustrine fringe wetlands were the most common HGM classes in the Central Basin ecoregion (table 4). Two classes, depressional impoundment and impoundment release, were recorded only in Great Salt Lake, and two classes, slope and lacustrine fringe, were recorded only in Utah Lake. Four Ecological Systems were recorded in the Central Basin, including Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland ("Great Basin woodland"), Inter-Mountain Basins Playa ("playa"), North American Arid West Emergent Marsh ("basin marsh"), and Inter-Mountain Basins Alkaline Closed Depression ("alkaline depression"). Alkaline depressions were the most abundant Ecological System, though both playas and basin marshes are more abundant in the Great Salt Lake stratum (table 4). Only one wetland in the Central Basin was classified as a Great Basin woodland. This

Table 4. Hydrogeomorphic classes and ecological systems in the Central Basin ecoregion and strata within the ecoregion, including estimated percentage of wetland area in each class and standard error in parentheses.

Class	Central Basin Ecoregion	Great Salt Lake	Jordan	Utah Lake
Hydrogeomorphic Class				
Depressional	**28.1 (6.2)**	25 (8.4)	90 (8.3)	30 (9.1)
Depressional impoundment	**19.3 (4.6)**	40 (9.4)		
Depressional impoundment fringe	**4.9 (3.1)**	10 (6.4)	10 (8.3)	
Impoundment release	**9.6 (3.3)**	20 (6.8)		
Lacustrine fringe	**22.9 (3.9)**			45 (7.1)
Riverine	**7.5 (3.6)**	5 (4.1)		10 (5.9)
Slope	**7.6 (3.6)**			15 (7)
Ecological System				
Great Basin woodland	**2.5 (2.1)**			5 (4)
Alkaline depression	**55.8 (5.8)**	30 (8.7)	70 (13)	80 (7.8)
Playa	**22.0 (5.6)**	35 (9.8)		10 (6)
Basin marsh	**19.7 (4.8)**	35 (9)	30 (13)	5 (4.2)

wetland was located on the floodplain of an intermittent creek in the Utah Lake stratum and dominated by the non-native woody shrub tamarisk (*Tamarix* spp.) with very low cover of other woody species.

In the Wasatch Mountains ecoregion, depressional, riverine, and slope wetlands are about equally prevalent (table 5). Depressional wetlands dominate the Semiarid Foothills and Wasatch Montane Zone strata, and slope wetlands dominate the Alpine Zone. Six Ecological Systems were recorded in the Wasatch Mountains ecoregion, including North American Arid West Emergent Marsh ("montane marsh"), Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland ("foothill shrubland"), Rocky Mountain Subalpine-Montane Riparian Shrubland ("montane shrubland"), Rocky Mountain Subalpine-Montane Riparian Woodland ("montane woodland"), Rocky Mountain Alpine-Montane Wet Meadow, and Rocky Mountain Subalpine-Montane Fen. The latter two Ecological Systems were grouped together and treated as "wet meadow" for analysis because they had indistinguishable plant community composition. Almost two-thirds of the wetland area in the Wasatch Mountains ecoregion is estimated to be wet meadow and this system was the most common in all but the Wasatch Montane Zone stratum (table 5). Only one wetland each in the Wasatch Mountains ecoregion was classified as montane marsh and montane woodland. The montane marsh was a cattail-dominated constructed marsh in the floodplain of the Provo River. The montane woodland had high cover of quaking aspen (*Populus tremuloides*) in the overstory and Kentucky bluegrass (*Poa pratensis*) in the understory with floristic affinity to wetlands in the wet meadow Ecological System.

Table 5. Hydrogeomorphic classes and ecological systems in the Wasatch Mountains ecoregion, strata within the ecoregion, and in non-alpine National Forest land, including estimated percentage of wetland area in each class and standard error in parentheses.

Class	Wasatch Mountains Ecoregion	Mountain Valleys	Semiarid Foothills	Wasatch Montane Zone	Alpine Zone	National Forest
Hydrogeomorphic Classes						
Depressional	35.3 (6)	38.5 (11.8)	66.1 (15.1)	73.3 (9)		28 (7.2)
Riverine	29.9 (5.8)	46.2 (12.8)	31.6 (14.9)	18.7 (7.4)	16.7 (13.7)	56 (8.6)
Slope	34.7 (4)	15.4 (8.3)	2.2 (2)	8 (4.2)	83.3 (13.7)	16 (6)
Ecological System						
Montane marsh	2.7 (2.2)		16 (13.1)			
Wet meadow (including fens)	63.5 (6.1)	69.2 (12)	52.4 (16.9)	16 (6.9)	83.3 (13.7)	32 (8.6)
Foothill shrubland	15.9 (4.7)	30.8 (12)	29.4 (14.8)			24 (6.4)
Montane shrubland	17.5 (4.6)		2.2 (1.9)	81.3 (7.5)	16.7 (13.7)	40 (8)
Montane woodland	0.4 (0.3)			2.7 (2.5)		4 (3.4)

Wetland Condition

Landscape Stressors

Potential water quality and hydroperiod stressors were identified prior to surveys based on GIS analysis of surrounding land cover and probable water sources. These landscape water quality stressors were most common and most severe in the Central Basin ecoregion (table 6); stressors were also common though less severe in the Mountain Valleys (table 7). Every site in the Great Salt Lake stratum was estimated to be impacted by moderate to severe point source dischargers and runoff from development. Runoff from roads was the only commonly recorded water quality stressor in the Wasatch Montane Zone and Alpine Zone.

Hydroperiod stressors were very common at the landscape scale; at least two moderate or high severity stressors were recorded at every Great Salt Lake and Jordan wetland site and 90% or more of the sites in Utah Lake and Mountain Valleys had at least one stressor recorded. A little over a quarter of the Semiarid Foothills and Wasatch Montane Zone sites had one or more hydroperiod stressors recorded; none were recorded in the Alpine Zone. Control structures, dikes or dams, irrigation return flow, runoff from impervious surface, and ditches are each estimated to affect >40% of the wetland area in the Central Basin ecoregion (table 6). Control structures blocking inflow, ditches feeding wetlands, and irrigation return flows are each estimated to occur at >61% of wetland area in the Mountain Valleys (table 7). Dams and berms blocking outflow are the most common hydroperiod stressor in the Semiarid Foothills and Wasatch Montane Zone.

Buffer Stressors

At least one stressor was recorded in each site's surrounding 100 m buffer except for two National Forest Wasatch Montane Zone sites. The mean number of buffer stressors per site was 4.0 with a maximum of 10 stressors recorded at one site. Linear disturbance features such as roads, railroad

Table 6. Landscape and buffer stressors in the Central Basin ecoregion, with estimated percentage of wetland area affected by each stressor and standard error in parentheses.

Stressor	Central Basin Ecoregion	Great Salt Lake	Jordan	Utah Lake
Landscape Water Quality Stressor				
Agricultural land	50.6 (5.1)	20 (7.1)	20 (8.3)	80 (7.5)
Development (including paved roads)	77.0 (4)	100 (0)	90 (8.3)	55 (8)
Quarries / mines	30.1 (5.6)	30 (8.2)	40 (11)	30 (8.1)
Point source dischargers	71.7 (4.2)	100 (0)	70 (12.9)	45 (8.4)
Sediment from miscellaneous sources	5.2 (2.9)	0	10 (9)	10 (5.5)
Landscape Hydroperiod Stressors				
Control structure managing inflow	51.3 (4.3)	85 (6)	20 (9.4)	20 (6.3)
Control structure managing outflow	49.9 (5.5)	40 (9.4)	0	60 (5.9)
Berm controlling inflow	46.1 (2.1)	95 (4.1)	40 (9.4)	0
Ditches bringing water	59.4 (5.5)	80 (6.6)	60 (11.3)	40 (8.5)
Ditches draining	2.5 (2.3)	0	0	5 (4.5)
Berm controlling outflow	36.4 (4.7)	70 (8.4)	10 (8.4)	5 (4.4)
Irrigation return flows	40.6 (5.4)	10 (5.2)	10 (8.3)	70 (9.3)
Impervious surface	54.7 (5.8)	75 (8.8)	90 (8.4)	35 (7.9)
Land Use Stressors in 100-m Buffer				
Agriculture	7.7 (3.5)	0	10 (8.3)	15 (6.9)
Development	10.2 (4.1)	10 (6)	40 (12.9)	10 (5.8)
Linear disturbances (roads, railroad tracks, power lines)	37.3 (6.4)	50 (10.3)	60 (14.6)	25 (8.1)
Livestock grazing	37.4 (6.2)	35 (8.8)	20 (8.3)	40 (8.7)
Human Visitation Stressors in 100-m buffer				
Trail	0.5 (0.1)	0	60 (14.8)	0
Trash	45.6 (7.3)	35 (10)	80 (10.3)	55 (10.6)
Off-road vehicles disturbance	22.3 (5.5)	30 (8.7)	20 (12)	15 (6.9)
Water Quality Stressors in 100-m Buffer				
Excessive filamentous algae	34.6 (6.6)	45 (9.7)	20 (11.9)	25 (9)
Discharges (stormwater or wastewater discharge)	0.3 (0.1)	0	40 (12)	0
Hydrologic Stressors in 100-m Buffer				
Modified channels and ditching	22.4 (5.2)	30 (7.6)	40 (14.1)	15 (7.1)
Human-made basin or pond	2.8 (2.2)	0	30 (12.5)	5 (4.4)
Dikes, dams, and water control structures	12.5 (4.2)	20 (7.5)	40 (15.1)	5 (4.4)
Riprap along shoreline	0.1 (0.1)	0	10 (8.3)	0
Vegetation Stressors in 100-m Buffer				
Vegetation control (e.g., spraying, mowing, burning)	30.2 (6.3)	30 (9.3)	50 (14.1)	30 (8.7)
Extensive damage from insects or mammals	2.4 (2)	5 (4.1)	0	0
Non-native plant species cover	95.2 (2.5)	90 (5.2)	100 (0)	100

Table 7. Landscape and buffer stressors in the Wasatch Mountains ecoregion, with estimated percentage of wetland area affected by each stressor and standard error in parentheses.

Stressor	Wasatch Mountains Ecoregion	Mountain Valleys	Semiarid Foothills	Wasatch Montane Zone	Alpine Zone	*National Forest*
Landscape Water Quality Stressors						
Agricultural land	29.9 (4.6)	69.2 (12)	32 (15)	0	0	0
Development (including paved roads)	32.3 (6.1)	46.2 (12.7)	34.2 (16.4)	32.4 (15.3)	16.7 (13.7)	24 (7.8)
Quarries / mines	9.3 (3.5)	15.4 (8.9)	16 (13.1)	8 (2.8)	0	12 (4.7)
Point source dischargers	16.3 (4.7)	38.5 (12.8)	16 (13.1)	0	0	0
Sediment from miscellaneous sources	4.2 (2.6)	0	4.5 (2.8)	24.4 (16)	0	16 (6.5)
Landscape Hydroperiod Stressors						
Control structure managing inflow	24.5 (4.9)	61.5 (11.3)	16 (13.2)	0	0	0
Control structure managing outflow	0	0	0	0	0	0
Berm controlling inflow	8.2 (3.7)	15.4 (8.8)	16 (13.1)	0	0	0
Ditches bringing water	27.6 (4.6)	69.2 (11.5)	18.2 (13.5)	0	0	4 (3.4)
Ditches draining	5.4 (2.9)	15.4 (8.5)	0	0	0	0
Berm controlling outflow	17.1 (4.7)	23.1 (10.3)	32 (15)	24.4 (15.9)	0	8 (4.3)
Irrigation return flows	24.5 (5.3)	61.5 (13.1)	16 (13.2)	0	0	0
Impervious surface	11.7 (4.4)	23.1 (11.1)	16 (13.1)	5.3 (3.5)	0	8 (4.8)
Land Use Stressors in 100-m Buffer						
Agriculture	8.2 (3.6)	23.1 (11.1)	0	0	0	0
Development	0	0	0	0	0	0
Linear disturbances (roads, railroad tracks, power lines)	37 (7.8)	38.5 (12.2)	61.3 (17.1)	51.5 (15.7)	16.7 (15)	44 (8.9)
Livestock grazing	40.1 (7.2)	69.2 (8.2)	45.4 (15.5)	16 (6)	16.7 (15)	48 (6.3)
Human Visitation Stressors in 100-m buffer						
Trail	30.2 (8)	15.4 (8.7)	20.4 (13.1)	32.4 (15)	50 (19.2)	28 (8.3)
Trash	23.2 (5.7)	23.1 (10.8)	45.4 (16.9)	51.5 (16.6)	0	44 (8.8)
Off-road vehicles disturbance	8.2 (4)	23.1 (10.6)	0	0	0	0
Water Quality Stressors in 100-m Buffer						
Excessive filamentous algae	26.5 (7.3)	38.5 (13)	22.7 (14)	24.4 (15.8)	16.7 (14.9)	20 (7.2)
Discharges (stormwater or wastewater discharge)	0	0	0	0	0	0
Hydrologic Stressors in 100-m Buffer						
Modified channels and ditching	24.9 (5.7)	53.8 (13.3)	34.2 (15.3)	0	0	4 (3.6)
Human-made basin or pond	8.2 (3.8)	7.7 (6.9)	32 (16.6)	0	0	0
Dikes, dams, and water control structures	10.9 (4.2)	15.4 (9.7)	32 (16.6)	0	0	0
Riprap along shoreline	5.8 (2.9)	7.7 (6.4)	18.2 (13.7)	0	0	4 (3.7)
Vegetation Stressors in 100-m Buffer						
Vegetation control (e.g., spraying, mowing, burning)	5.8 (2.9)	7.7 (6.3)	16 (13.2)	2.7 (2.3)	0	4 (3.6)
Extensive damage from insects or mammals	26 (7)	23.1 (10.9)	0	8 (3.7)	50 (19.8)	12 (5.3)
Non-native plant species cover	82.2 (6.2)	100 (0)	100 (0)	92 (2.8)	50 (19.7)	88 (4.1)

tracks, and utility corridors were widespread across the watershed, whereas agriculture and development were only found in buffers in the Central Basin ecoregion and in the Mountain Valleys (tables 6 and 7). Buffer livestock grazing was most common in the Mountain Valleys and least common in the Alpine Zone and Wasatch Montane Zone.

Stressors related to water quality were found in at least one site buffer per stratum. Excessive algae is estimated to occur in between 16.7% and 45% of wetland area, depending on strata. Forty percent of Jordan stratum wetlands are estimated to receive stormwater or wastewater discharge; this stressor was not recorded in any other strata. Buffer livestock grazing was estimated to have moderately severe water quality impacts on 16.0% and low impacts on 21.7% of wetland buffer area, with more severe impacts related to nutrient addition rather than sediment. Other contributors to wetland water quality stress from the buffer included dirt and gravel roads, trails, vegetation control, dikes, and off-road vehicle disturbance contributing sediment and crops, mines, and paved roads contributing other contaminants.

Hydroperiod stressors were not nearly as common within buffers as they were in the larger landscape and were, except for compaction from livestock and minor berming from roads, absent from the Wasatch Montane Zone and Alpine Zone. Human constructed ponds were common in the Jordan and Semiarid Foothills strata and compaction from livestock grazing was very common in the Mountain Valleys. Most buffer stressors were evaluated as having low impact on hydroperiods, though berms and ditches were frequently recorded as moderate to high severity, particularly in the Great Salt Lake, Semiarid Foothills, Mountains Valleys, and Jordan strata. Direct stormwater inputs and dredged depressions were also frequently recorded as having moderate to high severity hydroperiod impacts in the Jordan stratum.

Frequently recorded stressors to vegetation in the buffer included cover of non-native plants, excessive herbivory, and vegetation control. Non-native plant cover is the most common buffer stressor in the watershed, found at almost all wetlands and estimated as moderate to high severity in 72.8% of all wetland area. Excessive herbivory due to beetle kill was recorded in the Alpine Zone and Wasatch Montane Zone, and extensive mammalian browse on shrubs and trees was recorded in the Great Salt Lake, Mountain Valleys, and Wasatch Montane Zone. Vegetation control in the buffer, including spraying and mowing, was more common in the Central Basin ecoregion than in the Wasatch Mountains Ecoregion. Most of the control was aimed at non-native species, though mowing was sometimes conducted to limit fire danger or create walking paths.

Site Stressors

We recorded stressors present directly in the AA in three categories: hydroperiod, vegetation, and physical structure. An estimated 82.3% of wetland area in the Central Basin ecoregion and 65.9% of wetland area in the Wasatch Mountains ecoregion have at least one AA stressor (tables 8 and 9). Stressors affecting vegetation were the most widespread, found in approximately two-thirds of wetland area in each ecoregion. Livestock browse on vegetation and moderate to heavy filamentous algae were common vegetation stressors throughout the watershed. In contrast, excessive wildlife herbivory (including beetle-kill) was only found in the Wasatch Mountains ecoregion and impacts from off-road vehicles and vegetation control efforts were only found in the Central Basin ecoregion. The most common stressors to the physical environment were trampling from livestock grazing and, in the Central Basin only, off-road vehicle disturbance and dumping of garbage; physical stressors such as sediment

Table 8. Assessment area stressors in the Central Basin ecoregion, with estimated percentage of wetland area affected by each stressor and standard error in parentheses.

Stressor	Central Basin Ecoregion	Great Salt Lake	Jordan	Utah Lake
Any Stressor	82.3 (5.3)	85 (7.0)	70 (10.5)	80 (8.2)
Hydroperiod stressors, including dikes, channel modification, and soil compaction affecting hydrology	20.4 (5.2)	10 (4.4)	40 (14.8)	30 (9.5)
Physical stressors	55.1 (6.7)	50 (9.6)	50 (8.3)	60 (9.6)
Dumping of garbage	22.9 (5.8)	15 (7.3)	50 (8.3)	30 (8.8)
Vegetation stressors	67.4 (6.6)	70 (8.9)	60 (11)	65 (9.9)
Excessive wildlife herbivory	0	0	0	0
Moderate to heavy filamentous algae	32.3 (6.7)	40 (10.1)	30 (12.9)	25 (9)
Vegetation control (burning, spraying, mowing, etc.)	20 (5.5)	20 (7.6)	20 (9.9)	20 (8)
Chemical vegetation control	17.4 (5.2)	20 (7.6)	10 (8.5)	15 (7.3)
Vegetation mowing	2.6 (2.2)	0	10 (8.5)	5 (4.4)
Other mechanical vegetation removal	4.9 (2.3)	10 (4.7)	10 (8.5)	0
Burned wetlands	2.4 (2.2)	5 (4.5)	0	0
Livestock grazing within AA	37.4 (6.4)	30 (9.2)	0	45 (8.9)
Effect on hydroperiod	7.5 (3.3)	5 (4.1)	0	10 (5.2)
Effect on physical environment	30 (5.9)	20 (8.3)	0	40 (8.4)
Effects on vegetation / browse	20 (5.5)	15 (7)	0	25 (8.5)
Off-road vehicles or machinery	32.3 (6.2)	35 (9.2)	20 (9.9)	30 (8.8)
Effect on hydroperiod	10.4 (4.3)	0	20 (9.9)	20 (8.4)
Effect on physical environment	27.4 (5.8)	30 (8.6)	20 (9.9)	25 (8.1)
Effects on vegetation	22.4 (5.6)	25 (8.3)	20 (9.9)	20 (7.9)

deposition and anthropogenic surface erosion were rare. Similarly, compaction and entrenchment from livestock grazing in the entire watershed and off-road vehicles in the Central Basin ecoregion were the most common hydroperiod stressors. Other hydroperiod stressors, including channel modification and small dikes within sites, were uncommon and only found in the Great Salt Lake, Jordan, and Mountain Valleys strata.

At least one moderate or one high severity AA stressor is estimated to occur in 37.6% (SE 5.6) and 17.4% (SE 5.5) of the Central Basin and 37.9% (SE 8.0) and 8.5% (SE 3.7) of the Wasatch Mountains ecoregions, respectively. Livestock stressors were predominantly low severity in the Central Basin ecoregion and predominantly moderate in the Wasatch Mountains ecoregion; Mountain Valleys had the highest percent of sites with moderate (53.8%, SE 9.2) and high (7.7%, SE 6.2) severity stress from livestock. Chemical vegetation control in the Central Basin ecoregion was more often recorded as high severity than moderate or low severity. Excessive filamentous algae was usually recorded as moderate severity in both ecoregions. Off-road vehicle and dumping of garbage were almost always recorded as low severity except for at a few sites in the Utah Lake and Jordan strata.

