Lower South Platte River Basin Wetland Profile and Condition Assessment

Natural Heritage Program Colorado

April 2014

CNHP's mission is to preserve the natural diversity of life by contributing the essential scientific foundation that leads to lasting conservation of Colorado's biological wealth.

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Recommended Citation:
Lemly, J., L. Gilligan, and G. Smith. 2014. Lower South Platte River Basin Wetland Profile and Condition Assessment. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

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April 2014

EXECUTIVE SUMMARY

The Lower South Platte River Basin contains some of the most important migratory bird habitat in the state and is a priority area for the Colorado Parks and Wildlife (CPW) and many partner organizations. However, critical information needed for effective conservation has long been lacking. Through this project, Colorado Natural Heritage Program (CNHP), CPW's Wetland Wildlife Conservation Program, and Dr. Catherin Ortega partnered to address gaps in the knowledge of wetladn and riparian resources. This project had four main objectives: (1) to create a digital map of wetlands in the Lower South Platte River Basin; (2) to research habitat requirements of target wildlife species; (3) to identify reference condition wetlands in the basin; and (4) to conduct a statistically valid, field-based survey of wetland condition in the basin. Results produced through this project will inform decisions made by CPW and its partners for wetland restoration, enhancement and protection.

Converting original National Wetlands Inventory (NWI) maps from the 1970s into digital data allowed for the first estimate of wetland acres across the basin: 158,468 acres of wetlands and 95,193 acres of lakes and rivers were mapped by NWI in the 1970s. More than half these acres were concentrated along the South Platte floodplain, with an additional 15% spread across the Front Range. The mapping showed a clear dominance of herbaceous wetlands across the basin, though forested wetlands made up a notable 27% of mapped acres. Mapped wetlands and aquatic resources in the basin were overwhelmingly (83%) located on private lands.

Through a systematic accuracy assessment, however, the raw NWI acres proved to be unreliable for estimating the extent and distribution of wetlands within today's landscape. Overall accuracy of the map was less than 50%, which would be considered unacceptable for any mapping effort. Without conducting an in-depth analysis of aerial imagery from the 1970s, it is impossible to know exactly how much of the inaccuracy is related to change on the landscape since the original mapping was created and how much represents change in mapping methodology. A previous in-depth analysis comparing original NWI mapping to new, up-to-date mapping along the northern Front Range revealed that the change attributed to mapping methodology was two to three times greater than the change attributed to landscape (Lemly et al. 2013). It is reasonable to assume that mapping methods are similarly responsible for the majority of inaccuracies in the Lower South Platte. The greatest sources of inaccuracy in this study area were overmapped forested wetlands, many of which would be mapped as non-wetland riparian areas today, and overmapped herbaceous wetlands, many of which are now too dry to be considered wetlands. It is likely that most of the cottonwood galleries along the South Platte floodplain depicted in the forested wetland polygons were dry in the 1970s, as they are today, though they may be even less connected to the river channel than they were originally. However, further research would be needed to understand whether the overmapping of herbaceous wetlands represents true overmapping, even in the 1970s, or if basinwide trends towards a drier climate and increased hydrologic alterations have led to widespread drying of herbaceous wetlands.

Important conclusions can be drawn from the assessment of wetland condition as well. The Level 1 landscape analysis indicated that the majority of mapped wetlands experience high or severe stress (80% between the two stress classes). Field data also indicate high stress on wetlands and riparian areas in the basin. Based on the coarse classification of wetland/riparian source, 87% of sampled wetlands were considered natural, but altered or augmented and only 2% were considered relatively unaltered. Compared to mountainous areas of Colorado, this represents a very high degree of alteration to natural wetlands. However, few sites in the Lower South Platte (12%) were classified as non-natural features derived entirely from human action (intentional or unintentional). This is a significantly lower number than found in a focused study of wetlands in the urban Front Range corridor (74%: Lemly et al. 2013), indicating that, though stressed, the Lower South Platte wetland and riparian resources are still more natural than those found in Colorado's more highly developed regions.

Sites sampled in the basin included a wide range of wetland and riparian types, from those closely tied to rivers and streams, to those driven entirely by precipitation events. Many sites surveyed were either entirely dry, non-wetland riparian areas or were boarder line wetlands that contained relict hydric soils or remnant wetland plants. This does indicate that wetlands in the basin may be drying. Of all wetland and riparian types surveyed, warm water sloughs most consistently contained water and represent the majority of true wetlands within the basin. This underscores the importance of this wetland type, already considered a priority for land managers.