Table 9. Assessment area stressors in the Wasatch Mountains ecoregion, with estimated percentage of wetland area affected by each stressor and standard error in parentheses.

Indicator	**Wasatch Mountains Ecoregion**	**Mountain Valleys**	**Semiarid Foothills**	**Wasatch Montane Zone**	**Alpine Zone**	***National Forest***
Any Stressor	65.9 (7.8)	92.3 (6.4)	29.4 (10.3)	81.3 (6.1)	50 (19.2)	60 (7.4)
Hydroperiod stressors, including dikes, channel modification, and soil compaction affecting hydrology	18.6 (4.3)	46.2 (11.3)	4.5 (2.8)	10.7 (5)	0	24 (7.1)
Physical stressors	36.6 (7.5)	76.9 (8.9)	8.9 (3.5)	16 (6.5)	16.7 (15)	40 (7.4)
Dumping of garbage	6.6 (3.5)	15.4 (9.8)	2.2 (2.1)	5.3 (3.8)	0	12 (6.1)
Vegetation stressors	62.4 (8)	84.6 (9.4)	27.2 (10.7)	78.6 (6.4)	50 (19.2)	52 (7.4)
Excessive wildlife herbivory	12.1 (4.9)	15.4 (8.9)	4.5 (3.1)	2.7 (2.3)	16.7 (13.7)	12 (6.1)
Moderate to heavy filamentous algae	26.9 (7.3)	30.8 (12.6)	6.7 (3.7)	65.3 (9.2)	16.7 (14.9)	24 (7.2)
Vegetation control (burning, spraying, mowing, etc.)	0	0	0	0	0	0
Livestock grazing within AA	35.8 (7.3)	69.2 (8.2)	24.9 (9.9)	10.7 (5)	16.7 (15)	32 (5.8)
Effect on hydroperiod	13.2 (3.8)	30.8 (11.1)	4.5 (2.8)	10.7 (5)	0	24 (7.1)
Effect on physical environment	33.1 (7.2)	69.2 (8.2)	8.9 (3.5)	10.7 (5)	16.7 (15)	32 (5.8)
Effects on vegetation (not including composition)	32.3 (7.1)	61.5 (10.7)	22.7 (10.4)	8 (4)	16.7 (15)	24 (5.3)
Off-road vehicles or machinery	0	0	0	0	0	0

Rapid Assessment Condition Results

The landscape condition category is composed of three metrics, whole wetland connectivity, percent intact landscape, and overall buffer condition, the latter composed of four submetrics. At least 70% of wetland area in each stratum is estimated to be in good to excellent condition for whole wetland connectivity and only two strata, Jordan and Great Salt Lake, have any wetland area estimated to be in poor condition (figure 4). Percent intact landscape and overall buffer condition is estimated to be good to excellent in ≥75% and ≥90% of wetland area, respectively, for all but the Jordan and Mountain Valleys. Buffer vegetation was in poor condition much more frequently than other aspects of the buffer; buffer vegetation is estimated to be in poor condition in 44.9% of the Central Basin and 19.1% of the Wasatch Mountains wetland area.

AA soil disturbance was generally minimal; ≥93% of wetland area in each stratum except the Mountain Valleys was in good to excellent condition (figure 5). Soil disturbance was rated fair in only the Jordan, Utah Lake, and Wasatch Montane Zone strata and was never rated as poor.

The vegetation structure category is composed of the litter accumulation, woody debris, woody regeneration, and interspersion metrics. Litter accumulation is estimated to be good-excellent (AB) in 62.3% and 83.2 of wetland area in the Central Basin and Wasatch Mountains ecoregions, respectively (figure 6). Excessive litter is estimated to occur in 27.6% of Central Basin wetlands and sparse litter is estimated to occur at 10.1% of Central Basin and 16.8% of Wasatch Mountains wetlands. Horizontal interspersion was estimated in all wetlands but excluded in the calculation of overall condition scores in alkaline depression, playas, and basin and montane marsh sites because these systems naturally have

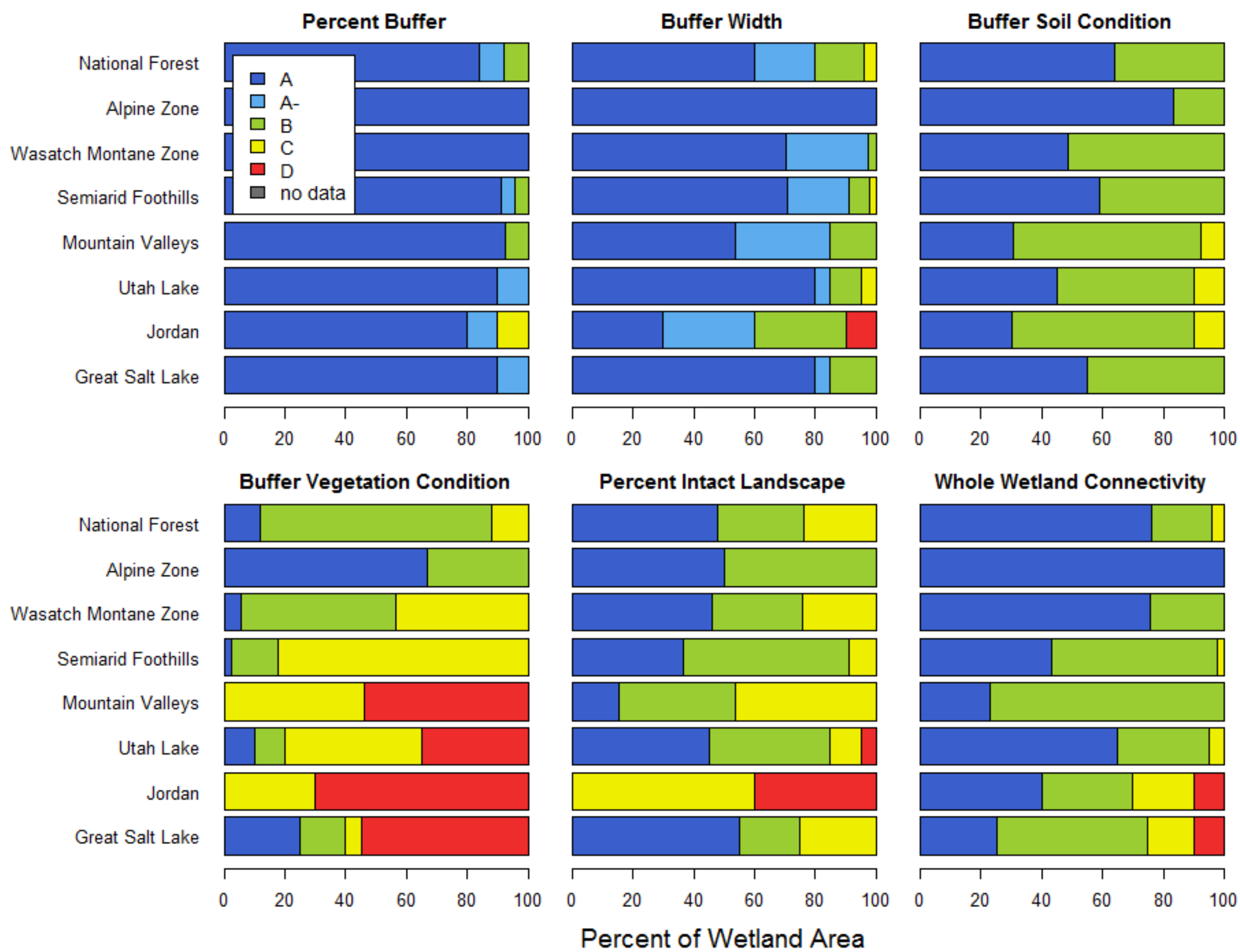

Figure 4. Estimate of percentage of wetland area in each stratum with each rank for landscape condition metrics, as well as estimates for the National Forest land.

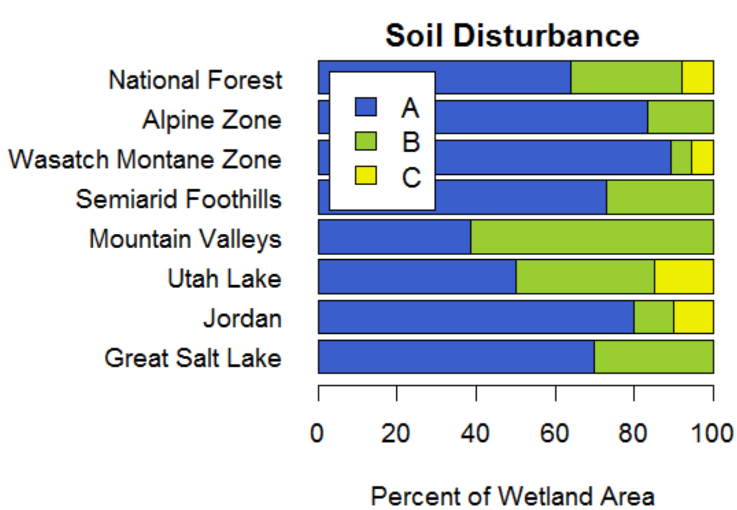

Figure 5. Estimate of percentage of wetland area in each stratum with each rank for the soil disturbance condition metric, as well as estimates for the National Forest land.

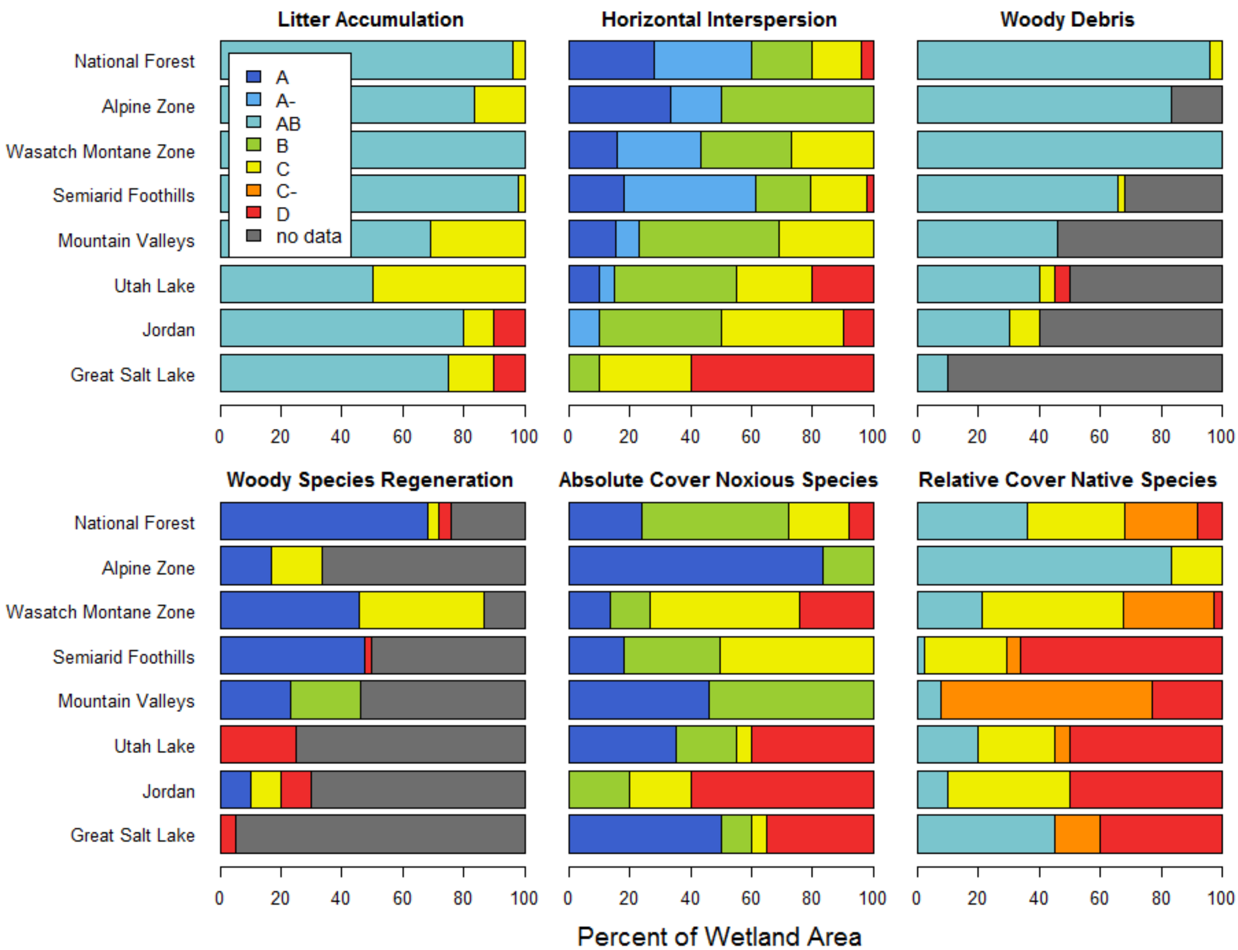

Figure 6. Estimate of percentage of wetland area in each stratum with each rank for vegetation structure and vegetation composition metrics, as well as estimates for the National Forest land.

low levels of interspersion. As expected, these Ecological Systems, and the Central Basin strata where they are found, scored poorly on the horizontal interspersion metric, though alkaline depressions showed more breadth of scores than other Ecological Systems. In the Wasatch Mountains ecoregion, wet meadows tended to have less horizontal interspersion than woody systems. The woody debris and woody species regeneration metrics were only scored at sites expected to have inputs of woody debris or woody species regeneration. Woody debris condition is estimated to be fair or poor in a small percent of wetland area in the Jordan, Utah Lake, and Semiarid Foothills strata and otherwise estimated to be good-excellent (AB). Woody species regeneration is estimated to be poor due to excessive canopy cover of invasive woody species in 5% of Great Salt Lake, 10% of Jordan, and 25% of Utah Lake wetland area. Forty percent of wetland area in the Wasatch Montane Zone is estimated to have only fair woody species regeneration with seedlings and saplings missing.

The vegetation composition category is composed of two metrics, absolute cover of noxious species and relative cover of native species. Sites that scored as excellent or good in the Central Basin ecoregion for relative native cover were frequently species-poor systems with <5 species, such as playas with only *Salicornia rubra* (red swampfire) or marshes with only one or two species of submerged aquatic vegetation. Half the Jordan and Utah Lake wetland area and 40% of Great Salt Lake is estimated to have poor relative cover of native plant species, defined as <50% relative cover of native species (figure 6). *Phragmites australis* ssp. *australis* (phragmites) was dominant at more than half of the sites with poor relative native cover; *Atriplex micrantha* (twoscale saltbush)*, Bassia hyssopifolia* (fivehorn smotherweed)*,* and *Tamarix* spp. (tamarisk) were often dominant or co-dominant at the remaining sites. *P. australis* ssp. *australis* and *Tamarix* spp. were also the most widespread noxious weeds encountered in the Central Basin ecoregion. Almost two-thirds of the Semiarid Foothills wetland area and one-quarter of the Mountain Valleys is estimated to be in poor condition for relative cover of native species. Dominant non-native species at these sites were often one or more non-native grasses, including *Agrostis gigantea* (redtop), *Alopecurus pratensis* (meadow foxtail), *Phalaris arundinacea* (reed canarygrass), *Phleum pratense* (timothy) and *Poa pratensis* (Kentucky bluegrass). Three sites in the Wasatch Montane Zone had more than 10% cover noxious weeds. All three had high cover of *Cirsium arvense* (Canada thistle). Noxious weeds were uncommon or occurred with low abundance in the Mountain Valleys and Alpine Zone.

Hydrologic condition is composed of six metrics, including wetland edge connectivity, water quality, hydroperiod, timing of inundation, turbidity and pollutants, and algae growth, though the latter two metrics are only evaluated in wetlands with standing water or desiccated filamentous algae. More than 85% of wetland area in each ecoregion is estimated to be in excellent condition for wetland edge connectivity (figure 7). Over half of the wetland area in the Great Salt Lake, Jordan, and Mountain Valleys strata is estimated to be in fair or fairly poor (C-) condition for hydoperiod and timing of inundation and half of the wetland area in the remaining strata is estimated to be good to excellent for these metrics. Water quality is estimated to be good to excellent in almost all wetland area in the Semiarid Foothills, Wasatch Montane Zone, and Alpine Zone and fair to poor in other strata, with the highest percent poor water quality in the Jordan stratum. Turbidity is estimated to be excellent in most wetland area where rated, though poor in 20% of Jordan wetland area and occasionally fair in Great Salt Lake, Jordan, Utah Lake, and Semiarid Foothills wetlands. Algae condition was fair to poor at almost all wetland area in the Great Salt Lake stratum where it was rated and occasionally fair in the Jordan, Utah Lake, Mountain Valleys, and Wasatch Montane Zone. Excessive dried algae was recorded at five Great Salt Lake, two Utah Lake, and one Semiarid Foothills wetlands.

The estimated mean overall condition scores per strata ranged from 3.5 in the Jordan to 4.77 in the Alpine Zone. Two Great Salt Lake wetlands and one Jordan wetland scored below 3.0 and one National Forest Wasatch Montane Zone wetland scored a perfect score of 5.0. At least one site in each stratum scored ≤3.9. except the Alpine Zone, where the lowest score was 4.4. Wetlands in the Semiarid Foothills had a very narrow range of scores; the estimated 10th and 90th percentile scores differed by only 0.29. The five highest scoring sites in the Central Basin, all with scores ≥4.5, included three marshes with predominantly submerged aquatic vegetation, one *S. rubra* playa, and a spring-fed wetland near Utah Lake. The five highest scoring sites in the Wasatch Mountains ecoregion, all with scores ≥4.9, were wet meadows and shrublands on National Forest land.

We compared the cumulative density functions of overall condition scores to determine whether the distributions differed by strata. We used $p < 0.01$ as the threshold to determine whether distributions differed instead of $p < 0.05$ because of the high number of comparisons being made

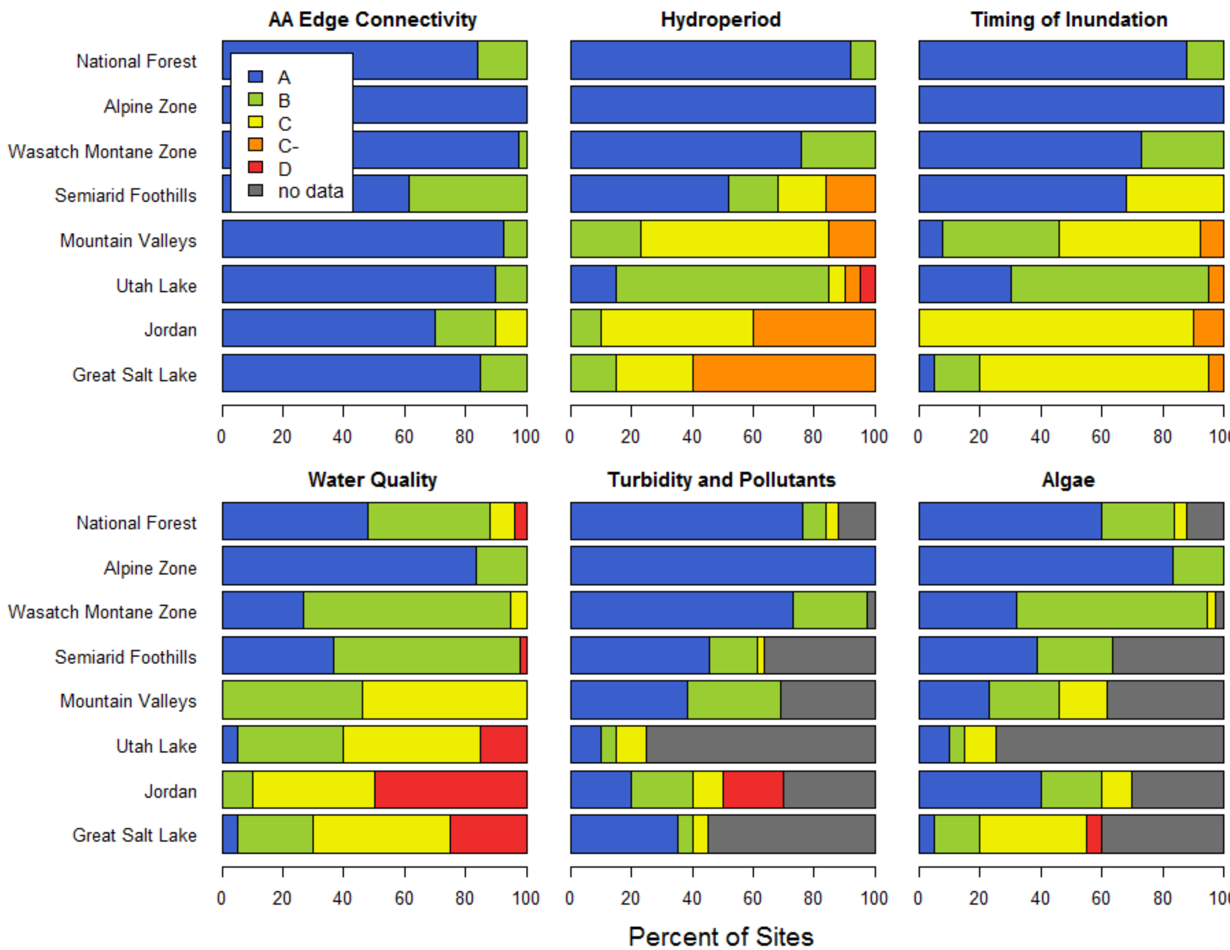

Figure 7. Estimate of percentage of wetland area in each stratum with each rank for hydrologic condition metrics, as well as estimates for the National Forest land.

(Kincaid, 2016). We could not compare the Alpine Zone to the Wasatch Montane Zone or the Jordan to the Mountain Valleys because there was too little data in different score classes for comparison. Jordan and Alpine Zone cumulative density functions differed from one another and all comparable strata, except there was no difference between the Alpine Zone and Semiarid Foothills (figure 8).

Wetland Function

Boreal Toad

We surveyed 27 sites in non-prime habitat and 25 sites in prime habitat for the boreal toad. All sites in the prime habitat scored as fair or better for the breeding waterbodies metric, indicating at least some surface water present at the sites; >90% wetland area in the prime habitat is estimated to be good or excellent for breeding waterbodies (table 10). Cover of surrounding shrub and forb vegetation, presence of north shore, and slope and water depth were the biggest limiting factors, estimated to be fair or poor in between 44% and 55% of wetland area. An estimated 68.1% (SE 9.2) of wetland area in the non-prime habitat have breeding waterbodies that scored above poor. In this subset of non-prime habitat, surrounding vegetation and presence of north shore were the two most common limiting

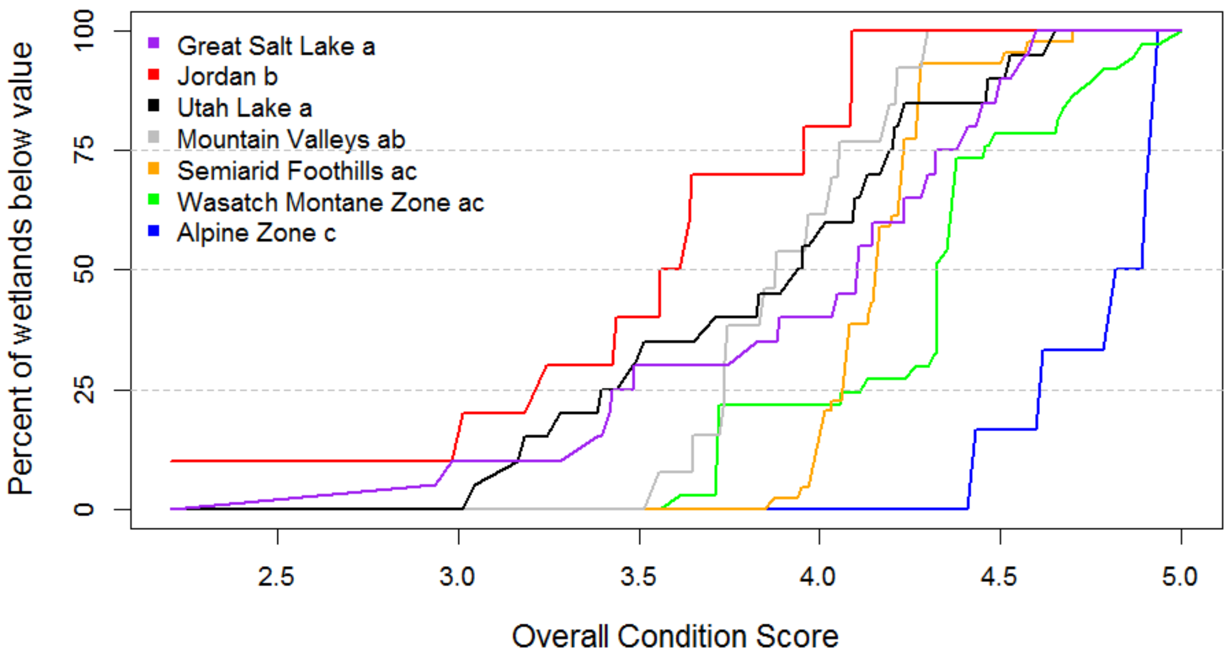

Figure 8. Cumulative density functions for overall condition scores showing the estimated percentage of wetland area with an overall URAP score at or below the indicated values. Strata that share lowercase letters do not significantly differ from one another in the shape of the density function, except for two comparisons, Alpine Zone – Wasatch Montane Zone and Jordan – Mountain Valleys, which did not have enough unique values for comparison

factors, estimated to be fair to poor at 77% and 65% of wetland area, respectively. Under-abundance of surrounding vegetation was more common than overabundance in both prime and non-prime habitat. The water temperature metric was almost always scored as good or fair and never scored as excellent. Beaver are estimated to be present in 14.0% (SE 6.0) of non-prime and 27.1% (SE 8.5) of prime wetland habitat.

About half the wetland area in the non-prime habitat is estimated to have a mean metric score <2.5, whereas the lowest mean score in the prime habitat was 2.8. About 44% of wetland area in the prime habitat and 35% in the non-prime habitat is estimated to have mean habitat metric scores ≥3.8, though most of the high scoring sites in the non-prime habitat are likely too low in elevation for the species, such as along the middle section of the Provo River. An adult boreal toad was observed at one site during surveys in the watershed; this site had the highest mean habitat metric score, 4.7, of all surveyed sites.

Key threats listed for the boreal toad in the Utah Wildlife Action Plan include chytrid, drought, problematic native species (tiger salamander), prescribed fire, and improper grazing management (J. Gragg, Utah Division of Wildlife Resources, unpublished information, 2015; Utah Division of Wildlife Resources, 2015). We did not evaluate the prevalence of chytrid or drought impacts at sites. We did not observe tiger salamanders at surveyed sites, though trout and other potentially predacious fish were observed at three sites in the non-prime habitat. We did not record any fire damage within sites or their

Table 10. Boreal toad habitat metric estimates, in non-prime and prime habitat (only considering those sites that scored at least fair or higher for breeding waterbodies). Value includes percentage of wetland area with standard error in parentheses.

Habitat Metric	A	B	C	D
Non-prime wetlands with potential breeding waterbodies (68% of wetland area)				
Breeding waterbody	35.8 (11.7)	30.5 (11.9)	33.7 (12.3)	*NA*
North shore	15.2 (8.9)	19.5 (9.1)	16.3 (9.1)	48.9 (11.5)
Slope and depth	40.2 (12.5)	56.6 (12.6)	2.1 (1.1)	1.1 (1)
Temperature	0	88.1 (6.6)	11.9 (6.6)	0
Vegetation (shrub/forb)	21.6 (8.5)	1.1 (0.9)	39.2 (11.9)	38.1 (10.4)
Hibernation	50.0 (8.8)	11.9 (6.5)	7.6 (6.7)	30.5 (10.9)
Prime wetlands with potential breeding waterbodies (100% of wetland area)				
Breeding waterbody	55.4 (12.5)	38.2 (12)	6.4 (1.9)	*NA*
North shore	37.2 (12.4)	19 (10.8)	13.3 (10.5)	30.5 (13.1)
Slope and depth	35.2 (11.6)	16.5 (9.9)	47.5 (13.1)	0.8 (0.7)
Temperature	0	66.9 (14)	30.7 (13.9)	2.4 (1.2)
Vegetation (shrub/forb)	20.6 (8.4)	24.1 (12.8)	30.3 (11.2)	24.9 (11.7)
Hibernation	55.3 (13.2)	33.1 (13.8)	11.7 (9.6)	0

buffers. Livestock grazing is estimated to occur in 14.9% (SE 10.5) of prime habitat wetland area, with an additional 1.6% (SE 0.8) of wetland area with grazing in the surrounding buffer. Only 1.8% (SE 1.7) of high scoring (i.e., mean metric scores ≥3.8) prime habitat wetland area is estimated to have grazing within or surrounding the site. Grazing was more common in the non-prime habitat; over one-third of wetland area is estimated to have grazing within the wetland or its buffer.

Turbidity and recreational use are two stressors not listed in the Wildlife Action Plan that may be important for boreal toad (Menuz, 2017). Turbidity tube measurements indicated potential issues with water clarity in an estimated 25.7% (SE 13.7) of high scoring prime wetland area; none of the lower scoring prime habitat wetlands had turbidity issues. In the non-prime habitat, turbidity is a potential issue in 17.0% (SE 13.4) of high scoring and 46.7% (SE 18.2) of lower scoring wetland area. We did not directly measure evidence of recreational use within sites, but we did find that 44.7% (SE 14.3) of prime wetlands and 17.0% (SE 7.3) of non-prime wetlands are estimated to be within 100 m of recreational trails and 15.4% (SE 6.2) of prime and 30.3% (SE 9.6) of non-prime wetlands are estimated to have trash in or near the wetlands. Trash directly in wetlands was much less common than trash adjacent to wetlands.

Columbia Spotted Frog

We evaluated Columbia spotted frog habitat at 50 randomly selected sites in the Central Basin ecoregion, 28 sites in non-prime montane habitat, and 24 sites in prime montane habitat. Potential breeding waterbodies (i.e., potential surface water) was found at about 83% of wetland area in the Central Basin ecoregion and in the non-prime montane habitat and about two-thirds of wetland area in the prime montane habitat (table 11). However, potential breeding waterbodies are estimated to be

Table 11. Columbia spotted frog habitat metric estimates, only considering those sites that scored at least C or higher for breeding waterbodies. (e.g., surface water likely). Value includes percentage with standard error in parentheses. Estimates for waterbody substrate are only available for sites surveyed in 2016.

Habitat Metric	**A**	**B**	**C**	**D**	**No data**
Central basin wetlands with potential breeding waterbodies (83.4% [SE 5.2] of wetland area)					
Breeding waterbody	26.2 (5.1)	0.4 (0.2)	73.4 (5.1)	*NA*	0
Vegetation in waterbody	10.3 (3.8)	21.7 (6.8)	39.9 (7.5)	28 (6.4)	0
Waterbody substrate	21.2 (5.8)	6.3 (3.6)	0	5.9 (3.7)	66.6 (7.0)
Overwintering waterbody	0.2 (0.2)	6.5 (3.5)	45.0 (6.7)	48.3 (7.1)	0
Non-prime montane wetlands with potential breeding waterbodies (83.0% [SE 7.0] of wetland area)					
Breeding waterbody	47.2 (12.3)	9.2 (8.2)	43.6 (12.4)	*NA*	0
Vegetation in waterbody	29.6 (11.8)	30.5 (11.9)	29.6 (11.4)	10.3 (6.8)	0
Waterbody substrate	29.6 (11.7)	21.2 (10.2)	1.9 (1.2)	0	47.3 (12.6)
North shore	37.1 (12.0)	11.1 (7.8)	11.1 (8.4)	40.8 (12.8)	0
Slope and depth	40.9 (10.9)	22.3 (10.1)	36.8 (11.1)	0	0
Overwintering waterbody	65.6 (11)	1.9 (1.2)	19.6 (8.5)	12.9 (8.0)	0
Prime wetlands with potential breeding waterbodies (62.5% [SE 10.6] of wetland area)					
Breeding waterbody	36.7 (13.8)	10.0 (8.3)	53.3 (14.3)	*NA*	0
Vegetation in waterbody	24.5 (10.9)	21.1 (12)	43.3 (14.8)	11.1 (8.8)	0
Waterbody substrate	63.3 (13.9)	10.0 (8.3)	0	0	26.7 (11.8)
North shore	20 .0(11.3)	14.5 (8.9)	21.1 (11.9)	44.4 (13.8)	0
Slope and depth	41.1 (14.6)	54.4 (14.6)	3.3 (1.6)	1.1 (1)	0
Overwintering waterbody	47.8 (12.1)	22.2 (12.1)	10.0 (8.7)	20.0 (11.3)	0

good or excellent in only about one-quarter of Central Basin, just over half of non-prime montane, and just under half of prime montane wetland area. We examined the ratings of the remaining habitat features to estimate which factors were the most limiting at sites with at least some potential for breeding waterbodies (i.e., those sites that scored fair or higher for the breeding waterbody metric). Waterbody substrate is estimated to be good to excellent in between 82% and 100% of wetland area per region where it was rated. The most widespread limiting factor in the Central Basin was the presence of overwintering waterbodies, which are estimated to be good or excellent in less than 7% of wetland area. Most areas either had no potential overwintering waterbodies or potential overwintering waterbodies that may freeze or were not particularly well-oxygenated. Just over two-thirds of wetland area in the Central Basin with potential breeding waterbodies had fair to poor waterbody vegetation. The most limiting factor in the prime and non-prime montane habitat was the presence of north shore, which was rated poor in >40% of wetland area. Overwintering waterbodies were rarely a limiting factor in the Wasatch Mountains ecoregion, estimated as good to excellent in more than two-thirds of wetland area with potential breeding waterbodies. Beaver were found at 17.4% (SE 7.5) of prime and 23.9% (SE 9.0) of non-prime montane habitat; evidence of beaver was not recorded in the Central Basin ecoregion.

About 42% of the non-prime montane, 35% of the prime montane, and 15% of the Central Basin wetland area is estimated to have a mean metric score ≥3.5, and about half the wetland area in the Central Basin and prime montane habitat and one-fifth the wetland area in the non-prime habitat are estimated to have mean scores <2.5. Six sites were surveyed in regions known to be occupied by Columbia spotted frog, including five in prime montane habitat along the Provo River and one in the Central Basin. One site received a mean metric score of 5.0; a Columbia spotted frog individual was observed at this site. Three sites were rated as good with scores ranging from 3.6 to 4.4, and two sites were rated as poor. One of the poor sites was a riparian wetland along the Provo River with no surface water and the other was a Central Basin spring that appeared to be severely drying.

Key threats listed for the Columbia spotted frog in the Utah Wildlife Action Plan include invasive non-native species, groundwater pumping, housing and urban development, and droughts (Utah Division of Wildlife Resources, 2015). Bullfrogs near Mona and groundwater pumping threats in Snake Valley are considered localized issues (J. Gragg, Utah Division of Wildlife Resources, unpublished information, 2015). Invasive non-native species is the only key threat from the Utah Wildlife Action Plan that was directly evaluated; bullfrogs and tiger salamanders were not seen at any survey sites. Over half (61.1%, SE 9.4) of wetland area in the prime montane stratum had at least one observed potential predator, versus 15.4% (SE 8.6) in the non-prime montane and 8.8% (SE 3.9) in the Central Basin. Avian predators, such as hawks, heron, and raven, were the most commonly observed threat, whereas other potential predators are estimated in 8% or less of wetland area.

Though groundwater stress and drought impacts were not directly evaluated at survey sites, field surveys and landowner conversations highlighted groundwater issues in northern Juab Valley, where we surveyed two spring sites. Both sites showed evidence of drying; one was completely dry and considered no longer target wetland and the other had marsh vegetation, but no surface water or soil saturation. Landowners at both sites expressed concerns about drying water levels, which they attributed to over-allocation of water in the region. Regional well data indicate that groundwater levels declined from 2015 to 2016, likely due to large irrigation withdrawals and less-than-average precipitation, and that there has been a generally declining trend since the late 1980s (Burden and others, 2016).

We used the distance to impervious surface and percent intact landscape metrics to evaluate potential impacts from housing and urban development. Almost all (>86%) of the wetland area with good breeding habitat (mean metric values ≥3.5) in the Central Basin and non-prime montane habitat was >300 m from impervious surface and <3% was within 100 m. In contrast, one-third of the good breeding habitat in the prime montane area was within 100 m of impervious surface and only about one-fifth was >300 m from impervious surface. Approximately half the wetland area with good breeding habitat in the Central Basin, 65% in the prime montane, and 83% in the non-prime montane have at least 60% unfragmented, natural land cover within 500 m of the wetland.

We evaluated three other potential stressors at sites, off-road vehicles, trash, and livestock grazing. Off-road vehicle disturbance was only recorded at sites in the Central Basin with low mean metric scores. Trash, a surrogate for human visitation, is estimated to be present at 29.8% (SE 16.2), 16.3% (SE 14.0), and 3.3% (SE 1.6) of basin, non-prime montane, and prime montane wetlands with good breeding habitat, respectively. Livestock grazing is estimated to occur within wetlands at none of the Central Basin, 5.0% (SE 1.7) of the prime montane, and 30.1% (SE 10.2) of the non-prime montane wetland area with good breeding habitat.

Water Quality Improvement

All but one site, a sparsely vegetated playa in the Utah Lake stratum, had at least some capacity for improving water quality based on the water quality indicator checklist, and >80% of sites had at least two indicators. Herbaceous vegetation ≥13 cm in height was the most common capacity indicator, estimated to occur in ≥90% of wetland area in all strata except for Great Salt Lake and Utah Lake. Clay or organic top soil, herbaceous vegetation, seasonal ponding, no or intermittent surface outlet and vegetation extending into lake were the most common capacity indicators in the Central Basin ecoregion, estimated to occur in between 30% and 61% of wetland area. In the Wasatch Mountains ecoregion, the most common capacity indicators include herbaceous vegetation, woody vegetation, soil or clay top soil, and seasonal ponding, estimated to occur in between 30% and 98% of wetland area. Mean number of capacity indicators found per site ranged from 2.1 in the Mountain Valleys to 3.7 in the Jordan stratum (table 12).

Landscape potential for water quality improvement was most common in the Jordan stratum, with a mean of 2.8 indicators per site, and absent from the Alpine Zone (table 12). Only wetlands in the Semiarid Foothills, Wasatch Montane Zone, and Alpine Zone sometimes lacked landscape stress indicators. Sources of sediment and nutrients and sources of other pollutants in the contributing basin were the two most common indicators and were more common in the Central Basin ecoregion than the Wasatch Mountains ecoregion. Sources of sediment/nutrients and other pollutants immediately adjacent to wetlands were less common, though estimated in between 15% and 20% of wetland area in the Semiarid Foothills, Mountain Valleys, Utah Lake, and Jordan stratum. Half of the Jordan wetlands are fed by stormwater pipes.

Alpine Zone wetlands had the most indicators of societal value for water quality improvement and Great Salt Lake had the least, with a mean of 3.5 and 0.25, respectively (table 12). All wetlands on land owned by the Uinta-Wasatch-Cache National Forest, including wetlands in the Alpine Zone, are classified as anti-degradation category 1 waters. Jordan has the most wetland area in impaired water quality assessment units and Great Salt Lake has the least, though most units in Great Salt Lake stratum have not been assessed.

We categorized wetlands as likely to provide a water quality service if they had at least one landscape indicator and two or more capacity indicators. Based on these criteria, over three-quarters of wetland area in the Central Basin ecoregion is estimated to provide water quality service, including 90% of the Jordan stratum wetland area (table 13). In contrast, less than half of the wetland area in the Wasatch Mountains ecoregion is estimated to provide water quality service. We categorized wetlands as representing a potential needs gap if they had at least one landscape indicator and one or no capacity indicators. About 22% of the Central Basin wetland area and 9% of the Wasatch Mountains ecoregion may have a needs gap, with the largest gaps in the Utah Lake and Mountain Valleys strata.

Wetland Vegetation

We recorded 2467 encounters with 435 unique plant species at random and reference sites, including 149 species found at only one site. Non-native species comprised 21% of these species. We were not able to identify to species 210 of the plants we encountered, of which 165 were tentatively

Table 12. Percentage of wetland area estimated to have each water quality functional indicator, with standard error in parentheses. Values in bold indicate the mean number of capacity, landscape, and society indicators per stratum.