Ecological Integrity Assessment (EIA) scores calculated for all random and reference condition sites confirm that the basin's wetland and riparian resources are stressed. Among reference sites, which were hand-picked to represent the best available condition, only four were rated in excellent (A) condition. The majority (62%) were rated as good (B) condition, while another 24% were ranked C. The lack of very high condition reference sites complicates the use of their site-level data to help refine and develop metrics for the plains. The purpose of reference sites is to help set the bar against which to measure the condition of randomly selected sites. When reference sites are in less than excellent condition, it is more difficult to know where along the bar those sites truly sit.

While condition assessment methods used in this project were developed and used successfully in several previous studies, the Lower South Platte River basin was the first study area on Colorado's plains. Several new wetland and riparian types were encountered in the study, including Western Great Plains Floodplain, Western Great Plains Riparian, and Western Great Plains Closed Depression (playas). For these three systems, one standard metric of biotic integrity (Mean C) did not appear to show the same strong response to disturbance. For this analysis, Mean C was removed from the metric scoring and a higher weight was given to other biotic measures, including percent non-native, percent noxious, and presence of aggressive natives. There is considerable need for further study of these wetlands types to refine the condition assessment methods. In addition, the hydrology metrics proved difficult to evaluate for plains systems, as the impact of many cumulative upstream stressors are difficult to quantify.

EIA scores for random sites, calculated with the above-mentioned modifications, showed that just over half (57%) of randomly selected sites were rated in C condition, while nearly a third were rated in B condition. An additional 12% were rated D, indicating significant deviation from reference. Among the component scores, sites rated highest for landscape context and lowest for biotic integrity. The generally rural landscape of the Lower South Platte River basin contained less modification than other, more developed regions of the state. However, the vegetation in South Platte wetlands and riparian areas is highly disturbed and contains considerable cover of non-native species. Wetlands in the basin are impacted by a range of stressors. The most frequently noted included unpaved and paved roads, agricultural crops, light to moderate grazing, and human recreation. Agricultural irrigation related stressors frequently impacted site hydrology within and surrounding the AA. Compaction and soil disturbance were common physiochemical stressors from human use or livestock.

Wildlife habitat research conducted through this project compiled a rich collection of information about priority wetland dependent species in the basin. A thorough report on this research is included here as Appendix A. From this research, new metrics were developed to assess the quality of wildlife habitat. Across all randomly sampled sites, there was a range of habitat values observed in the basin. Duck habitat, which is a major focus of wetland management in the basin, was rated as moderate overall by the indices. Duck habitat was highest in the two sandbars encountered and in warm water sloughs. Habitat for curlews appears to be in the best shape across the basin, though it is not common. Sandhill feeding and frog feeding habitat also appears to be generally good in the basin. However, both those species groups rely on other habitat characteristics during their life cycle, and those other habitat indices did not score as well. For frogs in particular, wintering habitat showed low scores, indicating that this may be the limiting factor or frog populations. This report included results on the initial evaluation of habitat quality, as this newly developed method is still under development. Additional work on the habitat indices will likely reveal other important trends.

ACKNOWLEDGEMENTS

The authors at Colorado Natural Heritage Program (CNHP) would like to acknowledge the U.S. Environmental Protection Agency (EPA) Region 8 and Colorado Parks and Wildlife (CPW)'s Wetlands Program for their financial support and encouragement of this project. Special thanks to Cynthia Gonzales, EPA Project Officer. Brian Sullivan, CPW Wetlands Program Coordinator, has been a major driver of this project and has helped clarify the data gaps needed for this basin.

Kevin Bon and Rusty Griffin from U.S. Fish and Wildlife Services (USFWS)'s National Wetland Inventory (NWI) Program have provided valuable assistance streamlining our NWI map conversion process. Special thanks to CNHP's Michelle Fink, who developed the Wetlands Landscape Integrity Model (LIM), the Wetland Condition Assessment Database (WetCAD), and the Wetland Habitat Assessment Database (WetHAB). Her knowledge and skills have been integral to our analyses.

We extend much gratitude to CNHP field technicians Erick Carlson, Laura Cascardi, Leah Fugere, Cole Reagan, and Dave Wesolowski for their hard work collecting data. Thanks to botanists extraordinaire Pam Smith of CNHP and Jennifer Ackerfield of the CSU Herbarium for help with plant identification. CNHP workstudy Claire Tortorelli was invaluable for entering and QC'ing pages and pages of field data.