	Great Salt	Jordan	Utah Lake	Mountain	Semiarid	Wasatch	Alpine	*National*
Capacity	**2.70 (0.22)**	**2.55 (0.26)**	**3.70 (0.39)**	**2.08 (0.20)**	**2.32 (0.34)**	**2.87 (0.22)**	**2.33 (0.24)**	**2.16 (0.14)**
Top of soil clay or organic	40.0 (8.1)	70.0 (12.4)	25.0 (7.2)	30.8 (11.9)	36.4 (16.6)	48.9 (16)	50.0 (19.8)	24 (8.1)
Slope <1% (slope/impoundment fringe classes)	20.0 (6.8)	0	10.0 (6.1)	15.4 (8.3)	0	2.7 (2.4)	16.7 (15)	4.0 (3.6)
Herbaceous vegetation >13 cm tall	45.0 (9.9)	90.0 (8.3)	75.0 (8.4)	100 (0)	93.3 (3.5)	94.7 (3.5)	100 (0)	80.0 (7)
Herbaceous vegetation >1 m tall	35.0 (9.7)	80.0 (12.3)	35.0 (9.1)	23.1 (9.4)	47.9 (15.8)	24.4 (14.9)	0	8.0 (4.6)
Woody vegetation >1 m tall	0	10.0 (8.1)	5.0 (4.o)	30.8 (12.0)	31.6 (14.9)	84.0 (6.9)	16.7 (13.7)	68.0 (8.6)
Seasonally ponded	45.0 (10.3)	50.0 (13.5)	65.0 (8.8)	15.4 (8.3)	6.7 (3.5)	48.9 (16)	50.0 (18.9)	28.0 (8.1)
No/intermittent surface outlet	55.0 (8.4)	70.0 (9.0)	5.0 (4.1)	7.7 (6.9)	32.0 (15.5)	2.7 (2.3)	0	4.0 (3.3)
Vegetation extending into lake	30.0 (8.6)	10.0 (8.3)	35.0 (7.9)	0	0	0	0	0
Landscape	**1.05 (0.04)**	**2.15 (0.17)**	**2.80 (0.15)**	**1.38 (0.15)**	**0.84 (0.36)**	**0.52 (0.16)**	**0**	**0.28 (0.11)**
Septic systems	0	0	5.0 (4.1)	0	0	0	0	0
Stormwater pipes	0	50.0 (8.3)	0	0	0	0	0	0
Adjacent sediment/nutrient	0	10.0 (8.1)	20.0 (7.7)	15.4 (8.8)	18.2 (13.7)	5.3 (3.5)	0	12.0 (5.9)
Adjacent pollutants	0	20.0 (9.9)	5.0 (4.1)	7.7 (6.9)	0	2.7 (2.6)	0	4.0 (3.5)
Power boats	0	0	40.0 (8.1)	0	0	0	0	0
Known algal bloom issues	0	0	40.0 (8.1)	15.4 (8.8)	47.9 (15.8)	0	0	0
Other sources of pollutants	0	0	0	7.7 (6.8)	0	0	0	0
Basin generating sediment/nutrient	75.0 (6.7)	50.0 (8.9)	90.0 (5.2)	76.9 (10.3)	16.0 (13.5)	21.8 (15)	0	4.0 (3.5)
Basin generating other pollutants	100 (0)	100 (0)	65.0 (5.6)	23.1 (10.1)	18.2 (13.7)	38.2 (16.6)	0	4.0 (3.4)
Within incorporated city	5.0 (4.2)	100 (0)	15.0 (5.7)	15.4 (8.3)	0	2.7 (2.3)	0	4.0 (3.6)
Society	**0.25 (0.15)**	**1.85 (0.17)**	**2.30 (0.18)**	**1.31 (0.27)**	**1.68 (0.36)**	**2.08 (0.42)**	**3.50 (0.19)**	**2.68 (0.12)**
Discharges to stream/lake	5.0 (4.1)	50.0 (12.7)	55 (7.6)	38.5 (13.0)	63.6 (14.6)	51.1 (16.6)	50.0 (19.2)	76.0 (7.9)
Impaired (category 4 or 5) water quality	10.0 (5.9)	90.0 (8.3)	65 (6.4)	38.5 (10.8)	34.2 (16.9)	51.5 (15.6)	100 (0)	24.0 (5.9)
Anti-degradation status (category 1 or 2)	0	0	0	0	20.1 (5.8)	42.7 (12.3)	100 (0)	100 (0)
Record of water quality exceedances (category 3)	0	0	0	15.4 (8.9)	15.6 (5.0)	10.7 (3.9)	0	44.0 (7.9)

Table 13. Wetland water quality functioning, including percentage of wetland area with both landscape potential and two or more capacity indicators (i.e., providing service) and percentage of wetland area with one or fewer capacity indicators and 1 or more landscape indicators (i.e., needs gap).

Stratum	% Wetland Area Providing Service[1]	Needs Gap	
		≤1 capacity, 1 landscape	≤1 capacity, 2+ landscape
Central Basin ecoregion	**77.4 (5.7)**	**12.5 (4.5)**	**10.1 (4.3)**
Great Salt Lake	85.0 (6.8)	10.0 (6.0)	5.0 (4.2)
Jordan	90.0 (8.3)	0	10.0 (8.3)
Utah Lake	70.0 (9.2)	15.0 (6.7)	15.0 (7.4)
Wasatch Mountains ecoregion	**42.4 (5.6)**	**5.8 (3.3)**	**2.7 (2.4)**
Mountain Valleys	76.9 (11.2)	15.4 (9.5)	7.7 (6.9)
Semiarid Foothills	50.2 (15.7)	0	0
Wasatch Montane Zone	46.2 (16.1)	2.7 (2.3)	0
Alpine Zone	0	0	0
National Forest	*16.0 (6.8)*	*4.0 (3.6)*	*0*

[1]Sites with two or more capacity indicators and at least one landscape potential indicator

identified to genus only and the remainder were identified to lifeform. *Atriplex* was the most frequent genus not identified to species. Members of this genus typically fruit late in the growing season; surveyors revisited some sites in September to obtain fruiting specimens. Other genera commonly not identified to species include *Typha*, *Epilobium*, *Viola*, *Tamarix*, and *Carex*, typically because specimens lacked flowers and fruit. All *Typha* in the study area are native and have a C-value of 2 and all *Tamarix* were considered introduced and noxious, so we included unidentified members of each genus in the floristic data analysis. Excluding *Typha* and *Tamarix*, only 20 unidentified plant records had >2% cover at a site and only 5 had ≥10% cover.

Plant Community Composition Metrics

Most floristic quality assessment measures indicated that Jordan wetlands have the poorest plant community composition and Alpine Zone wetlands the best. The Jordan stratum had the lowest mean values for mean C and cover weighted mean C and the highest mean values for percent non-native species and absolute cover of noxious weeds; the reverse was true of the Alpine Zone wetlands (table 14). Great Salt Lake wetlands had the widest range of values for all five metrics. Each stratum had at least one site with close to 100% relative native cover and, except for in the Alpine Zone, one site with <37% relative native cover.

We compared the cumulative density functions of three metrics to determine whether the distribution of each metric differed by strata. Alpine Zone sites had a different distribution for relative percent native cover than all other strata, except the Wasatch Montane Zone, and Mountain Valleys differed from Great Salt Lake, Utah Lake, and Wasatch Montane Zone (figure 9). All wetlands in the Alpine Zone had very high relative native cover (≥94.8%) and wetlands in the Mountain Valleys rarely

Table 14. Plant community composition measures, with the estimated mean, standard deviation in parentheses, and range.

Strata	Relative Cover Native Species	Absolute Cover of Noxious Weeds	Percent Non-Native Species	Mean C	Cover Weighted Mean C
Central Basin Ecoregion	61.5 (34.7) 0-100	17.8 (28.4) 0-100	36.1 (22.8) 0-100	2.3 (0.9) 0-5	2.3 (1.5) 0-5
Great Salt Lake	62.8 (39.2) 0-100	23.5 (35.5) 0-100	32.4 (28.5) 0-100	2.4 (1.1) 0-5	2.3 (1.5) 0-5
Jordan	57.8 (34.1) 3.5-96.6	34.1 (33) 1-92.2	48.3 (16.6) 26.7-80	2.0 (0.7) 0.5-2.9	2.0 (1.2) 0.1-4.3
Utah Lake	60.3 (29.7) 10.5-100	12.1 (17.6) 0-70.5	39.4 (14.9) 0-66.7	2.3 (0.7) 0.8-3.5	2.3 (1.4) 0.3-4.9
Wasatch Mountains Ecoregion	75.2 (23.4) 27.6-100	1.6 (3) 0-15.5	23.3 (18.3) 0-65.4	4.0 (1.5) 1.3-6.2	4.0 (1.7) 0.6-6.7
Mountain Valleys	58.7 (14.7) 36.6-98.9	0.6 (0.8) 0-2.6	39 (8.6) 26.1-52.6	2.8 (0.4) 2.0-3.5	2.9 (0.8) 1.6-4.4
Semiarid Foothills	54.9 (21.6) 27.6-99.9	3.1 (3) 0-8.5	37.5 (13.2) 3.8-65.4	2.7 (0.8) 1.3-4.6	2.3 (1.2) 0.6-5.7
Wasatch Montane Zone	84.8 (13.3) 32.8-100	6 (4.5) 0-15.5	13.6 (6.7) 0-36.8	4.2 (0.5) 2.9-5.5	4.5 (0.8) 1.6-6.6
Alpine Zone	98.9 (1.9) 94.8-100	0.2 (0.4) 0-1	3.6 (4.5) 0-12.5	5.7 (0.8) 4-6.2	5.9 (0.7) 4.6-6.7
National Forest	83 (18.6) 32.9-100	2.9 (4.3) 0-15.5	18.7 (14.2) 0-65.4	3.9 (0.9) 1.5-5.5	4.2 (1.1) 1.6-6.6

had very low or very high relative native cover. Alpine Zone sites had a different distribution for absolute cover of noxious species than all other strata except Mountain Valleys; the Alpine Zone and Mountain Valleys distributions could not be compared. Jordan wetlands differed from Great Salt Lake and Mountain Valleys and Mountain Valleys also differed from the Wasatch Montane Zone. Sites in the Alpine Zone and Mountain Valleys all had <3% cover of noxious weeds; noxious weeds were widespread and frequently abundant in the Jordan stratum. Alpine Zone and Wasatch Montane Zone wetlands had a different distribution for mean C than all other strata; these two strata's distributions could not be compared. Mean C was consistently higher in these strata than in all others. The distribution of mean C values also differed between Jordan and Mountain Valleys.

Noxious Weed Plant Species

In the Central Basin ecoregion, *Phragmites australis* was the most widespread and abundant noxious weed species, found at over half of the surveyed sites and estimated to occupy 13.6% of wetland area (table 15). This species was most abundant in the Great Salt Lake and Jordan strata, estimated to occupy just under one-quarter of the wetland area in each. *Tamarix* spp. is common in the

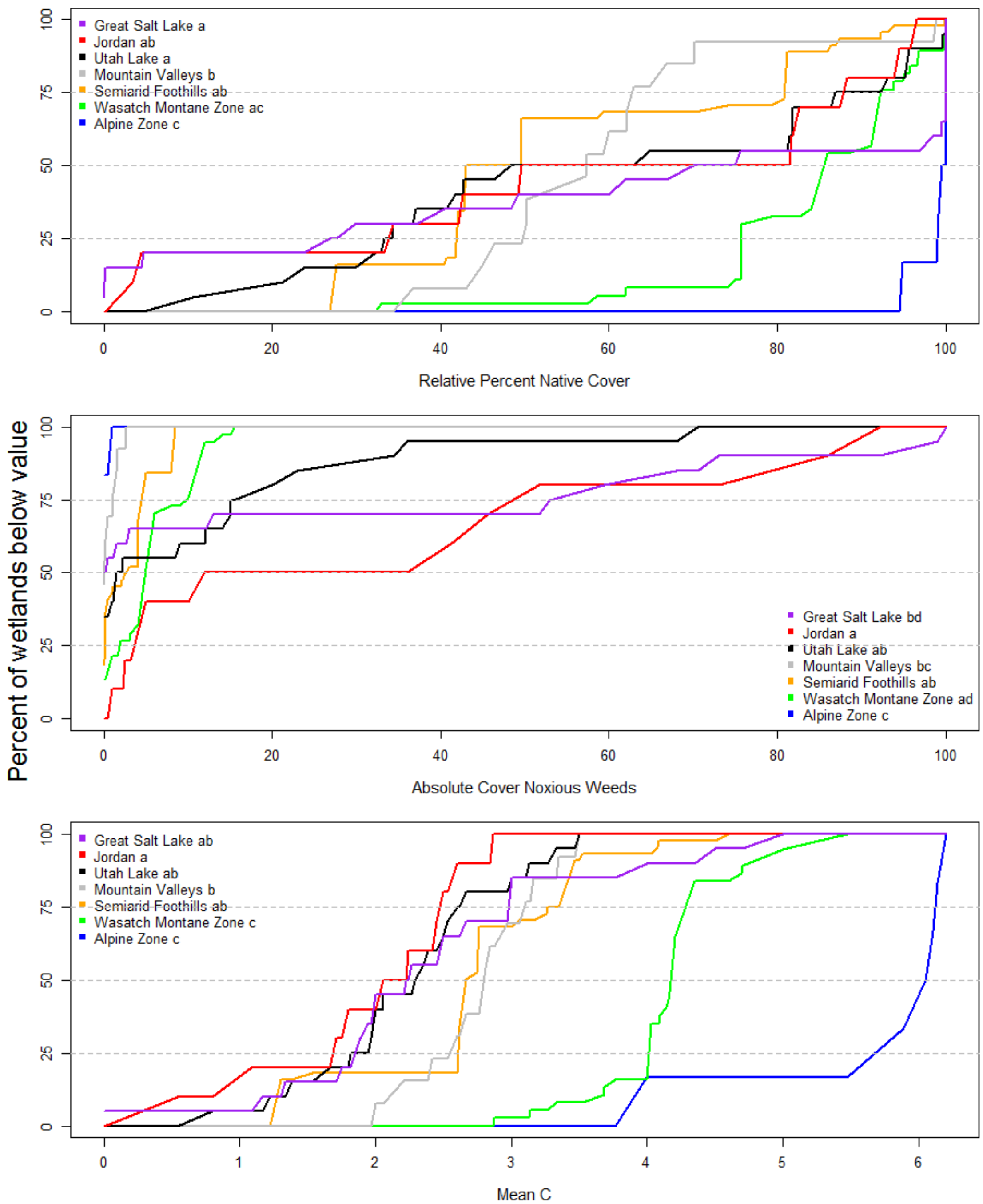

Figure 9. Cumulative density functions for plant composition metrics showing the estimated percentage of wetland area with metric value at or below the indicated values. Strata that share lowercase letters do not significantly differ from one another in the shape of the density function. Alpine Zone and Mountain Valleys could not be compared for noxious weed species and Alpine Zone and Wasatch Montane Zone could not be compared for mean C due to limited data.

Table 15. Noxious weed species detected in the Central Basin ecoregion, including ecoregion-wide and strata-specific estimates of percent cover within wetlands, followed by the standard deviation in parentheses. The number of sites per stratum with each species follows the cover estimates. Arid West wetland indicator ratings are shown.

Scientific Name (Common Name)	**Noxious Weed Listing**	**Wetland Indicator**	**Central Basin Ecoregion**	**Great Salt Lake (n=20)**		**Jordan (n=10)**	**Utah Lake (n=20)**
Cardaria draba (white top)	Class 3	None listed	0.03 (0.4)	0		2.1 (4) n=3	0.03 (0.1) n=1
Carduus nutans (musk thistle)	Class 3	FACU	0.05 01)	0		0.1 (0.1) n=2	0
Cirsium arvense (Canada thistle)	Class 3	FACU	0.2 (0.9)	0		2.1 (4.4) n=6	0.4 (1.1) n=3
Conium maculatum (poison hemlock)	Class 3	FACW	0.03 (0.6)	0		2.2 (5.9) n=3	0.03 (0.1) n=1
Convolvulus arvensis (field bindweed)	Class 3	None listed	0.002 (0.004)	0		0.02 (0.04) n=2	0
Cynoglossum officinale (gypsyflower)	Class 3	FACU	0.04 0.004)	0		0.1 (0.3) 0.1 n=4	0.005 (0.02) n=1
Elaeagnus angustifolia (Russian olive)	Class 4	FAC	0.04 (0.6)	0		2.4 (5.9) n=6	0.03 (0.1) n=2
Lepidium latifolium (broadleaved pepperweed)	Class 3	FAC	0.5 (2.4)	0.2 (0.7) n=3		0.1 (0.2) n=1	0.8 (3.3) n=2
Phragmites australis[1] (common reed)	Class 3	FACW	13.6 (27.1)	23 (35.3) n=10		24.5 (30.9) n=8	4.5 (9) n=9
Tamarix spp.[2] (tamarisk)	Class 3	FAC	3.4 (10.4)	0.3 (1.3) n=1		0.6 (1.2) n=4	6.3 (13.9) n=10

[1]Observations in the field may include both the native and the non-native subspecies of *Phragmites australis*, though all observations recorded as the European subspecies or recorded without subspecies are assumed to be non-native.
[2]Utah lists only *Tamarix ramosissimum* (saltcedar), but all species of *Tamarisk* were considered noxious for this study.

Jordan and Utah Lake strata and, in the latter stratum, sometimes occurred with high abundance. Other noxious weed species in the ecoregion typically occurred with low cover, though all except *Convolvulus arvensis* (field bindweed) and *Cynoglossum officinale* (gypsyflower) were found with ≥10% cover at one or more sites. Noxious weeds were most diverse and widespread in the Jordan stratum.

The only noxious weed species estimated to occupy >1% of the Wasatch Mountains ecoregion was *Cirsium arvense*; this species was also the most widespread noxious weed in the ecoregion (table 16). *C. arvense* often occurred with low cover but had between 5% and 15% cover at seven sites. Most of the other recorded noxious weed species in the ecoregion were facultative upland or upland species that typically occupied <1% of sites. Most of the noxious weed species found in the Jordan watershed are Class 3, widely spread species where management should focus on containing new populations. However, we recorded one Class 1B species, *Leucanthemum vulgare* (oxeye daisy), at one wetland each in the Mountain Valleys and Semiarid Foothills. Both sites were along the Provo River, one just north of Deer Creek Reservoir and one upstream from the Jordanelle Reservoir near the county boundary

Table 16. Noxious weed species detected in the Wasatch Mountains ecoregion, including ecoregion-wide and strata-specific estimates of percent cover within wetlands, followed by the standard deviation in parentheses. The number of sites per stratum with each species follows the cover estimates. Western Mountains, Valleys, and Coast wetland indicator ratings are shown.

Scientific Name (Common Name)	**Noxious Weed Listing**	**Wetland Indicator**	**Wasatch Mountains Ecoregion**	**Mountain Valleys (n=13)**	**Semiarid Foothills (n=14)**	**Wasatch Montane Zone (n=19)**	**Alpine Zone (n=6)**	***National Forest (n=25)***
Cardaria draba (white top)	Class 3	None listed	0.02 (0.1)	0.08 .03) n=1	0.1 (0.2) n=2	0	0	0.02 (0.1) n=1
Carduus nutans (musk thistle)	Class 3	UPL	0.2 (0.9)	0.05 (0.1) n=2	0.5 (1.1) n=4	0.4 (2) n=2	0	0.6 (2.4) n=4
Cirsium arvense (Canada thistle)	Class 3	FAC	1.2 (2.6)	0.2 (0.3) n=5	1.4 (1.8) n=8	5.6 (4.3) n=14	0.2 (0.4) n=1	2.2 (3.5) n=17
Conium maculatum (poison hemlock)	Class 3	FAC	0.01 (0.1)	0.04 (0.1) n=1	0	0	0	0
Cynoglossum officinale (gypsyflower)	Class 3	FACU	0.3 (0.9)	0.3 (0.6) n=5	1 (1.8) n=10	0.02 (0.1) n=2	0	0.1 (0.2) n=8
Leucanthemum vulgare (oxeye daisy)	Class 1B	FACU	0.02 (0.1)	0.008 (0.03) n=1	0.1 (0.2) n=1	0	0	0

between Summit and Wasatch. Class 1B species occur in limited populations within Utah and are a high priority for eradication to prevent further spread in the state.

Sensitive Ecological Features

Wildlife Species

Surveyors noted wildlife species observed during surveys, including signs such as tracks and droppings. Surveyors were trained to identify boreal toad by personnel at the Utah Division of Wildlife Resources and participated in a field survey for the species each year. They were asked to document through photographs when possible any amphibians observed during surveys. Identification of other wildlife was left up to the discretion and ability of surveyors; observations were sometimes recorded very generally, such as “hawk” or “riparian birds.” Wildlife observation data are presented as a minimum list of wildlife use in the watershed and should not be considered a complete list because wildlife observations were not a focal component of the survey method. Birds were documented in all strata, mammals in all but the Alpine Zone, amphibians and reptiles in all but Great Salt Lake and Mountain Valleys, and fish in the Jordan, Utah Lake, and Semiarid Foothills strata (table 17).

Three state sensitive wildlife species were observed during field surveys, including boreal toad, Columbia spotted frog, and American white pelican. One boreal toad was documented in a montane shrubland in the Wasatch Montane Zone and one Columbia spotted frog was documented in a wet meadow in the Semiarid Foothills. Identifications were confirmed by personnel with the Utah Division of Wildlife Resources. Both locations were previously known to be occupied by the respective species, though boreal toad had not been found at the location for many years. American white pelicans were observed at one location each in the Great Salt Lake, Jordan, and Utah Lake strata, including at a

Table 17. Wildlife observations during wetland surveys.

Strata	Birds	Mammals	Amphibians and Reptiles	Fish
Great Salt Lake	American avocet; American white pelican; barn owl; black necked stilt; Caspian tern; gull; heron; marsh wren; northern harrier; teal; yellow-headed blackbird; white-faced ibis	bobcat; raccoon; muskrat		
Jordan	American white pelican; Canada goose; Caspian tern; hawk; heron; hummingbird; mallard; red-winged blackbird; tree swallow; wading birds; white-faced ibis	raccoon; deer; muskrat	boreal chorus frog; snake	carp
Utah Lake	Caspian tern; Cinnamon teal; goose; gull; hawk; killdeer; pelican; swallow; western meadowlark; white-faced ibis	cottontail; coyote, deer, raccoon	garter snake	carp
Mountain Valleys	duck; heron; northern harrier; osprey; red-tailed hawk; red-winged blackbird; sandhill crane	beaver; deer; gopher		
Semiarid Foothills	duck; green-winged teal; kingfisher; warblers	bat; beaver; deer	Columbia spotted frog; garter snake	cutthroat trout
Wasatch Montane Zone	raven; red-tailed hawk; Stellar's jay	beaver; deer; elk; moose; raccoon	boreal chorus frog; boreal toad	
Alpine Zone	gray jay; mountain bluebird; raven		boreal chorus frog	
National Forest	*Green-winged teal; raven; red-tailed hawk*	*bat; beaver; deer; elk; moose; racoon*	*boreal chorus frog; boreal toad; garter snake*	*cutthroat trout*

subjectively selected Great Salt Lake site, along the southwestern shore of Utah Lake, and at Decker Lake Park in Salt Lake County. Identifications were not independently verified, though American white pelicans are very distinctive birds.

Sensitive Plant Species

We recorded *Leersia oryzoides* (rice cutgrass) at one site. This plant species is on the current draft list of Utah's plant species of greatest conservation need (M. Wheeler, Utah Department of Natural Resources, written communication, February 9, 2018) and is listed as state imperiled in Utah by NatureServe (http://explorer.natureserve.org/servlet/NatureServe?init=Species). *L. oryzoides* is a native obligate wetland grass found throughout southern Canada and the contiguous United States. Surveyors recorded the species with <1% cover in a wetland in Utah County on the north side of Provo Bay at a site that is frequently inundated by Utah Lake, but was dry at the time of survey. The site is owned by the Utah Division of Forestry, Fire, and State Lands and was difficult to access on foot. The species was not collected, but *L. oryzoides* is very distinctive due to the lack of glumes and strongly compressed lemmas.

We recorded *Callitriche heterophylla* (twoheaded water-starwort) at three sites, though identification needs to be confirmed since specimens were not obtained and the species may be confused with other members of the genus. This plant species is on the draft list of species of greatest conservation need and is listed as state critically imperiled in Utah by NatureServe. *C. heterophylla* is a native emergent obligate wetland plant known from the United States and Canada. The species was recorded at an artificial impoundment in the floodplain of the Provo River downstream from Jordanelle Reservoir, in a small snowmelt-fed meadow on U.S. Forest Service land near headwaters to Lake Creek, and in a montane shrubland on U.S. Forest Service land in Big Cottonwood Canyon. The species occupied <1% cover at each site.

Fens and Other Peatlands

Fens are groundwater-dominated wetlands that accumulate peat or muck due to persistent anaerobic conditions that prevent organic matter from decomposing. Fens are essentially irreplaceable wetlands because of the slow pace at which organic matter accumulates. This, coupled with the fact that fens often have unique biotic assemblages, often makes them a priority for identification and protection (U.S. Fish and Wildlife Service, 1999; U.S. Forest Service, 2012; U.S. Army Corps of Engineers, 2017). The U.S. Fish and Wildlife Service (1999) defines fens as groundwater-dominated wetlands with soils that are either a histosol (≥40 cm of organic matter in top 80 cm of soil) or have a histic epipedon (organic surface horizon ≥20 cm thick). We screened sites in the office to determine whether they met the U.S. Fish and Wildlife Service definition of fen by evaluating soil profiles and hydrologic inputs. Ten sites had both organic soils and substantial groundwater inputs, including one Utah Lake, four Mountain Valleys, two Wasatch Montane Zone, and three Alpine Zone wetlands. We refer to these sites as peatlands rather than fens because it was often difficult to tell whether groundwater was the *dominant* water source.

Peatlands in the Jordan River watershed spanned a range of characteristics. The peatland in Utah Lake was a spring-fed wetland in Juab Valley dominated by *Schoenoplectus americanus* (chairmaker's bulrush) that was completely dry at the time of survey and, according to the landowner, has been drying up lately. The four peatlands in the Mountain Valleys were in separate valleys from one another, with one each near the towns of Francis, Wallsburg, and Independence and one in the Heber Valley. All four sites receive water from a combination of groundwater from nearby springs and direct or indirect irrigation. Three sites were dominated by sedges, typically *Carex aquatilis* (water sedge), and the fourth was dominated by *Phalaris arundinacea*. The two peatlands in the Wasatch Montane Zone are located near the headwaters of the South Fork and Little South Fork of the Provo River in locations that receive a combination of groundwater, direct snowmelt, and flow from small spring channels or ponds. *Carex utriculata* (Northwest Territory sedge) was the dominant species at both sites. The three peatlands in the Alpine Zone were in the Uinta Mountains near the headwaters of the Provo River and received a combination of groundwater and direct snowmelt. Sites had high cover of sedge species including *Carex aquatilis* or *Carex utriculata*.

We evaluated the mapped NWI Cowardin classes that overlapped soil pit locations at peatland sites to determine whether certain Cowardin classes were indicative of peatland soils. All but one of the sites was mapped as palustrine emergent; the outlier site was mapped as beaver-influenced aquatic bed. Peatlands in the Mountain Valleys were all mapped as seasonally flooded, and peatlands in the Alpine Zone were all mapped as saturated, and one wetland each was unmapped or mapped as semipermanently flooded or intermittently exposed. Neither the seasonally flooded nor the saturated water regimes were strongly associated with peatlands in emergent wetlands. Only three of the eight soil pits mapped as emergent saturated and four of the 22 soil pits mapped as emergent seasonally flooded were peatlands.

Vegetation Community Ordination

With NMDS analysis, complex data on the presence and cover of plant species 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 plot 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 between the variables and the species composition data, 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 stratum or HGM class, have similar species composition (i.e., tend to cluster together). We used NMDS to evaluate whether species composition for different Ecological Systems appeared driven by sampling factors (e.g., year surveyed, observer team), natural environmental variability (e.g., climate, HGM class), and measures of wetland condition and stress.

The optimal NMDS solution for the ordination of all sites in the Central Basin led to a warning about potential insufficient data because the stress level was very close to zero. Upon examination of the results, it was clear that one site was an extreme outlier. This site had only one identified species with 0.2% total cover and did not share any species with other sites in the ecoregion. The optimal NMDS solution for the ordination of the remaining sites after that site was dropped consisted of two axes and had a stress value of 0.16 (table 18). Composition varied by Ecological System ($p < 0.001$), HGM class ($p = 0.006$), local modeled stress ($p = 0.03$) and the first axis of the water level PCA ($p < 0.001$), which was positively correlated with more surface water and potential for deep water. Playa and basin marsh sites clustered on opposite ends of the first NMDS axis with alkaline depression sites in the middle, though there was considerable overlap between alkaline depression and basin marsh sites (figure 10). Plant community composition did not vary by any of the sampling effect variables.

The optimal NMDS solution for all sites in the Wasatch Mountains ecoregion was two axes, with a stress value of 0.22 (table 18). Composition was correlated with most of the tested environmental variables. Sites were arranged along the first axis in order of the elevation of their associated strata, with some intermixing and one distinct cluster of Mountain Valleys sites in the top middle of the plot (figure 11). Sites tended to cluster near other sites within the same Ecological System, though Alpine Zone wet meadows were distinct from other wet meadows and some wet meadows and montane shrublands appear to have very similar composition.

Table 18. P-values for correlation analysis between plant community composition and wetland condition, landscape stress, natural variation, and sampling effects, based on NMDS. P-values in bold are < 0.01 and p-values < 0.05 are in light gray.

Variables	**Central Basin Ecoregion**	**Playa**	**Alkaline Depression**	**Basin Marsh**	**Wasatch Mountains Ecoregion**	**Wet Meadow**	**Foothill Shrubland**	**Montane Shrubland**
Number of sites	53	10	30	12	55	27	11	15
Stress	0.16	0.19	0.22	0.09	0.22	0.20	0.15	0.11
Axes	2	1	2	1	2	2	2	2
URAP Score								
Overall score	0.976	0.969	0.618	0.030	**<0.001**	**<0.001**	0.287	0.043
Hydrologic	0.130	0.525	0.658	0.764	**0.007**	0.018	**0.003**	0.406
Landscape	0.096	0.048	0.015	0.048	0.018	0.015	0.204	0.375
Physical structure	0.94	0.958	0.094	0.421	0.023	0.070	0.509	0.194
Vegetation composition	0.628	0.843	0.236	**0.001**	**<0.001**	**0.002**	0.098	**0.004**
Vegetation structure	0.545	NA	0.198	0.568	0.048	0.663	0.500	0.121
Vegetation Metric								
Mean C	0.659	0.602	0.910	0.012	**<0.001**	**<0.001**	0.033	**0.002**
Cover-weighted mean C	0.793	0.441	0.094	0.283	**<0.001**	**<0.001**	**0.006**	**0.001**
Landscape Stress Value								
Local stress	0.025	0.884	**0.001**	0.440	**0.006**	**0.002**	0.069	0.171
Watershed stress	0.823	0.612	0.784	0.819	0.039	0.013	0.026	0.799
Natural variation								
Climate PCA Axis 1	0.200	0.672	0.822	0.345	**<0.001**	**<0.001**	0.066	**0.009**
Climate PCA Axis 2	0.177	0.797	0.719	0.440	0.101	**<0.001**	0.652	0.327
Water level PCA axis 1	**<0.001**	[1]	0.505	0.050	0.484	0.623	0.590	0.011
Water level PCA axis 2	0.457	[1]	0.267	0.123	0.721	0.713	0.632	0.937
Hydrogeomorphic class	**0.006**	0.011	**<0.001**	0.164	**<0.001**	0.066	0.746	0.212
Strata	0.137	0.644	**0.003**	0.281	**<0.001**	**<0.001**	0.010	0.329
Ecological System	**<0.001**	*N/A*	*N/A*	*N/A*	**<0.001**	*N/A*	*N/A*	*N/A*
Sampling								
Day of season	0.101	0.794	0.082	0.130	**0.007**	**0.002**	0.999	0.283
Year	0.586	0.934	0.042	0.073	0.316	0.197	0.415	**0.035**
Observer team	0.966	0.434	0.109	0.378	0.428	0.482	0.144	0.268

[1]PCA could not be calculated due to lack of variation in surface water data.

Plant community composition in half the Ecological Systems was correlated with sampling variables (table 18). Survey year was correlated with composition of montane shrublands and alkaline depressions and day of the season was correlated with wet meadows. These correlations may be due to study design constraints rather than changes in survey methods over time (e.g., becoming more or less thorough with species' lists, changing understanding of species' identifications). For example, high elevation sites were only surveyed in the second half of the survey season; these higher elevation wet meadows may have different species composition than lower elevation wet meadows. Also, Jordan alkaline depressions were only surveyed in 2016. Composition in playas was correlated with HGM class and composition in alkaline depressions with HGM class and strata.

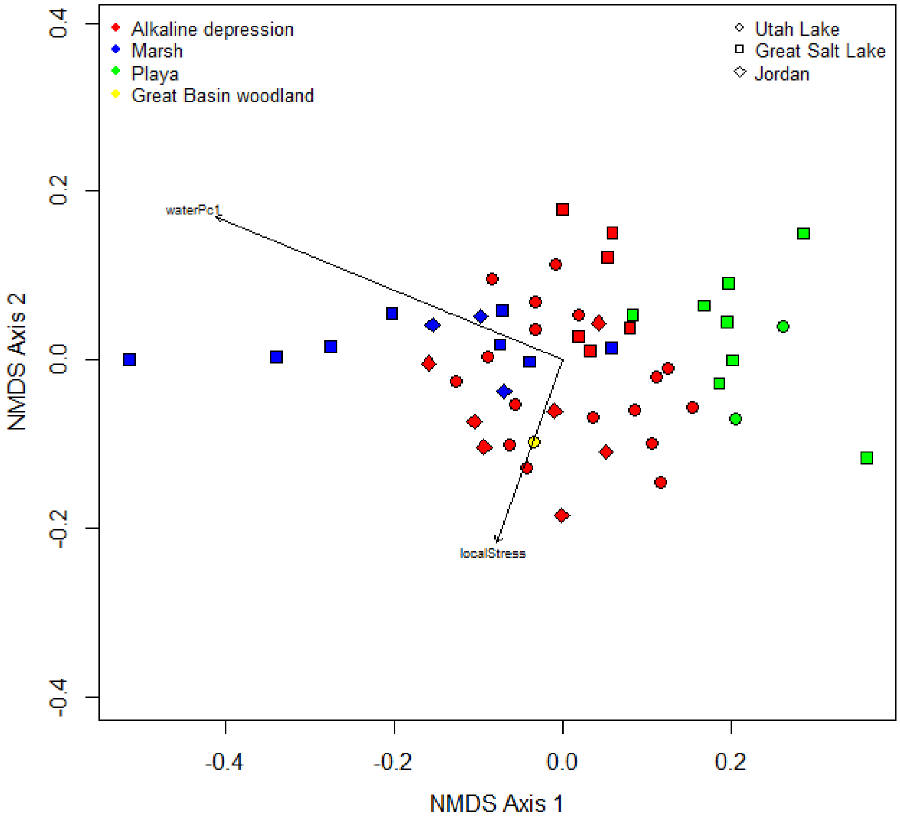

Figure 10. Plant community composition plot of Central Basin ecoregion sites, with sites symbolized by Ecological System and strata. Vectors show direction and strength of correlations with two environmental variables, local stress from the statewide stress model and the first axes of the surface water PCA.

Natural environmental variables were correlated with plant community composition for all Ecological Systems, with the most frequent correlates including water level, HGM class, and strata. Ideally, we would analyze vegetation composition for sites that varied based on condition and not on natural variation so we could determine how wetland condition influenced the plant community. Strong correlations with environmental variables may indicate that Ecological Systems should be split into additional subsystems. This appears to be particularly true for alkaline depressions, where composition varied strongly by HGM class and wet meadows, where composition varied strongly by climate and strata.

Correlations between plant community composition and measures of condition were more prevalent and generally stronger for Ecological Systems in the Wasatch Mountains ecoregion. Composition in all three Ecological Systems in the ecoregion were correlated with both vegetation metrics whereas only composition in basin marshes in the Central Basin ecoregion was correlated with mean C. Landscape stress values were correlated with composition for alkaline depressions, wet meadows, and foothill shrublands. Plant community composition by Ecological System was frequently weakly correlated with URAP landscape score and never correlated with the physical structure or

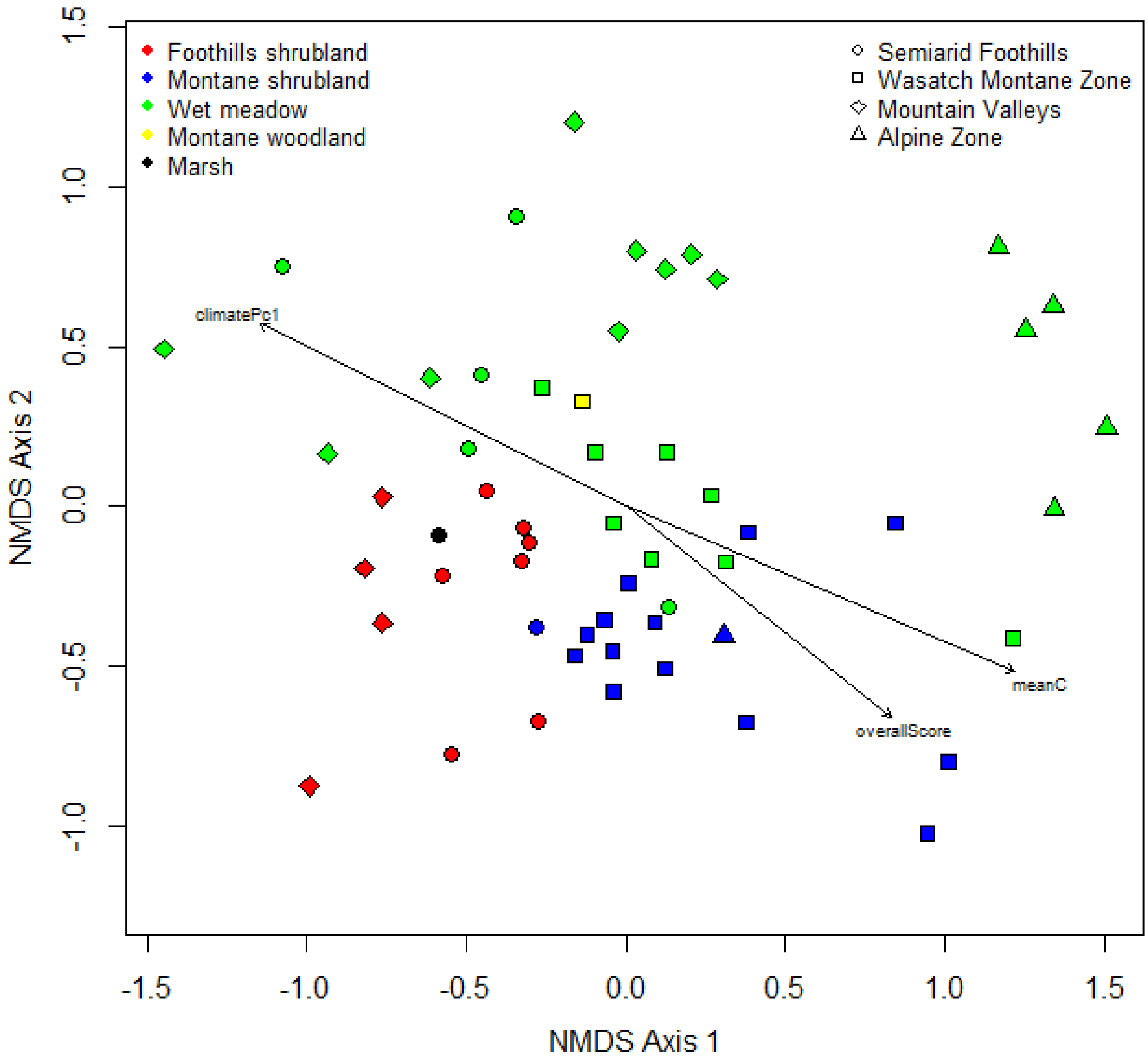

Figure 11. Plant community composition plot of Wasatch Mountains ecoregion sites, with sites symbolized by Ecological System and strata. Vectors show direction and strength of correlations with three environmental variables, overall URAP score, mean C, and the first axis of the climate PCA.

vegetation structure scores. Wet meadows showed the strongest and most frequent correlations with URAP scores, and foothill shrublands, basin marshes, and playas were each only correlated with one measure.

Characterization of Ecological Systems

Ecological System Descriptions

Six Ecological Systems were common enough to develop ecological descriptions and screen for high quality reference sites, including three in each ecoregion. In the Central Basin ecoregion, there were 10 playas, 13 basin marshes, and 30 alkaline depressions. In the Wasatch Mountains ecoregion, there were 11 foothill shrublands, 15 montane shrublands, and 27 wet meadows (including fens). Summary information on each Ecological System can be found in table 19.