The project could not have happened without the support and assistance of local partners in the Lower South Platte River Basin. Special thanks to the four members of our steering committee: Colin Lee of NRCS/RMBO/CPW, Noe Marymor of NRCS, Matt Reddy of Ducks Unlimited, and Greg Stoebner of USFWS. Thanks also go to agency biologists and land managers who let us survey on their lands. And a very special thanks to the private landowners who allowed us onto their lands.

During the course of this project, we gained tremendous technical assistance, ideas and overall guidance from our colleagues at CNHP, especially Dave Anderson, Denise Culver, Karin Decker, Amy Lavender, Renee Rondeau, Joe Stevens, and Jeremy Sueltenfuss. Thanks also go to Quinn Eccleston for contributions to analysis and writing. Finally, we would like to thank Mary Olivas and Carmen Morales with Colorado State University for logistical support and grant administration.

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1.0 INTRODUCTION

The South Platte River runs from the Continental Divide, through the largest metropolitan areas of Colorado's Front Range, and onto the High Plains of Eastern Colorado. The floodplain of the South Platte and its associated wetland complexes represent important migratory bird habitat, contribute significantly to return flows in the main channel, and help filter pollutants from both urban and agricultural landscapes (Sprague et al. 2006, SPWFAC 2002; Strange et al. 1999). The lower portion of the river basin, from the base of the Rocky Mountains east to the state line (Figure 2), has been a primary focus area of the Colorado Parks and Wildlife (CPW)'s Wetland Program, U.S. Fish and Wildlife Service (USFWS)'s Partners for Fish and Wildlife Program, National Resource Conservation Service (NRCS)'s Wetland Reserve Program, Ducks Unlimited (DU), and many other conservation organizations. Numerous wetland restoration, enhancement and conservation projects have been supported by these organizations, representing millions of dollars invested in the Lower South Platte River's wetlands. However, to date, there has been no systematic, scientifically grounded accounting of the acreage, types, distribution, and condition of the basin's wetlands because the necessary information and tools to carry out such an assessment were lacking. This project created a "profile" of wetlands and riparian areas in the Lower South Platte River Basin that documents the spatial distribution of wetlands by type, ecological condition, landowner category and protection status, as well as the extent of suitable wildlife habitat and the most pressing stressors facing wetlands in the basin. This information is necessary to prioritize on-the-ground efforts for efficient and effective conservation action.

Wetland complexes of the Lower South Platte River Basin have long supported waterfowl migration and wintering areas, as well as habitat for rare amphibians, fish and invertebrates. Before human modification of the landscape began in the late 1800s, the basin sustained numerous shallow water wetlands driven by spring flooding and periodic heavy rainfall. It has been estimated that wetlands historically covered 70,000 acres within the Lower South Platte River corridor, or roughly 15% of the landscape (PLJV 2010). These wetlands filled in the spring and fall at optimal times for migratory birds traveling the long route between the arctic and warmer climates to the south. Today, the river and surrounding landscape are heavily modified by municipal use along the Front Range and agricultural use along much of its length. Flow within the river is highly variable, both spatially and temporally, due to extensive withdrawals and engineered recharge (Cariveau & Risk 2007; Strange et al. 1999).

However altered the environment, the basin's wetlands remain critical to a host of wildlife species. In fact, given the extent of alteration, the importance of these wetlands is that much greater because they provide refuge for wildlife, regulate hydrology in the basin, and filter water pollutants from agriculture and other land uses. CPW's Wetlands Program and its many partners place a high priority on maintaining or improving the population status of wetland-dependent wildlife species, primarily through voluntary conservation of critical wetland habitat on private land and the enhancement of wetland habitat on state land. Through partnerships, CPW and others have invested heavily in the Lower South Platte Basin's wetlands. Well over 100 projects, representing millions of dollars in funding, have been supported in the past 15 years. In conjunction with investment in on-the-ground projects, there is also a healthy body of research documenting the characteristics of project wetlands and their success in attracting target bird species (Cariveau & Risk 2007; Steel & Cariveau 2006).

In the 1990s, CPW established the South Platte Wetland Focus Area Committee (FAC) to help shape the vision for wetland conservation within the basin. This committee is comprised of private landowners, concerned citizens, sportsmen, non-profits and land trusts, and natural resource professionals from local, state, and federal agencies. In 2002, the South Platte Wetland FAC developed a strategy for wetland conservation within the South Platte River Basin (SPWFAC 2002). Within the strategy, the FAC called for landscape scale wetland conservation to preserve both wildlife habitat and important hydrologic functions. Their stated goal is to conserve "a sufficient quantity of quality wetlands that are distributed across the landscape" in order to "maintain natural communities and wetland dependent species." Though an important goal for guiding action within the basin, this strategy begs the questions: How much is sufficient? What is a quality wetland? How should they be distributed across the landscape? It is clear that to move forward, research is needed to address these questions.

This project aimed to answer the questions of quantity, quality, and distribution through four targeted objectives. The first step was to quantify the acreage of wetlands that currently exist in the basin. The USFWS began mapping wetlands across the U.S. in the 1970s through the National Wetland Inventory (NWI) program. Though all of Colorado was mapped in the early years of the program, very little of that mapping was available in a digital format from which total acreage could be calculated. This project digitized the existing NWI mapping for the basin and assessed its accuracy. The second step addressed the question of quality. Research on the specific habitat requirement of CPW's target wildlife species was conducted through literature review and expert interviews. In addition, a set of wetlands known to be in the best condition available were selected within the basin to serve as a point of reference against which other wetlands can be compared. The final step was to conduct a probabilistic survey of wetland condition and habitat suitability across the entire river basin. Using the mapping, habitat research, reference condition wetlands, and overall condition assessment, a wetland profile was created to documents the current spatial distribution of wetlands by type, ecological condition, landowner category, and protection status, as well as the extent of suitable wildlife habitat and the most pressing stressors facing the basin.

Wetland profiles have been shown to be an effective means of summarizing wetland diversity, abundance, and functions and can be used to establish baseline conditions, assess cumulative impacts to wetland condition and function, and inform strategic goals (Bedford 1996; Gwin et al. 1999; Johnson 2005). By incorporating ecological condition and associated stressors into a wetland profile, conclusions can be drawn regarding the integrity of the basin's wetland resource and its ability to provide natural ecological functions and services, such as suitable wildlife habitat. As human stressors negatively impact wetlands, habitat value of those wetlands will also be negatively impacted. Combining the assessment of ecological condition and status of key wildlife habitat features provides a coarse filter for prioritizing on-the-ground efforts targeted at protecting and restoring wetlands and their associated wildlife.