Table 19. Summary of ecological attributes of wetland sites by Ecological System. Values for percent shallow water and subsequent measures include the mean, with the range in parentheses, except for number of unique species, which is the number of unique species across all sites.

Attribute	Playa	Basin Marsh	Alkaline Depression	Foothill Shrubland	Montane Shrubland	Wet Meadow
Number of sites	10	13	30	11	15	27
Elevation Range (m)	1283-1379	1282-1370	1282-1498	1652-2151	2154-2924	1654-3189
Number of Sites per Strata	Great Salt Lake (8), Utah Lake (2)	Great Salt Lake (9), Jordan (3), Utah Lake (1)	Great Salt Lake (6), Jordan (7), Utah Lake (17)	Mountain Valleys (4), Semiarid Foothills (7)	Semiarid Foothills (1), Wasatch Montane Zone (13), Alpine Zone (1)	Mountain Valleys (9), Semiarid Foothills (5), Wasatch Montane Zone (8), Alpine Zone (5)
Number of Sites per Hydrogeomorphic Class	Depressional Impoundment Fringe (2), Depressional (7), Depressional Impoundment (1)	Lacustrine Fringe (1), Depressional Impoundment Fringe (1), Depressional Impoundment (7), Depressional (4)	Slope (3), Riverine (2), Lacustrine Fringe (8), Impoundment Release (4), Depressional Impoundment Fringe (1), Depressional (12)	Slope (1), Riverine (9), Depressional (1)	Riverine (8), Depressional (7)	Slope (12), Riverine (4), Depressional (11)
% Shallow Water (<20 cm)	0 (0-0)	32.8 (0-100)	9.6 (0-100)	9.3 (0-30)	12.5 (0-36)	13.7 (0-55)
% Deep Water (≥20 cm)	0 (0-0)	56.3 (0-100)	0.1 (0-4)	12.6 (0-45)	4.4 (0-20)	3.8 (0-35)
% Total Water	0 (0-0)	89.1 (1-100)	9.8 (0-100)	22 (0-55)	17.0 (0-40)	17.5 (0-70)
pH[1]	NA	8.1 (6.4-9.5, n=13)	8.0 (7.1-8.7, n=10)	8.0 (7.0-8.7, n=9)	7.7 (5.6-9.0, n=13)	7.8 (5.1-9.1, n=21)
Electroconductivity (uS)[1]	NA	2372 (393-8690)	2957 (1401-5150)	443 (191-1062)	328 (52-1023)	230.3 (13-744)
Number of Unique Species	22	61	136	133	174	223
Forb Richness	4.9 (1-10)	9.5 (1-23)	14.5 (1-35)	28.9 (8-52)	31.9 (10-50)	26.0 (8-47)
Shrub Richness	0.2 (0-1)	0.2 (0-1)	0.2 (0-2)	4.7 (2-8)	4.6 (1-8)	0.9 (0-5)
Tree Richness	0 (0-0)	0.5 (0-4)	0.8 (0-5)	2.1 (0-5)	1.6 (0-4)	0.7 (0-3)
Absolute Forb % Cover	20 (0.6-51)	74 (0.1-136.2)	75.5 (6-121.8)	52.1 (16.8-82.3)	62.5 (16.7-92.7)	93.2 (35.2-105.3)
Absolute Shrub % Cover	0.8 (0-7)	0.4 (0-5)	1 (0-28)	39.8 (1.5-63.1)	58.0 (27.5-90.1)	2.3 (0-20)
Absolute Tree % Cover	0 (0-0)	0.3 (0-2.5)	4.5 (0-55)	12.2 (0-33)	1.9 (0-11)	0.8 (0-7.1)
Relative % Native Cover[2]	73.7 (37-100)	91.6 (42.6-100)	48.1 (0-99.7)	66.9 (36.6-99.9)	90.7 (62-100)	70.9 (27.6-100)
Mean C[3]	2.5 (1.8-5.0)	2.7 (2.2-3.1)	2.0 (0-3.3)	3.1 (2.0-4.6)	4.3 (3.5-5.5)	3.7 (1.3-6.2)
Cover-weighted Mean C	3.4 (1.6-5.0)	2.8 (1.7-4.3)	1.9 (0-4.9)	3.4 (1.6-5.7)	4.8 (3.2-6.6)	3.7 (1.6-6.7)
Absolute % Noxious Cover	1.3 (0-13)	5.8 (0-51.7)	32.7 (0-100)	1.8 (0.1-5)	2.2 (0-12)	3.3 (0-40.1)
Relative % Cover of Wetland Herbaceous[4]	64.1 (0-100)	98.9 (95.7-100)	77.7 (13-100)	55.8 (17.2-92.3)	50.3 (12.2-95.7)	61.5 (16.2-98.4)
Relative % Cover of Wetland Shrub[5]	NA	NA	NA	92.9 (80.3-99.8)	96.6 (87.3-100)	NA

[1]The mean and range of the mean water quality parameter values at each site. Number of sites with water quality data shown in parentheses.
[2]At sites where ≥80% of plant species by cover had known nativity
[3]At sites where ≥80% of the plant species had known C-values
[4]Cover of facultative wetland and obligate herbaceous species divided by all herbaceous cover, only shown for sites where ≥80% of the herbaceous cover had known wetland indicator values.
[5]Cover of facultative wetland and obligate shrub species divided by all shrub cover, only for sites with ≥5% shrub cover and where ≥80% of the shrub cover had known wetland indicator values. Data only shown for strata with more than two sites with relevant data.

Playa

Ten sites in the Central Basin were classified as playas, including one subjectively selected site. All but two were in the Great Salt Lake stratum, with the remaining near the south end of Utah Lake. Playas were typically classified as depressional, though one or two sites were each classified as depressional impoundment or depressional impoundment fringe. The playa classified as a depressional impoundment is artificially flooded in the fall; water is rarely backed up in the site the remainder of the year when a culvert is kept open. Depressional impoundment fringe sites included a mudflat and a depression filled by overflow from a nearby impoundment. Playas around Great Salt Lake were frequently flooded by canals or impoundments as well as receiving direct precipitation. None of the surveyed playas had surface water at the time of survey or internal channels or pools, though they frequently had a high amount of soil cracking. Hydric soil indicators found in playas include depleted matrix (F3) and depleted below dark surface (A11), with the former being much more widespread.

Individual sites had low diversity and typically low cover of plant species; only 22 unique plant species were recorded in playas. *Salicornia rubra* and *Distichlis spicata* were the two most frequently encountered species, and they had relatively high mean cover where they were found, 12.5% and 9.5%, respectively. Both species were found at one or two sites with 40-50% cover; no other species had more than 10% cover. *Allenrolfea occidentalis* (iodinebush), the only shrub species encountered, was recorded at two sites. *Bassia hyssopifolia* and *Frankenia pulverulenta* (European seaheath) were the two most frequently encountered non-native species.

Basin marsh

Thirteen sites in the Central Basin ecoregion, including two subjectively selected sites, were classified as basin marshes, a classification which includes both emergent and submergent-dominated systems. In the Great Salt Lake stratum, where most basin marshes occurred, all but one marsh was classified as a depressional impoundment and all marshes had managed hydrology. In contrast, the marsh in the Utah Lake stratum was a lacustrine fringe wetland on the edge of Utah Lake and marshes in the Jordan stratum were depressional wetlands that received urban run-off or treated wastewater. Marshes had ≥85% surface water cover at the time of survey, except for one depressional impoundment marsh that was mostly dry for management of *Phragmites australis*. Marshes had a wide range of pH (6.4-9.5) and EC (393-8690 µS) values. The most common hydric soil indicators were hydrogen sulfide odor (A4) and depleted below dark surface (A11).

Marsh sites were typically dominated by *Typha* spp., *Phragmites australis*, *Lemna minor* (common duckweed), submerged aquatic vegetation, or a combination thereof. *Schoenoplectus* spp. were found at just over half the sites, though frequently with low cover. Most marsh sites had ≥65% vegetation cover, though three sites had ≤22% cover, and marshes had an average of ten species per site. At least 95% of all plant cover at each site was composed of facultative wetland or obligate wetland species. Marsh sites tended to have a higher proportion of native versus introduced plant species compared to other Ecological Systems in the Central Basin ecoregion.

Alkaline depression

Thirty sites, including one subjectively selected site, in the Central Basin ecoregion were classified as alkaline depressions. Some were intermediate between alkaline depression and basin marsh based on the plant community composition, with characteristic marsh species such as *Typha* spp.

and *Schoenoplectus* spp. present. These intermediate sites were classified as alkaline depressions if they typically did not hold water ≥20 cm deep for most of the growing season, based on evaluation of conditions at time of the survey, the landscape position of the wetland, and examination of aerial imagery. All but one of the seven alkaline depression wetlands in the Jordan stratum were classified as depressional and located near the floodplain of the Jordan River; the seventh site was located on the edge of an artificial pond. These sites frequently received water from a combination of urban run-off and a seasonal high-water table. Six wetlands were classified as alkaline depressions in the Great Salt Lake stratum, including four impoundment release sites. These wetlands received water from overbank flooding from channels and ditches or from discharge from upgradient impoundments. Eight of the 17 alkaline depressions in the Utah Lake stratum were classified as lacustrine fringe; these sites were all located on the edge of Utah Lake and received most of their water from lake flooding. Other alkaline depressions in the stratum were located near Utah Lake but received water from other sources or were in the southern half of the watershed and were groundwater-fed slope wetlands. Nine sites had surface water present, including three sites with >50% water; surface water was typically <20 cm deep. Pools, swales, or channels within the AA were uncommon. pH ranged from neutral to strongly alkaline (7.1 to 8.7) and EC ranged from 1401 to 5150 µS. Thirteen hydric soil indicators were documented in soil pits. Depleted matrix (F3) was the most common, followed by histosol (A4), depleted below dark surface (A11), and hydrogen sulfide odor (A4).

Phragmites australis was found at 70% of alkaline depressions and was the most abundant species at 12 sites. The non-native species *Bassia hyssopifolia* and *Tamarix* ssp. and the native species *Juncus arcticus* ssp. *littoralis* (mountain rush), *Schoenoplectus americanus,* and *Schoenoplectus acutus* (hardstem bulrush) were among the dominant species at three or four sites each. Alkaline depressions had the lowest mean values for mean C and relative cover of native species and the highest mean value for noxious weeds of all Ecological Systems.

<u>Foothill shrubland</u>

Eleven sites were classified as foothill shrublands. These sites did not overlap in elevation with montane shrubland sites and had an upper limit of 2151 m. Foothill shrublands included both Mountain Valleys and Semiarid Foothills wetlands and were almost always classified as riverine. Wetlands included relatively narrow riparian corridors, wetlands formed along secondary channels, oxbows, and former channels of larger braided river, beaver-influenced wetlands, and wetlands along intermittent channels that probably receive a combination of snowmelt and overbank flooding. Sites had a variable amount of surface water; seven sites had between 15% and 55% surface water, three sites had <2% cover, and two sites had no surface water. Sites with more surface water were typically influenced by beaver. EC was typically ≤762 µS, though one site had an EC of 1060 µS. pH values ranged from neutral to strongly alkaline. The most widespread hydric soil indicators were redox dark surface (F6) and depleted matrix (F3).

Sites contained between two and eight shrub species and typically had at least one tree species present. *Alnus incana* (gray alder), *Cornus sericea* (redosier dogwood), *Lonicera involucrata* (twinberry honkeysuckle), and willows including *Salix exigua* (narrowleaf willow), *Salix boothii* (Booth's willow), *Salix lucida* (shining willow), and *Salix lutea* (yellow willow) were widespread and frequently dominant woody species. Herbaceous cover was typically dominated by introduced grasses, sometimes in combination with native forbs and rushes. *Phalaris arundinacea* (reed canarygrass) was the most widespread and abundant non-native grass, found at seven sites with a mean of 34.7% cover. Common native forbs included *Epilobium ciliatum* (fringed willowherb), *Maianthemum stellatum* (starry false lily of the valley), and *Geum macrophyllum* (largeleaf avens). The noxious weeds *Cirsium arvense Cynoglossum officinale* were very widespread, found at 8 and 10 foothill shrubland sites, respectively. Every site had at least one noxious weed species recorded.

Montane shrubland

Fifteen sites were classified as montane shrublands. These sites were all above 2150 m in elevation and were classified as either depressional or riverine. Sites were located in typically wide riparian areas, off-channel flooded depressions, headwater depressions, or, in one case, the margin of a lake. Montane shrublands were predominantly in the Wasatch Montane Zone, but also included sites in ecoregions just above and just below the Wasatch Montane Zone. The eight beaver-influenced montane shrublands had between 15% and 40% surface water; other sites had ≤15% surface water cover. At all but three sites where measurements were taken, pH was between 7 and 9 and electroconductivity was between 200 and 531 µS. Two sites had slightly to moderately acidic pH (≤6.2) and very low EC (≤74 µS) and one site had much higher mean EC (1023 µS). Redox dark surface (F6) was the most common hydric soil indicators in soil pits in the montane shrublands.

Woody cover was dominated by *Salix boothii* or *Salix drummondiana* (Drummond's willow) at all but one site, which was dominated by *Salix planifolia* (diamondleaf willow). Other common shrubs included *Lonicera involcrata* and *Ribes inerme* (whitestem gooseberry). Most sites had one or two tree species, including *Alnus incana* or species of fir or spruce. Herbaceous components of wetlands were highly variable, dominated by sedges, native grasses, non-native grasses, diverse mixtures of native forbs, or a combination thereof. Two of the most widespread and abundant species were the native sedge *Carex utriculata* and the non-native grass *Poa pratensis*. All but two montane shrublands had ≥84% relative cover of native species; six sites had no noxious weeds.

Wet meadow

Twenty-seven sites were classified as wet meadows, including five in the Alpine Zone, nine in the Wasatch Montane Zone, four in the Semiarid Foothills, and nine in the Mountain Valleys. Wet meadows in the Mountain Valleys were located near springs, in the floodplain of the Provo River, or along old braided channels now used for irrigation in the Heber Valley; most wet meadows in the Mountain Valleys receive substantial irrigation water inputs. Most of the remaining wet meadows were located near springs or headwaters of streams and received water from a combination of groundwater and snowmelt, though two wet meadows contained a series of created ponds, one wet meadow was adjacent to a lake that sometimes flooded the site, and one wet meadow was a shallow isolated catchment pond. About half of the sites contained small channels and four had evidence of past or current beaver activity. Seven sites were completely dry at the time of survey, 14 sites had between 2% and 25% surface water, and six sites had >40% surface water; most of the surface water was shallow. EC values were very low (≤54 µS) in the Alpine Zone and at one Wasatch Montane Zone wet meadow, somewhat higher in the southern portion (Spanish Fork and Utah Lake HUC8s) of the Wasatch Mountains (465 and 744 µS), and moderate elsewhere (139 and 590 µS). Site pH values ranged from strongly acidic to very strongly alkaline. The most common hydric soil indicator in wet meadows was redox dark surface (F6), followed by depleted below dark surface (A11), thick dark surface (A12), histic epipedon (A2), and depleted matrix (F3).

Just over half of the wet meadows were dominated by *Carex utriculata* or *Carex aquatilis*, sometimes in combination with other sedges, grasses such as *Calamagrostis canadensis* (bluejoint) or *Poa pratensis*, and non-native forbs such as *Cirsium arvense* and *Trifolium repens* (white clover). The remaining wet meadows were typically dominated by combinations of species that frequently included *Juncus arcticus* ssp. *littoralis*, non-native grasses including *Agrostis gigantea* and *Phalaris arundinacea,* and other sedge species. Woody species were by definition not abundant at wet meadow sites and about two-thirds of sites had one or fewer woody species. Willows, especially *Salix boothii*, were the most common woody species in wet meadows, followed by conifers, *Populus tremuloides,* and *Rosa woodsi* (Woods' rose).

Reference Sites

We had between four and nine reference sites per Ecological System, though thresholds for selection had to be loosened to obtain enough reference sites for Ecological Systems in the Central Basin ecoregion (table 20). The hydroperiod screen was loosened for all three Ecological Systems; each of the other screens were loosened once or twice. Two of the four subjectively selected potential high-quality sites passed the screen and were considered reference sites, including one playa and one basin marsh.

Thresholds to indicate good condition ranged from 1.98 to 5.22 for mean C and 3.96 to 4.83 for URAP scores; the lowest were in alkaline depressions and the highest in wet meadows (table 21). Thresholds. Of the four subjectively selected high-quality sites, two had mean C values and one had a URAP score above the threshold for their Ecological System, whereas one of the three subjectively selected high disturbance sites had a mean C value above the threshold. Between 16.7% and 46.7% of sites per Ecological System had both mean C and URAP values above the respective thresholds.

Sites rated as good for both metrics for an Ecological System were typically within a single stratum. Good condition wetlands were in the Great Salt Lake stratum for playas and basin marshes, the Semiarid Foothills for foothill shrublands, the Wasatch Montane Zone for montane shrublands, and the Alpine Zone for wet meadows. Alkaline depressions were the only exception, though all but one of the

Table 20. Screening values used to determine reference sites. Boxes shaded in gray indicate values that were altered from the initial threshold values to obtain enough reference sites in the category.

Ecological System	Buffer stress	AA Stress	Landscape Water Quality Stress	Landscape Hydroperiod Stress	% Relative Native Cover
Initial value	≤2	≤1	≤4	≤4	≥80
Playa	≤2	≤1	≤4	≤9	≥75
Basin marsh	≤2.12	≤2	≤4	≤15	≥80
Alkaline depression	≤2.92	≤1	≤5	≤5	≥80
Foothill shrublands	≤2	≤1	≤4	≤4	≥80
Montane shrublands	≤2	≤1	≤4	≤4	≥80
Wet meadow	≤2	≤1	≤4	≤4	≥80

Table 21. Raw values for mean and 25th percentile mean C and condition scores from reference sites by Ecological System and percentage of sites with values greater than the 25th percentile for each metric and the combination of the two.

Ecological System	# Sites	# Reference Sites	Mean Value, Reference Sites		25th Percentile, Reference Sites		Percent of Sites with Values ≥25th Percentile		
			Mean C	URAP Score	Mean C	URAP Score	Mean C	URAP Score	Mean C and Score
Playa	10	4	3.37	4.46	2.13	4.38	40.0%	40.0%	20.0%
Basin marsh	13	5	2.92	4.38	3.00	4.23	30.8%	38.5%	23.1%
Alkaline depression	30	6	2.50	4.10	1.98	3.96	60.0%	23.3%	16.7%
Foothill shrublands	11	4	3.80	4.38	3.27	4.17	27.3%	45.5%	18.2%
Montane shrublands	15	9	4.38	4.59	4.09	4.46	66.7%	60.0%	46.7%
Wet meadow	27	6	5.56	4.77	5.22	4.83	18.5%	14.8%	11.1%

good condition sites was in the Utah Lake stratum. In most cases, good condition wetlands were in the stratum that was most common for an Ecological System. However, <15% of the wet meadows were in the Alpine Zone, but all the good condition sites were located there.

Landscape Analysis

Analysis of Sample Frame Accuracy

The percent of random sample points overlapping the NWI sample frame that was actually wetland or other aquatic habitat ranged from 46% in the Jordan stratum to 86.7% in the Great Salt Lake stratum, excluding points classified as uncertain (table 22). Non-target aquatic features were common. Dry mudflats comprised 16.7% (SE 5.3) and treatment ponds comprised 6.7% (SE 3.3) of sample frame area in the Great Salt Lake stratum. Dry mudflats comprised 2.6% (SE 5.1) and water >1 m deep comprised 23.1% (SE 5.4) of Utah Lake sample frame area. Treatment ponds comprised 16.2% (SE 5.1) and water >1 m deep comprised 8.1% (SE 3.7) of Jordan sample frame area. Water >1 m deep is also estimated to comprise 13.4% (SE 7.2) of the Semiarid Foothills and 19.0% (SE 8.3) of the Wasatch Montane Zone sample frame.

There was no obvious explanation for the inaccuracy of the NWI data for most points classified as non-aquatic. Most of these points fell at locations that appeared relatively unaltered. Potential causes of mapping inaccuracy include overly inclusive mapping by NWI, loss of wetland area due to drying caused by climate trends or water diversion, or a combination of the two. Most wetlands in the study area were mapped using imagery from 1998, when Salt Lake City had almost 50% more precipitation than average, whereas precipitation in Salt Lake City was about average or just below average during the two years of the study (National Climatic Data Center, 2018). Obvious anthropogenic landscape alteration such as development did overlap wetland points in two strata, estimated at 32.4% (SE 6.9) of random points in the Jordan stratum and 5.1% (SE 3.2) of random points in the Utah Lake stratum. Given uncertainties in the original mapping accuracy and potential drying trends, we cannot be certain that development replaced wetlands that would otherwise be extant today.