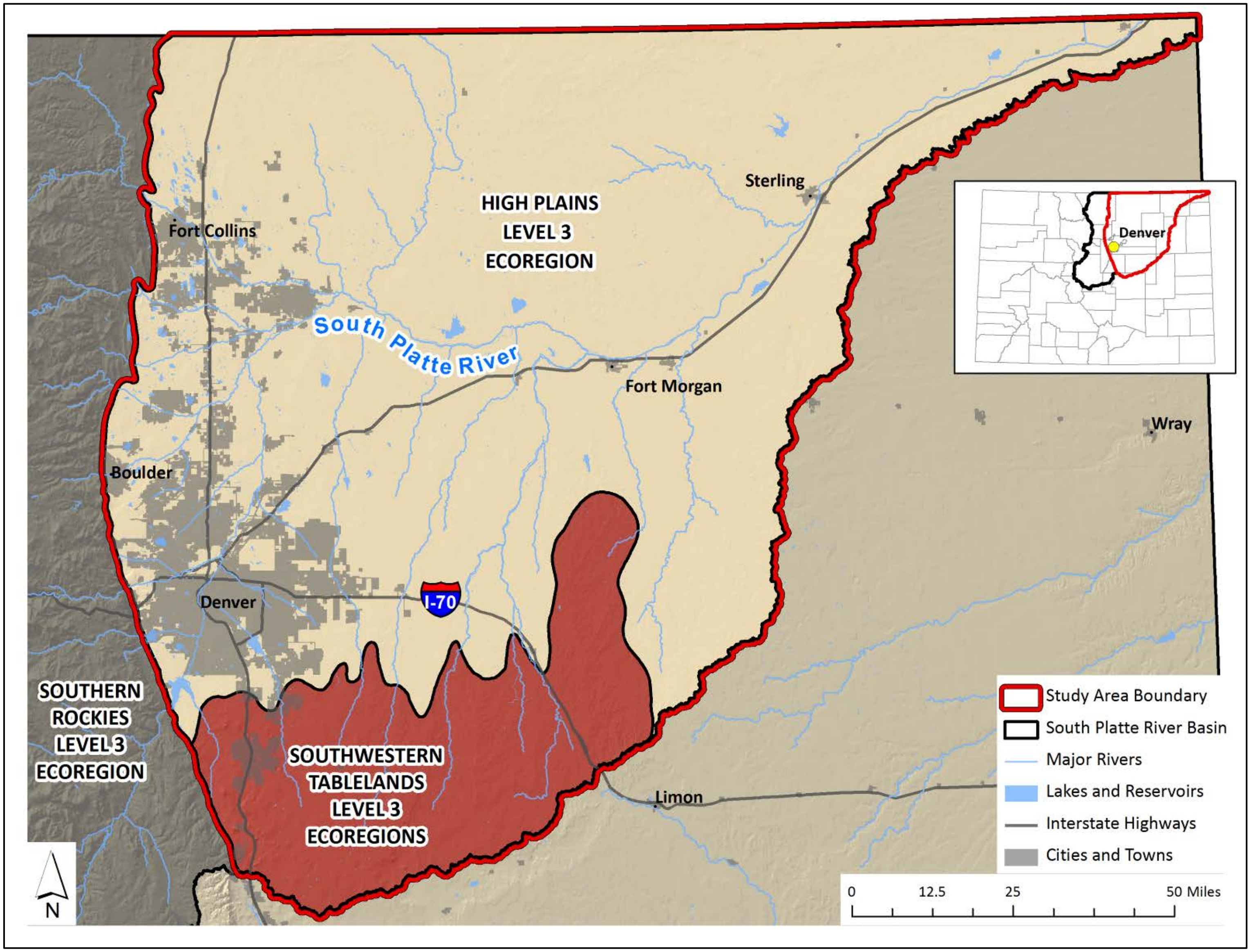

Figure 1. Lower South Platte River Basin study area. The study area encompasses all portions of Colorado's South Platte River Basin (HUC 6 101900) within the High Plains (light tan) and Southwestern Tablelands (red) Level 3 ecoregions. Portions of the South Platte River Basin within the Southern Rockies Level 3 ecoregion (gray) are excluded from the study. Inset map shows river basin and study area in relation to Denver and Colorado counties.

1.1 Project Objectives

The project objectives are to (1) create a digital map of wetlands in the Lower South Platte River Basin and determine its accuracy; (2) research habitat requirements of priority wetland-dependent wildlife species; (3) identify and survey a set of reference condition wetlands in the basin; and (4) conduct a statistically valid, field-based survey of wetland condition in the basin. These objectives were carried out through the following steps.

1) **Create a digital map of wetlands in the Lower South Platte River Basin and determine its accuracy.**
   - NWI mapping created in the 1970s as paper maps paper was converted to digital spatial data in ArcGIS 10.0. The specific process of selecting only wetland polygons from the scanned images and excluding other features, such as the hand drawn attribute labels and other reference lines, has been developed by CNHP and CPW over the past five years and is a highly efficient means of converting original NWI data into a digital format.
   - To determine accuracy of the wetland map, 1200 randomly distributed points were selected across the basin and evaluated using the most recent aerial photography. An error matrix was developed documenting how frequently wetlands occur on the landscape without wetland mapping and how frequently wetlands are mapped where no wetlands occurs.
2) **Research habitat requirements of priority wetland-dependent wildlife species.**
   - Literature on the specific wetland habitat needs of priority wetland-dependent wildlife species was reviewed to determine key habitat features that can be easily and repeatedly measured in the field (i.e., hydrological regime, water depth, plant associations, open water interspersion, proximity of upland types, food sources, etc.).
   - Where literature was not sufficient, experts on the priority species were interviewed to add additional information.
   - Based on information obtained through literature review and interviews, field and GIS-based metrics to determine habitat suitability were developed.
   - See Appendix A for the stand alone results of this objective.
3) **Identify and survey a set of reference condition wetlands in the basin.**
   - Thirty six reference condition (best available) sites were hand selected across the basin to represent new wetland types not currently included in CNHP's condition assessment protocols.
   - Reference sites included common wetland and riparian Ecological System groups and three priority wildlife habitat types (warm water slough, moist soil units, and recharge ponds).

- Level 3 surveys were conducted in these reference sites, including a fully detailed vegetation plot, 2–4 soil profiles, estimates of surface water cover and/or water table depth, and other relevant metrics.

4) Conduct a statistically valid, field-based survey of wetland condition in the basin.

- A spatially balanced probabilistic sample design was developed based on the principles in EPA's Environmental Monitoring and Assessment Program (EMAP: Stevens & Olson 2004; Detenbeck et al. 2005).
- Over 100 random wetland sites were targeted. A portion of these sites was dedicated to the three priority wildlife habitat types (warm water slough, moist soil units, and recharge ponds). The remainder was distributed randomly within the NWI mapping. The survey was stratified by Level 4 ecoregion (Omernik 1987) to ensure spread across the basin.
- Field methods followed the rapid and intensive wetland condition assessment protocols developed by CNHP, including the Floristic Quality Assessment (FQA: Rocchio 2007) and Ecological Integrity Assessment (EIA: Lemly & Rocchio 2009a), and also included the metrics developed through wildlife habitat research.

1.2 Wetland Monitoring and Assessment Frameworks

To maximize the utility of the information, work conducted through this project can be viewed through two important frameworks. First is the EPA's Level 1-2-3 Framework for wetland assessment, which defines an approach to wetland assessment at multiple scales of time, cost, and accuracy. The second is NatureServe's Ecological Integrity Assessment Framework, which outlines an approach to assessing the condition of ecological resources, in this case wetlands. Both frameworks are discussed briefly below.

1.2.1 EPA's Level 1-2-3 Framework for Wetland Assessment

Acknowledging that it is impossible to visit every wetland across a landscape to determine the range of condition, EPA recommends a three tiered approach to wetland assessment. Within the Level 1-2-3 Framework[1], Level 1 assessments are broad in geographic scope and used to characterize resources across an entire landscape. They generally rely on information available digitally in a GIS format or through remote sensing. Goals of Level 1 assessments may include summarizing the extent and distribution of a resource (such as wetland mapping from air photography) or modeling the condition of wetlands based on anthropogenic stressors such as roads, land use, resource extraction, etc. The wetland profile concept is essentially a Level 1 assessment. Level 1 assessments can be applied across a large area and can summarize general patterns, but may not accurately represent the condition of a specific wetland on the ground.

Level 2 assessments are rapid, field-based assessments that evaluate the general condition of wetlands using a suite of easily collected and interpreted metrics. The metrics are often qualitative or narrative multiple choice questions that refer to the condition of various attributes (e.g., buffers,

[1] For more information on EPA's Level 1-2-3 framework, see http://www.epa.gov/owow/wetlands/pdf/techfram.pdf.

hydrology, vegetation, soil surface disruption) based on stressors present on site. Rapid assessments should be conducted within one to two hours of field time and are often used to assess a large number of wetlands on the ground to make an overall estimate of condition or evaluate which sites deserve more intensive monitoring.

Level 3 assessments involve the most intensive, field-based protocols and are considered the most accurate measure of wetland condition. These assessments are based on quantitative data collection and the establishment of data-driven thresholds. They require skilled practitioners to carry out sampling and can take numerous hours for every site. Level 3 protocols are generally developed separately for different wetland attributes, such as vegetation, macro-invertebrates, water chemistry, hydrology, or wildlife habitat. In some cases, repeat sampling may be necessary to fully capture a wetland's condition.

Within the Level 1-2-3 Framework, data from more detailed levels can be used to calibrate and validate levels above. Level 3 surveys can inform the narrative ratings of Level 2 assessments, and both can help refine Level 1 GIS models. Over time and with sufficient data, coarser level assessments can provide a fairly accurate overview of wetland health across a broad area. However, detailed Level 3 assessments will always provide the most accurate measure of site-specific condition.

1.2.2 NatureServe's Ecological Integrity Assessment Framework

The Ecological Integrity Assessments (EIA) Framework was developed by NatureServe[2] and ecologists from several Natural Heritage Programs across the country (Faber-Langendoen et al. 2006; Faber-Langendoen et al. 2008a). The EIA Framework evaluates wetland condition based on a multi-metric index. Biotic and abiotic metrics are selected to measure the integrity of key wetland attributes within four major categories:

1. Landscape context
2. Biotic condition
3. Hydrologic condition
4. Physiochemical condition.

Using field and GIS data, each metric is rated according to deviation from its natural range of variability, which is defined based on the current understanding of how wetlands function under reference conditions absent human disturbance. The farther a metric deviates from its natural range of variability, the lower the rating it receives. Numeric and narrative criteria define rating thresholds for each metric. Once metrics are rated, scores are rolled up into the four major categories. Ratings for these four categories are then rolled up into an overall EIA score. For ease of communication, category scores and the overall EIA score are converted to ranks following the ranges shown in Table 1. The scores and ranks can be used to track change and progress toward meeting management goals and objectives. With past funding from EPA Region 8 and CPW, CNHP developed EIA protocols for seven wetland types in the Southern Rocky Mountain Ecoregion (Rocchio 2006a-g), field tested one set of these protocols (Lemly and Rocchio 2009a), and refined

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[2] NatureServe is a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action. For more information about NatureServe, see their website: www.natureserve.org.

the protocols through the Rio Grande and North Platte Basin condition assessments (Lemly et al. 2011, Lemly and Gilligan 2012).