Table 22. Accuracy of original NWI wetland data based on assessment of randomly selected points, including percentage of the points that were actually aquatic (including non-target deepwater) and the estimated area in hectares, with standard error in parentheses, of target wetlands, non-target aquatic features, non-wetland area, and unknown in each stratum. Features that were not surveyed in the field were classified based on inspection of aerial imagery or left as uncertain, if not able to be classified. Uncertain acreage is ignored in the calculation of percent aquatic.

Strata	% Aquatic	Target Wetland	Non-target Aquatic Feature	Non-aquatic	Uncertain
Central Basin ecoregion	82.3%	21,892 (2150)	10,215 (1597)	6892 (1483)	2418 (968)
Great Salt Lake	86.7%	10,863 (1112)	4002 (893)	2287 (662)	0 (NA)
Jordan	46.0%	150 (40)	168 (43)	374 (51)	0 (NA)
Utah Lake	80.0%	10,879 (1760)	6044 (1291)	4231 (1203)	2418 (968)
Wasatch Mountains ecoregion	75.1%	2031 (197)	662 (144)	895 (198)	773 (181)
Mountain Valleys	84.6%	541 (146)	309 (106)	155 (90)	618 (152)
Semiarid Foothills	52.8%	297 (111)	232 (94)	473 (124)	155 (86)
Wasatch Montane Zone	82.7%	405 (79)	121 (60)	110 (56)	0 (NA)
Alpine Zone	83.3%	788 (129)	0 (NA)	158 (129)	0 (NA)
National Forest	70.3%	238 (27)	43 (18)	119 (22)	0 (NA)

Updated Wetland Mapping

We mapped 3043 ha of wetland and deepwater and 291 ha of riparian area in the mapping project area (table 23). Lakes were the most abundant mapped feature, followed by riverine, emergent meadow, and lacustrine unconsolidated shore. Almost two-thirds of the wetland area was mapped as excavated or impounded (table 24). The most abundant water regime was artificially flooded, which was predominantly applied to Rio Tinto's northern tailings impoundment. Temporarily flooded and seasonally flooded were the next two most prevalent water regimes. Seasonally saturated and continuously saturated regimes, frequently associated with groundwater systems, comprised only 5.3 ha.

Approximately one-third less wetland area was mapped by UGS than is present in the original NWI data (table 23). One of the most obvious changes in the data is the absence of Rio Tinto's southern tailings impoundment in the UGS data. This impoundment, previously mapped as a 1059 ha lacustrine unconsolidated shore, has now been reclaimed. Changes in both the mapping and classification of Rio Tinto's north and south tailings ponds account for many of the largest changes between the two mapping efforts, including the increase in acreage of lakes, excavated features, and the artificially flooded water regime and decrease in acreage of lacustrine unconsolidated shores, impounded features, and the temporarily flooded water regime (tables 23 and 24).

Less wetland area was mapped as vegetated in the UGS data than in the original NWI data, with only half as much emergent meadow and a near absence of woody wetlands in the UGS data (table 23). Visual inspection of some of the largest features mapped as emergent in the NWI data showed development or other obvious land use change now in their place, though some may have been

Table 23. Hectares of mapped wetlands, by wetland class, in existing National Wetlands Inventory (NWI) data and updated UGS data and Cowardin codes associated with each wetland class.

Wetland Class	NWI Wetland Area (ha)	UGS Wetland Area (ha)	Cowardin Codes for Wetland Class
Emergent marsh	36.3	28.5	System P, Class EM, Regime D, E, F
Emergent meadow	760.0	368.3	System P, Class EM, Regime A, B, C, J
Scrub shrub	70.8	4.5	System P, Class SS
Forested	35.2	0	System P, Class FO
Pond	155.1	247.7	System P, Class UB, AB
Palustrine unconsolidated shore	112.5	155.9	System P, Class US
Lacustrine unconsolidated shore	2137.0	381.0	System L, Class US
Lake	296.2	1327.8	System L, Class UB, AB
Riverine	844.6	529.7	System R
Total wetland	**4447.7**	**3043.4**	
Emergent riparian	N/A	39.2	System Rp, Class EM
Scrub shrub riparian	N/A	252.0	System Rp, Class SS
Total riparian	N/A	**291.1**	

Table 24. Comparison of modifiers and water regime in mapped wetlands in original NWI data and UGS data.

Wetland Classification	NWI Wetland Area (ha)	UGS Wetland Area (ha)
Modifier		
Artificial substrate	0	36.0
Beaver	0	5.9
Excavated	664.6	1654.8
Impounded	1816.2	250.6
Water Regime		
Intermittently flooded (J)	0	142.9
Temporarily flooded (A)	2521.3	597.5
Seasonally saturated (B)	1.4	2.6
Seasonally flooded (C)	1160.1	517.0
Continuously saturated (D)	0	2.7
Semi-permanently flooded (F)	537.2	98.9
Intermittently exposed (G)	58.6	356.4
Permanently flooded (H)	153.7	130.0
Artificially flooded (K)	15.4	1195.4

originally over-mapped or have been lost to drying trends, as described above. Some historical emergent wetlands have been converted to ponds or lakes, including a portion of Rio Tinto's northern tailings impoundment. Much of the area mapped as woody by NWI was mapped as riparian or riverine in the UGS data.

Differences between the NWI and UGS data reflect a combination of factors, including land use change, changes in wetland mapping standards, and differences in decision-making by mappers, which makes it impossible to quantify exactly how much change in wetland area and wetland classes has occurred in the study area. Land use change has both eliminated some features and created new features. UGS likely mapped some features that were missed in the original NWI data due to the increased resolution of aerial imagery. Mappers may have interpreted the signature of marginal areas differently, leading to differences in the mapping of features with drier water regimes. Application of classification codes also likely differed between years. For example, UGS mapped the Rio Tinto's northern tailings pond as artificially flooded while NWI predominantly mapped it as temporarily flooded or semipermanently flooded.

Landscape Profile

In the Central Basin ecoregion, lakes and emergent meadows were the most abundant wetland types in the sample frame, each making up about 28% of the total wetland area (table 25). However, abundance varied by wetland strata. Unconsolidated shore and emergent marsh were the two most abundant wetland types in the Great Salt Lake stratum and only Utah Lake had a high proportion of wetlands classified as lake (figure 12). Scrub shrub, forested, and pond wetlands were the least common and most frequently stressed wetland types in the Central Basin. Local stress was highest in the Jordan stratum, where over two-thirds of the wetland area was in the high stress category and <1% in the low stress category (table 26). Over half the wetland area in the ecoregion was classified as riparian, with the least amount of riparian area in the Jordan and the most in the Utah Lake stratum.

Just over half the mapped Wasatch Mountains ecoregion wetlands were classified as emergent meadow, and emergent meadow was the most common wetland type in all strata in the ecoregion except in the Wasatch Montane Zone, where scrub shrub and ponds were most abundant (table 25, figure 12). Emergent marshes were the least common wetland type and subject to the highest levels of stress, with <2% of total wetland area and about 75% of the area in the high stress class. In contrast to the Central Basin ecoregion, scrub shrub and pond wetlands in the Wasatch Mountains ecoregion had the lowest levels of modeled local stress. Local stress was highest in the Mountain Valleys, where about half the wetland area was classified as high stress and <1% classified as low stress (table 26). Over three-quarters of wetland area was classified as riparian except in the Alpine Zone, which was about half riparian. Watershed stress at riparian wetlands was highest in the Mountain Valleys and lowest in the Wasatch Montane Zone and Alpine Zone.

Just over half of the wetland area in the Jordan River watershed is privately owned, with a similar percent private in each Level III ecoregion (table 27). Half the privately-owned wetland area in the Great Salt Lake stratum is managed for conservation, mitigation, or wildlife and between about 8% and 14% of the privately-owned wetland area in the Jordan and Wasatch Montane Zone are part of CWMUs. The remaining privately-owned wetland area is almost all unclassified. State-managed wetlands are very common in the Central Basin ecoregion, particularly in the Great Salt Lake and Utah Lake strata, with most managed as sovereign land or as part of Farmington Bay Waterfowl Management

Table 25. Wetland class by Level III ecoregion, including total wetland area and percentage of area in low, moderate, or high local landscape stress class.

Wetland Class	Area (ha)	Local Stress Class		
		Low	Moderate	High
Central Basin Ecoregion				
Emergent marsh	8,223	7.7%	87.8%	4.5%
Emergent meadow	11,791	26.2%	57.1%	16.7%
Scrub shrub	524	15.7%	43.0%	41.3%
Forested	96	0.0%	31.4%	68.6%
Unconsolidated shore	8,658	52.5%	32.2%	15.3%
Pond	507	2.7%	50.5%	46.7%
Lake (<2 m deep)	11,617	0.1%	99.4%	0.5%
Total	*41,417*	*20.2%*	*69.5%*	*10.2%*
Wasatch Mountains Ecoregion				
Emergent marsh	84	3.7%	20.7%	75.6%
Emergent meadow	2,309	19.8%	36.1%	44.1%
Scrub shrub	723	32.7%	58.6%	8.7%
Forested	213	3.7%	70.0%	26.3%
Unconsolidated shore	385	5.4%	82.1%	12.5%
Pond	424	45.0%	45.9%	9.2%
Lake (<2 m deep)	224	0.3%	98.9%	0.7%
Total	*4,361*	*21.0%*	*49.4%*	*29.6%*

Table 26. Percentage of wetland area in low, moderate, and high local and watershed stress category and percentage of wetlands classified as riparian. Only riparian wetland area tabulated for the watershed stress category.

Stratum	Local Stress Category			% Riparian	Watershed Stress Category		
	Low	Moderate	High		Low	Moderate	High
Great Salt Lake	28.3%	63.5%	8.2%	77.1%	0.0%	1.9%	98.1%
Jordan	0.7%	31.2%	68.1%	52.4%	0.1%	11.0%	88.9%
Utah Lake	15.0%	75.0%	10.0%	93.1%	0.8%	44.7%	54.5%
Mountain Valleys	0.3%	48.3%	51.4%	89.2%	0.0%	68.9%	31.1%
Semiarid Foothills	17.5%	55.2%	27.2%	87.7%	13.3%	82.3%	4.3%
Wasatch Montane Zone	40.9%	55.8%	3.3%	77.4%	29.9%	70.1%	0.0%
Alpine Zone	53.3%	40.6%	6.1%	53.6%	24.2%	75.8%	0.0%
National Forest	31.2%	67.0%	1.8%	79.4%	49.9%	49.9%	0.3%

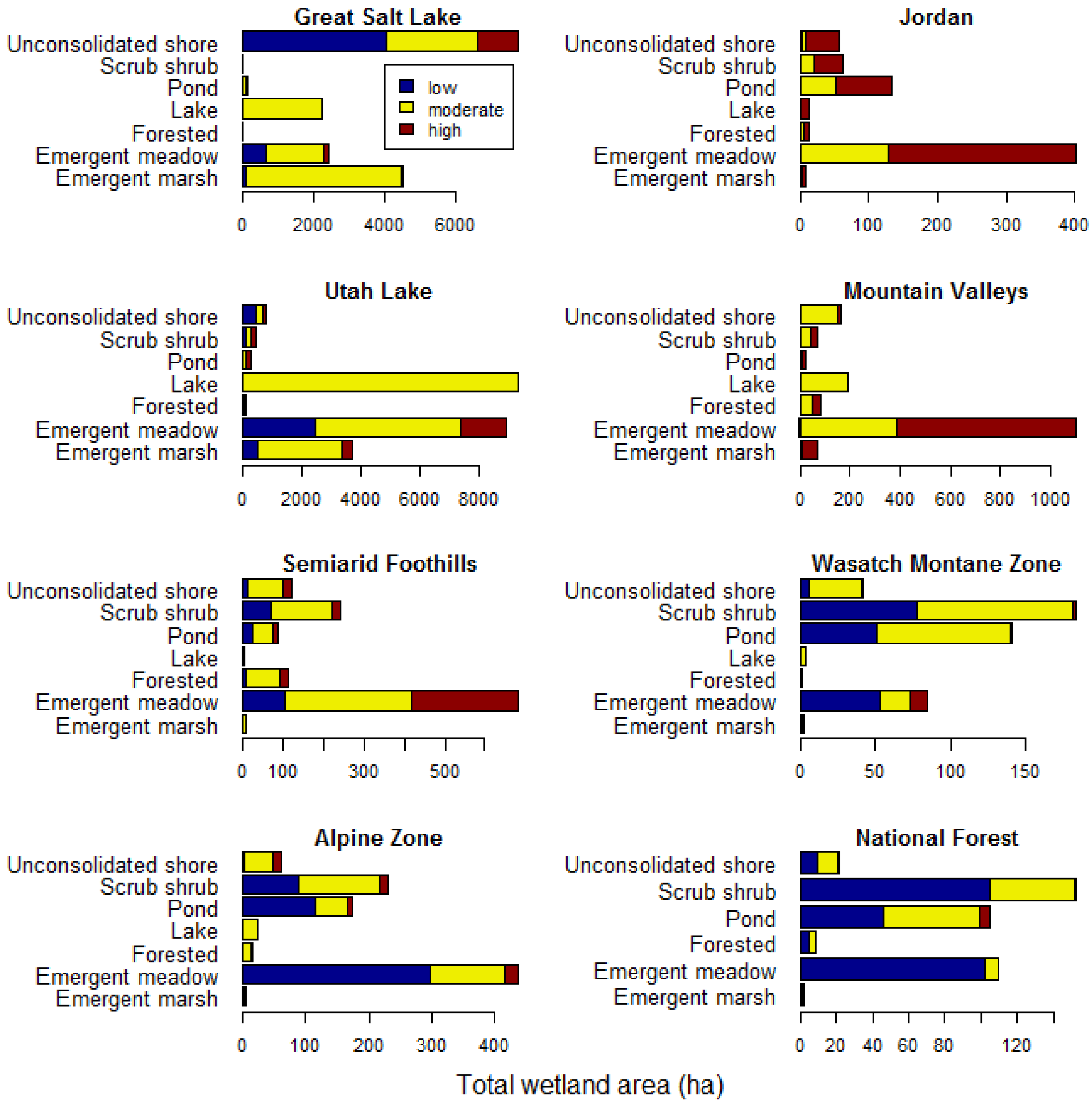

Figure 12. Wetland area by landscape stress class and wetland type for each stratum and for National Forest land.

Area. In the Wasatch Mountains ecoregion, private and state ownership declines and federal ownership increases with increasing elevation. Privately-owned wetlands comprise most of the wetland area in the Mountain Valleys and Semiarid Foothills, with state parks and, in the Semiarid Foothills, U.S. National Forest, containing most of the remaining wetlands. Over 50% of the wetland area in the Wasatch Montane Zone and over 90% of those in the Alpine Zone are on National Forest, with the remainder in both primarily on private land. In the Jordan, Utah Lake, Mountain Valleys, and Semiarid Foothills strata, wetlands are very underrepresented on federal land. For example, federal land comprises 20% of the Mountain Valleys, but only 0.7% of wetland area is on federal land (tables 1 and 20). Wetland area is

Table 27. Wetland ownership by strata, with the percentage of wetland area in each ownership category and overall percentage private, state, and federal ownership.

Ownership Class	Great Salt Lake	Jordan	Utah Lake	Mountain Valleys	Semiarid Foothills	Wasatch Montane Zone	Alpine Zone
Private	**60.8%**	**92.6%**	**42.6%**	**74.9%**	**68.4%**	**45.0%**	**8.3%**
Duck hunting reserve	22.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Conservation or mitigation	8.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CWMU	0.0%	7.9%	0.9%	0.1%	0.6%	14.0%	0.0%
Other private land	29.9%	84.7%	41.6%	74.8%	67.8%	31.0%	8.3%
State	**39.2%**	**7.3%**	**54.6%**	**24.4%**	**17.0%**	**1.8%**	**0.0%**
Sovereign land	19.0%	0.0%	54.3%	0.0%	0.0%	0.0%	0.0%
Farmington Bay WMA	19.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other wildlife areas	0.0%	0.0%	0.2%	0.0%	2.3%	0.1%	0.0%
State park	0.0%	1.0%	0.0%	24.3%	14.7%	1.7%	0.0%
Other state	0.9%	6.3%	0.1%	0.1%	0.0%	0.0%	0.0%
Federal	**0.0%**	**0.1%**	**2.9%**	**0.7%**	**14.6%**	**53.3%**	**91.7%**
U.S. National Forest Wilderness	0.0%	0.0%	0.0%	0.0%	0.1%	7.6%	1.0%
Other U.S. National Forest	0.0%	0.0%	0.0%	0.0%	14.0%	45.7%	90.7%
Other federal land	0.0%	0.1%	2.9%	0.7%	0.5%	0.0%	0.0%

overrepresented on State-owned land in the Jordan, Utah Lake, Mountain Valleys, and Semiarid Foothills and overrepresented on private land in the Alpine Zone.

Over two-thirds of mapped wetland area in the Wasatch Montane Zone and Alpine Zone, about 40% in the Great Salt Lake stratum, 29% in the Semiarid Foothills, and <7% in the remaining strata did not overlap the Water Related Land Use data (table 28). Over two-thirds of the remaining wetland area in the Great Salt Lake, Utah Lake, Wasatch Montane Zone, and Alpine Zone overlapped riparian or aquatic features. Wetland area mapped as pasture comprised about half the wetland area in the Mountain Valleys, around one-fifth in the Utah Lake and Semiarid Foothills strata, and <11% elsewhere. Agriculture overlapped <6% of wetland area in each stratum, as did hay except in the Mountain Valleys and Semiarid Foothills, where hay production was more common. Wetland area mapped as urban was uncommon except in the Jordan, and, to a lesser extent, Great Salt Lake strata, though urban acreage in the latter was primarily because Rio Tinto's tailings impoundment was mapped as urban. Almost half of the wetland area in the Mountain Valleys and just under one-fifth the wetland area in the Semiarid Foothills overlap areas mapped as irrigated; overlap was <6% in all other strata. Irrigated wetlands were typically mapped as pasture (69.0% of the area); hay production (17.5%) and alfalfa (11.6%) were less common.

Discussion

Target Population and Limitations on Inference

Generalizations about wetland condition and other study findings only pertain to the target population. We included sparsely vegetated playas and submergent marshes in our definition of

Table 28. Percentage of mapped wetland area overlapping each Water Related Land Use class, including area not mapped and irrigation class.

	Great Salt Lake	**Jordan**	**Utah Lake**	**Mountain Valleys**	**Semiarid Foothills**	**Wasatch Montane Zone**	**Alpine Zone**	***National Forest***
Land Use Class								
Agriculture	3.70%	5.90%	5.70%	3.60%	2.10%	0.30%	0.00%	*0.00%*
Grass hay	0.00%	0.10%	1.10%	8.40%	13.70%	0.00%	0.30%	*0.00%*
Pasture	0.50%	10.20%	22.60%	49.10%	19.50%	3.40%	3.00%	*0.80%*
Urban	11.80%	43.80%	2.40%	6.90%	3.40%	1.20%	0.50%	0.30%
Riparian and aquatic	44.20%	33.50%	67.10%	29.90%	31.90%	30.80%	30.30%	20.20%
Not mapped	39.80%	6.30%	0.90%	2.00%	29.40%	64.50%	65.90%	*78.60%*
Irrigation Class								
% Irrigated	0.10%	5.90%	4.70%	45.50%	17.60%	3.10%	2.40%	*0.00%*
% Subirrigated	0.30%	14.40%	5.40%	13.20%	10.40%	0.20%	0.70%	*0.00%*

wetland and excluded mudflats that appeared persistently dry in aerial imagery, even though these features may be briefly inundated each year or serve as refugia habitat during extremely wet years. We recommend continuing to include playas and submergent marshes in future studies because of the importance of these systems to wildlife, water quality, and other functions and reconsidering the exclusion of the drier mudflats, though additional measures may need to be collected at these sites since they often lack vegetation, surface water, and other indicators of wetland condition.

Our study design allows us to make inference to mapped wetlands, but unfortunately the NWI sample frame was imperfect for our purposes and often inaccurate. Almost one-quarter of the sample frame was comprised of non-target aquatic features and 17% was comprised of non-aquatic features, much of the latter of which may have been incorrectly mapped or lost to changes in hydrology; about 3% of wetland area appears lost to development. While we can estimate the amount of mapped wetland area that is not in fact target 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 or newly created wetlands. If unmapped wetlands are similar in characteristic to mapped wetlands or small in proportion to the size of the mapped target population, then target population estimates will still be robust. 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 unmapped wetland area so that extent estimates can be adjusted appropriately.