Table 1. Definition of Ecological Integrity Assessment ratings. Modified from Faber-Langendoen et al. 2008b.

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

2.0 STUDY AREA

2.1 Geography

The South Platte River Basin (HUC6 101900)[3] is located in northeast Colorado and includes the South Platte River from its headwater tributaries out to the plains. The study area for this project includes only the lower elevation portions of the basin, referred to as the 'Lower South Platte' Basin (Figure 1; Figure 2). The study area includes the heavily populated Front Range at the base of the foothills and the rural, agricultural eastern plains. The west boundary is the edge of the Level III High Plains Ecoregion, with the Southern Rockies Ecoregion adjacent to the west. The northern study area boundary is delineated by the Colorado/Wyoming state line. The eastern portion is abutted by the Republican River basin and the southern portion by the Arkansas River basin.

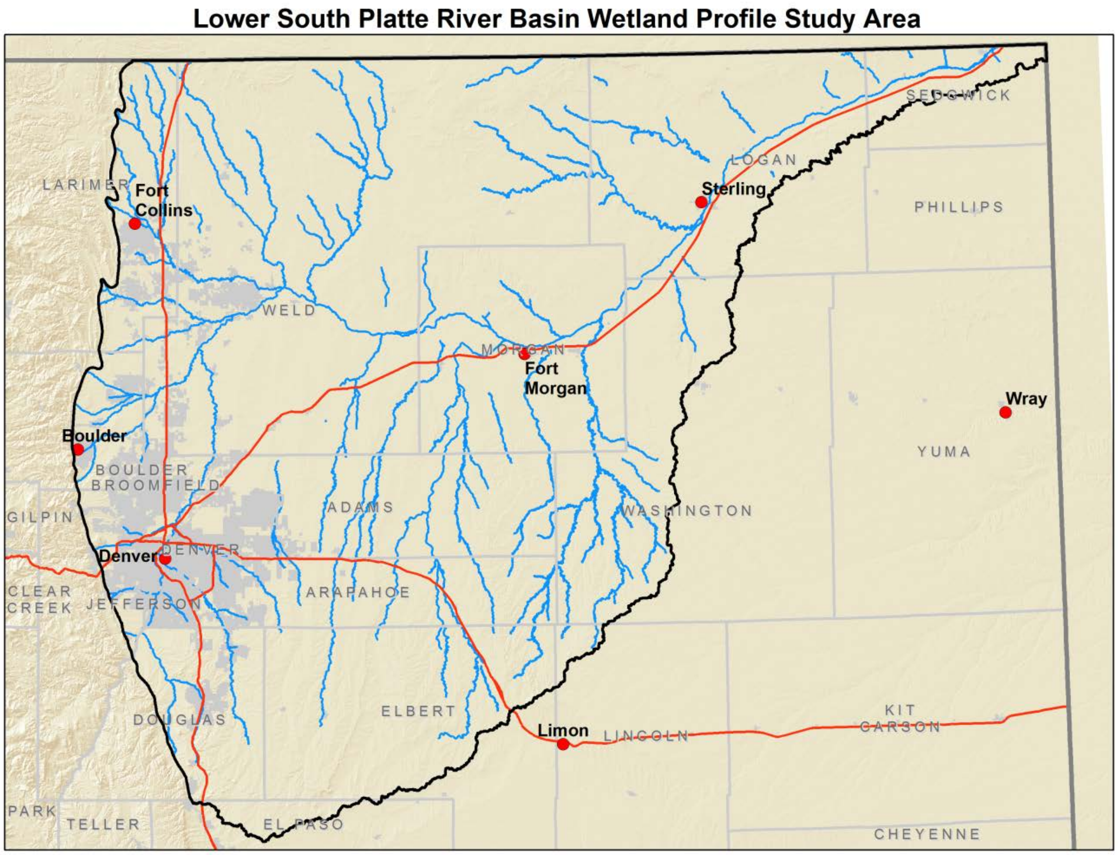


Figure 2. The Lower South Platte River Basin study area boundary.