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. We had a very high rate of participation in all but the Mountain Valleys and Semiarid Foothills strata, two of the three strata with the highest rates of private ownership. Access rates were much higher than they were in a recent study of the Weber River watershed (Menuz and others, 2016c), which we credit to sending out letters to landowners and having two years to arrange access.

Wetland Condition

In many respects, wetlands in the Jordan River watershed are in good condition. Most wetland area has minimal soil disturbance and healthy herbaceous and woody litter accumulation. Most wetland area is also embedded in relatively intact landscapes with wide buffers and intact soils, though often buffers were extensions of the assessed wetland since AAs were frequently embedded within larger wetlands. We documented three main threats to wetlands in the watershed; non-native plant species, water quality stressors, and hydrologic alteration.

Non-Native Plant Species

Altered plant communities are one of the most common disturbances to wetlands in the Jordan River watershed. About 38% of the plant cover in Central Basin wetlands and 25% of cover in Wasatch Mountains wetlands is estimated to be from non-native species and wetland buffers also frequently had high non-native plant cover. 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 and therefore may be correlated with other site stressors such as nutrient enrichment, hydrologic alteration, or livestock grazing. For example, *Poa pratensis*, the most frequently recorded introduced plant species in the Wasatch Mountains ecoregion, can be associated with livestock grazing (Uchytil, 1993). At the same time, many non-native species are considered desirable and are intentionally planted; many 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).

In the Central Basin ecoregion, the most widespread introduced species is *Phragmites australis*, which is a noxious weed of high management concern due to the ecological and social impacts of its invasion. Other noxious weeds likely to impact Central Basin wetlands include *Cardaria draba* (whitetop), *Cirsium arvense, Conium maculatum* (poison hemlock), *Elaeagnus angustifolia* (Russian olive), *Lepidium latifolium* (broadleaved pepperweed), and *Tamarix* spp. Each of these species was documented with ≥10% cover at least once and most have wetland indicator ratings of facultative or wetter, signifying that they likely can persist in wetlands. Some of the documented impacts of these species include reduced forage quality and increased soil salinity and streambank erosion by *L. latifolium* (DiTomaso and others, 2013c), displaced native willow and cottonwood stands by *E. angustifolia* (DiTomaso and others, 2013d), reduced pasture productivity by *C. arvense,* (DiTomaso and others, 2013a), and poisoning of humans and livestock by *C. maculatum* (California Invasive Plant Council, undated). Other potential introduced species of concern in the Central Basin include *Bassia hyssopifolia* and *Dipsacus fullonum* (Fuller's teasel). *B. hyssopifolia* was widespread and occurred with very high cover (≥21%) at three Utah Lake sites. The species can be toxic to livestock in large amounts, though it is considered good forage in small quantities (DiTomaso and others, 2013b). *D. fullonum* was found in half the sites in the Jordan stratum and occurred at two sites in the Central Basin with 10% cover. The species is listed as a noxious weed in Colorado and can outcompete or shade out native plant species (California Invasive Plant Council, undated).

In the Wasatch Mountains ecoregion, several widespread and at least occasionally abundant non-native species were facultative species frequently planted for erosion control or livestock forage, including *Poa pratensis*, *Phleum pretense* (timothy), *Alopecurus pratensis* (meadow foxtail), *Trifolium repens* (white clover), all of which can displace native plant species (California Invasive Plant Council, undated). Noxious weed species of concern include *Cirsium arvense*, *Carduus nutans* (musk thistle), *Cynoglossum officinale*, *Cirsium vulgare* (bull thistle), and *Leucanthemum vulgare*, though all but *C. arvense* were typically found with low cover and are facultative upland or upland species. Two other species merit special attention. The submergent aquatic *Potamogeton crispus* (curly pondweed) was found at one site in a pond along the Provo River. This species can impede water flow and deplete nutrients when it grows in abundance; it is listed as a noxious weed in some states (California Invasive Plant Council, undated). *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 some 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, particularly in the Mountain Valleys and Semiarid Foothills and, as a facultative wetland species, is more likely to be problematic in wetlands than other common non-native species.

We recommend three actions to improve plant community composition of wetlands in the Jordan River watershed. First, land owners and land managers should continue control efforts for invasive plant species and coordinate efforts for widely distributed species such as *Phragmites australis* to increase effectiveness. Second, native plant species should be used for seeding efforts whenever possible; the Native Seed Network provides seeding recommendations and information on seed availability (http://nativeseednetwork.org). Third, wetlands with intact plant communities should be prioritized for protection since they are infrequent on the landscape outside the Alpine Zone, particularly in alkaline depression and foothill shrublands.

Water Quality

Most wetland area in the Great Salt Lake, Jordan, Utah Lake, and Mountain Valleys strata is subject to potentially high levels of water quality stress due to impaired source water, point source discharges, and run-off from surrounding agriculture and development. Buffers were typically over 50 m wide, which may be wide enough to remove most sediment, nitrogen, phosphorus, and pesticides before reaching wetlands (McElfish and others, 2008, Zhang and others, 2010), though about 9% of wetland area was not completely surrounded by buffer and 5% of buffers had significant soil disturbance that may render buffers less effective. Furthermore, water quality stressors often came to wetlands directly from streams, lakes, or canals, bypassing buffers entirely. Over half of the surveyed wetlands were hydrologically connected to impaired waterbodies, including ≥70% of sites in each of the Central Basin strata. Water quality stress often did not translate to visibly apparent water quality degradation; 30% of sites with poor water quality had good to excellent ratings for both the algae and turbidity metrics.

A combination of strategies may be necessary to protect and improve wetland water quality in the Jordan River watershed. First, water quality of impaired source water can be improved through development of Total Maximum Daily Load (TMDL) plans or other approaches. Fortunately, just five impaired waterbodies supply water to over one-fifth of the surveyed sites, four of which are high priorities for TMDL development or alternative approaches (Utah Lake, Jordan River-1, Jordan River-6, and Provo River-4; Utah Division of Water Quality, 2016a). State Canal, the fifth waterbody, may benefit from improvement of the upstream Jordan River-1 assessment unit. Second, land owners and land managers should continue to sustainably manage grazing, off-road vehicle use, and other activities within and adjacent to wetlands and use appropriate buffers to protect wetlands from adjacent runoff. Private land owners can often receive technical and financial assistance from agencies such as the U.S. Natural Resources Conservation Service, the Utah Department of Agricultural and Food, and the Utah Department of Natural Resource's Watershed Restoration Initiative to support good management practices. Last, the Utah Division of Water Quality may want to consider developing wetland-specific water quality standards so that impairment within wetlands can be evaluated and more directly addressed.

We recommend continuing to collect water quality data across a range of wetland types to better understand the relationship between site stress, site condition, and water quality parameters. Data could be analyzed by Ecological System or HGM class across project areas to increase sample sizes. Analysis of water quality parameters such as nutrients or total suspended solids could help elucidate the extent to which water quality stressors degrade wetland condition and may help identify thresholds above which degradation is likely to occur.

Wetland Hydropattern

Wetland hydropattern, including the frequency and duration of flooding (hydroperiod) and timing of inundation, 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). All or almost all wetland area in the Great Salt Lake, Jordan, Utah Lake, and Mountain Valleys strata and half the wetland area in the Semiarid Foothills are estimated to have some degree of hydropattern alteration. Alteration was most pronounced in the Great Salt Lake, Jordan, and Mountain Valleys strata, due to management for wildlife habitat, urban run-off, and direct and indirect agricultural irrigation inputs, respectively. Most wetlands in the Great Salt Lake stratum are managed for the benefit of wildlife; management should be optimized to support natural functioning within the constraints of management goals and water availability. Wetlands in the Jordan stratum frequently receive stormwater run-off; maintaining natural water inputs may help buffer these wetlands from flashy flows. In the Mountain Valleys, artificial water sources could be important for creating or supporting wetlands, especially wetlands with declining natural inputs, as has been found in other regions (Sueltenfuss and others, 2013; Berkowitz and Evans, 2014). Reducing irrigation on the landscape may allow some wetlands to return to a more natural hydropattern, but could cause the loss of other wetlands, particularly those whose natural water inputs have been impacted by water diversion.

One question meriting further study is the extent to which wetlands in the Jordan River watershed are affected by changes in water availability. Circumstantial evidence suggests that wetlands may be losing their water; many areas previously mapped as wetland by NWI no longer appear to have wetland hydrology, and field and landowner observations in Juab Valley indicate that wetlands there may be impacted by declining water levels. More focused data collection and analysis is necessary to evaluate whether a drying trend does indeed exist and, if so, to identify the main drivers of the trend. Potential drivers include anthropogenic water withdrawal, natural climate fluctuations, and changes in land use; regarding the latter, irrigated acreage has declined substantially in the Jordan and Utah basins over the past two decades (Utah Division of Water Resources, 2014b and 2014c), which could threaten wetlands supported by irrigation water.

Wetland Function

This study directly investigated two functions in the Jordan River watershed, amphibian habitat and water quality improvement. Two additional functions can be inferred from our results, wildlife use and recreational use. We documented wildlife use in each stratum, including 30 species of birds, 11 mammals, and 3 amphibians; this probably significantly underrepresents wetland wildlife use since surveyors did not conduct targeted species surveys. Wetland recreational use in the Jordan River watershed includes hunting, bird watching, and hiking near wetlands. About 15% of the wetland area in the watershed is privately or publicly managed for duck hunting. Much of the wetlands in the watershed are on public land and hiking trails near wetlands are common except in the Great Salt Lake and Utah Lake strata.

Amphibian Habitat

Wetlands in the Jordan River watershed provide habitat for two sensitive amphibian species, boreal toad and Columbia spotted frog. Almost half of the wetland area in the prime habitat for boreal toad has the potential to provide suitable breeding habitat for the species based on mean metric scores, though threats related to water quality issues (turbidity) and recreational use were common. Other threats to the species listed in the Utah Wildlife Habitat Plan were either not documented or uncommon at suitable breeding sites. Lack of adequate shrub and forb cover was the most common limiting habitat factor in the prime habitat; adult boreal toad select for areas with high shrub cover to prevent evaporative water loss (Oliver, 2006a). Wetlands in the region may naturally have low shrub cover; there is no indication that low shrub cover was associated with lack of woody species regeneration or current livestock grazing within wetlands.

Just over one-third of prime montane habitat and about 15% of Central Basin ecoregion wetland area may be suitable for Columbia spotted frog based on mean metric scores, though scoring thresholds have not been tested at known occupied sites. We found evidence of many of the threats listed in the Utah Wildlife Action Plan. Declining water levels are an important issue in northern Juab Valley, and potential fragmentation and water quality issues related to roads and other development are a common threat near wetlands in prime montane habitat; livestock overgrazing and human recreation were not widespread problems. Fair or poor waterbody vegetation and north shore exposure were common at prime montane sites, though these characteristics were almost exclusively found at sites with marginal breeding waterbodies and thus are probably either not limiting or co-limiting habitat factors. Suitable breeding habitat in the Central Basin ecoregion appears limited by an overabundance of emergent vegetation and lack of nearby suitable overwintering habitat. Further work should be done to determine whether Columbia spotted frog can breed in impoundments and rivers in the Central Basin since almost all known sites in the ecoregion are at spring complexes.

Water Quality Improvement

Most wetlands in the Jordan River watershed are estimated to currently provide some water quality improvement function, with both capacity and landscape need for improvement. Function was less common in the Semiarid Foothills, Wasatch Montane Zone, and Alpine Zone due to lack of landscape need, but wetlands in these areas have capacity for water quality improvement that could become important in the face of future landscape changes such as fires or new development. About 22% of wetland area in the Central Basin and 8.5% of wetland area in the Wasatch Mountains is estimated to have a needs gap, defined as wetlands that receive water quality stressors and only have one capacity indicator. It is important to note, however, that these wetlands may still have ample capacity to assimilate stressors, since we do not know how each indicator translates to actual level of capacity. Furthermore, lack of capacity does not necessarily mean that a wetland needs to be restored. Wetlands naturally differ in their ability to improve water quality; we evaluated data from a few randomly selected sites with a needs gap and found no obvious issues to restore.

Trends by Ecoregional Strata

We surveyed alkaline depressions, basin marshes, and playas in the Great Salt Lake stratum. Most wetlands in the stratum are embedded within large wetland complexes and thus wetlands frequently have few stressors immediately adjacent to them besides linear disturbances (e.g., roads, dikes), livestock grazing, and the invasive grass *Phragmites australis*. 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. Vegetation treatment, primarily aimed at controlling *P. australis*, is also very common. Based on the landscape profile, unconsolidated shores, which include playas and mudflats, are the most common wetland type in the stratum and the most frequently associated with high local stress.

We surveyed alkaline depressions and basin marshes in the Jordan stratum. Wetlands in the Jordan stratum appear to be in poorer condition than wetlands anywhere else in the watershed. Jordan wetlands had the most buffer disturbance, highest levels of noxious weeds, most issues with turbidity and water quality stressors, and amongst the most altered hydrology. Wetlands in the Jordan stratum are predominantly classified as private, though often owned by local government entities, and frequently receive stormwater run-off. Despite their poor condition, Jordan wetlands likely provide important functions such as water quality improvement and wildlife habitat. The Jordan stratum has likely experienced the highest rate of wetland loss of all strata in the watershed and thus preserving the remaining wetlands is important for maintaining those functions on the landscape.

Utah Lake wetlands exhibited a diversity of HGM classes and wetland types, including lacustrine wetlands on the shore of Utah Lake, depressional wetlands, and the only slope wetlands surveyed in the Central Basin. This stratum also had the most sensitive ecological features observed in the Central Basin with both a peatland site and a site with a sensitive plant species. Lacustrine fringe wetlands occur in large relatively intact landscapes within complexes of wetlands and deepwater and may be affected by impaired water quality from Utah Lake. Wetlands were more frequently grazed and surrounded by agriculture compared to wetlands in other parts of the Central Basin. Landowners are concerned about groundwater levels in the southern portion of the study area. Almost all wetlands in the stratum are considered riparian, with a much higher percent considered moderately impacted by watershed stress compared to the Great Salt Lake and Jordan stratum, where virtually all riparian wetlands are classified as highly stressed.

Wetlands in the Mountain Valleys primarily fell into one of two categories, foothill scrublands along the Provo River and irrigation-influenced depressional wet meadows frequently used as pasture. Mountain Valleys also had the most slope wetland area outside of the Alpine Zone and the most peatland sites of any strata. Almost two-thirds of the wetland area in the Mountain Valleys is estimated to receive irrigation water via tail water run-off, subjecting wetlands to unnaturally timed and potentially polluted waters. Widespread livestock grazing led to sparse litter at some sites, but only had a small impact on soil disturbance. Wetlands in the Mountain Valleys are subject to more water quality stressors than other wetlands in the Wasatch Mountains ecoregion, which ranged from landscape stressors, including agriculture, development, and point source dischargers, and buffer stressors, including linear disturbances, agriculture, and livestock grazing. Most wetland area had fairly poor or worse relative native plant cover, though noxious weeds were not very abundant. Continued development in the Mountain Valleys is anticipated, with the population in the four largest towns in the region expected to more than triple from 2010 to 2060 (Utah Governor's Office of Management and Budget, 2012). Wetland conservation in the Mountain Valleys through land purchases and easements may be crucial for wetland preservation in the face of development pressure.

Wetlands in the Semiarid Foothills were predominantly depressional and included montane shrublands, montane marshes, foothill shrublands, and wet meadows. Semiarid Foothills wetlands are heavily impacted by non-native plant species; over half of the wetland area in the stratum is estimated to have <50% relative native plant cover. Semiarid Foothills wetlands also tend to have more water quality stress and hydrologic manipulation than wetlands at higher elevations. About one-quarter of wetland area is estimated to have livestock grazing, though disturbance from livestock grazing was typically low severity.

We surveyed montane woodlands, wet meadows, and montane shrublands in the Wasatch Montane Zone, with >80% of wetland area in the latter category. Wetlands were in relatively intact landscape settings with few apparent hydropattern or water quality stressors and primarily undisturbed soils. Nonetheless, woody species regeneration and plant community composition metrics were frequently rated as fair or poorer. Wetlands frequently lacked woody regeneration and relatively little area rated as good-excellent for relative cover of native species. Furthermore, almost three-quarters of Wasatch Montane Zone wetlands had ≥3% cover of noxious weeds, the majority comprised of *Cirsium arvense*. Over half the wetland area is managed by the U.S. Forest Service and much of the remaining land is privately owned and part of the CWMU program.

We surveyed montane shrubland and wet meadow in the Alpine Zone. All but one wetland was slope and half qualified as peatlands. Alpine Zone wetlands are in the best condition of all wetlands in the watershed based on most measures, with wide, intact buffers, minimal landscape and water quality stress, little if any hydrologic alteration, and very intact plant communities. Only two stressors were common in Alpine Zone buffers, trails and mountain pine beetle-killed trees. Over 90% of the wetland area in the stratum and all the surveyed sites are part of the Uinta-Wasatch-Cache National Forest.

We surveyed montane woodland, foothill shrubland, wet meadow, and montane shrubland on the National Forest, which included wetlands in the Semiarid Foothills and Wasatch Montane Zone strata. Vegetation community composition tended to be better on the National Forest than other wetlands in the the Semiarid Foothills and Wasatch Montane Zone strata; most National Forest sites had ≥80% relative native cover and ≤3% noxious weed cover. Livestock grazing is estimated to occur in about one-third of National Forest wetlands, and soil disturbance was more common in National Forest wetlands than in other wetlands in the strata, though typically low severity. Hydropattern alteration was very uncommon and water quality condition was generally good to excellent, though one site was rated as poor due to proximity to a mine. Most of the highest condition wetlands in the Jordan River watershed are on land managed by the Uinta-Wasatch-Cache National Forest, including sites in the Alpine Zone. All 13 sites with the highest condition scores, 12 of the 13 sites with the highest mean C values, and 17 of the 19 high-quality reference sites in the Wasatch Mountains ecoregion were all on Uinta-Wasatch-Cache National Forest land.

Ecological Systems and Reference Values

We conducted an exploratory analysis of high-quality reference sites in the Jordan River watershed by screening for sites with low levels of stress and then determining the 25th percentile value for mean C and overall URAP condition scores at those sites. High-quality wetlands were less common in the Central Basin than in the Wasatch Mountains ecoregion; we had to loosen the screen to obtain enough reference sites for each of the Ecological Systems in the former ecoregion and none in the latter. Mean C and condition score thresholds were lower in Ecological Systems in the Central Basin ecoregion than the Wasatch Mountains, perhaps due to the loosening of the stressor screening.

We have several recommendations based on this exploratory analysis. First, we should increase our sample of sites to obtain more high-quality reference sites in each Ecological System. We had to loosen the screen for all the Central Basin ecoregion sites, and threshold mean C values were relatively low. C-values of <3 are indicative of species frequently found in converted ecosystems such as old fields, ditches, and managed roads (Rocchio and Crawford, 2013); two of our Ecological Systems had threshold values below 3. Second, we should evaluate the Ecological Systems to determine whether they are parsimonious and complete in grouping sites to obtain meaningful and actionable data. There was considerable overlap in plant community composition between wet meadows and alkaline depressions; these Ecological Systems could be combined or parsed to create more distinct groups of sites. Wet meadows may also need to be divided into several subclasses. Wet meadows spanned the broadest elevation, included the most strata, and had the strongest correlations between plant community composition and natural environmental variability. Four of the six wet meadow reference sites were in the Alpine Zone, and none were in the Mountain Valleys; the reference sites may not represent practical restoration targets for lower elevation wet meadows. Third, we should consider whether to assess submergent marshes and playas differently and separately from other Ecological Systems. Submergent marshes were classified as part of basin marshes, but marshes with emergent vegetation may need to be assessed separately from the typically species-poor submergent marshes, at least for vegetation metrics. Four of the five high-quality reference basin marshes were comprised entirely of submergent and floating vegetation. We recommend obtaining a separate set of reference sites for emergent and submergent marshes and comparing water quality parameters across types. Playa wetlands were also species-poor systems, and half the surveyed playas had ≤6% vegetation cover. It may be important to focus on other aspects of playas, such as soil salinity, or to survey sites very early or very late in the growing season to obtain more data on the condition of playa wetlands.

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