[3] The U.S. Geologic Service (USGS) has divided the Unites States into a hierarchy of hydrologic units, specified by hydrologic unit codes (HUCs). Each level in the hierarchy is noted by the number of digits within the HUC (e.g., HUC6 101800 has 6 digits). The HUC6 level is referred to as the river basin scale. For more information and to download GIS data, see the website: http://water.usgs.gov/GIS/huc.html.

The Lower South Platte Basin (referred to as 'basin' hereafter) spans ~160 miles from east to west and ~135 miles from north to south, encompassing 8,417,519 acres (13,152 $miles^2$ or 3,406,463 ha). The basin includes all or portions of fifteen counties: Weld, Morgan, Adams, Arapahoe, Larimer, Boulder, Jefferson, Douglas, El Paso, Elbert, Washington, Logan, Sedgwick, Denver, and Broomfield (Figure 2). The cities of Denver, Boulder, and Fort Collins are situated within the basin. Denver is the largest city both in the basin and the state of Colorado, supporting an estimated population of 634,265 (U.S. Census Bureau 2012). Fort Morgan and Sterling are the largest cities in the plains region of the basin; they support populations of 11,451 and 14,727, respectively (U.S. Census Bureau 2012).

Topography in the basin is mostly rolling to near-flat across much of the basin, but it becomes more variable and dissected where scattered buttes to the west and deeper draws and arroyos to the east characterize the tablelands portion of the southern part of the study area. The land also begins to rise approaching the foothills at the western edge of the basin. Elevations across the basin mostly range from 3,500–5,500 ft., but as the very northwestern to southwestern portions of the basin approach the foothills, elevations rise to >6000 ft.

2.2 Ecoregions and Dominant Vegetation

The basin falls within two Omernik Level III ecoregions: the High Plains and the Southwest Tablelands (Figure 1; Omernik 1987[4]). Level IV Ecoregions further divide the plains landscape into finer units based on transitions in vegetation, topography and geology (Figure 3).

East of the Front Range, *Buchloe dactyloides* (buffalograss) and *Boutelous gracilis* (blue grama) create a low carpet of shortgrass steppe prairie across the plains. *Opuntia* spp. (prickly pear cactus) and *Pascopyrum smithii* (western wheatgrass) are also common across the prairie in low to high cover. Short, drought-tolerant shrubs such as sand sage (*Artemesia filifolia)* and rabbitbrush (*Chrysothamnus* spp.) scatter in open patches across the upland prairie. Cottonwoods (*Populus deltoides*) are the most common tree species in the basin, and they form large galleries along the South Platte floodplain and along some of its southern tributary rivers and creeks. Cottonwoods are also common in western riparian areas, but their understories have larger patches of coyote willow (*Salix exigua*) and higher understory diversity. Plains riparian areas north of the South Platte River tend to be herbaceous in stature, dominated by mixed graminoids and forbs. Saltgrass (*Distichlis spicata*) is one of the most commonly occurring wetland grasses, and is widespread throughout the entire study area. *Distichlis* is common in meadows ranging from mesic to wet, growing in soils that tend to be high in salinity and presently or historically irrigated. In the southern ecoregions, oak (*Quercus* spp.) and hawthorn (*Craetagus* spp.) cover begins to intersperse with the cottonwood ecosystems. Noxious weeds and non-natives are present in patches of high cover throughout the basin's wetlands, riparian areas, and uplands.

Aside from marshy zones of bulrush (*Schoenoplectus* spp.) and cattail (*Typha* spp.), species that spread throughout impounded wetlands and stream and slough edges, wetland vegetation tends to

[4] For more information on Omernik/EPA Ecoregions and to download GIS shapefiles, visit the following website: http://www.epa.gov/wed/pages/ecoregions.htm.

be small patch and not a dominant cover type in the study area. The natural wetland types in the basin tend to be the smaller wetland features: narrow warm water sloughs along the South Platte floodplain, scattered playas embedded in the shortgrass prairie, and small wet meadows along the foothills where the water table is high. Small wetland patches such as willows and cordgrass (*Spartina* spp.) swales also occur in small patches as part of a mosaic within floodplain and riparian areas. Those natural wetland types comprise some of the smallest NWI-mapped wetland acreages in the basin, and they are often not mapped or differentiated from larger riparian features in the basin.

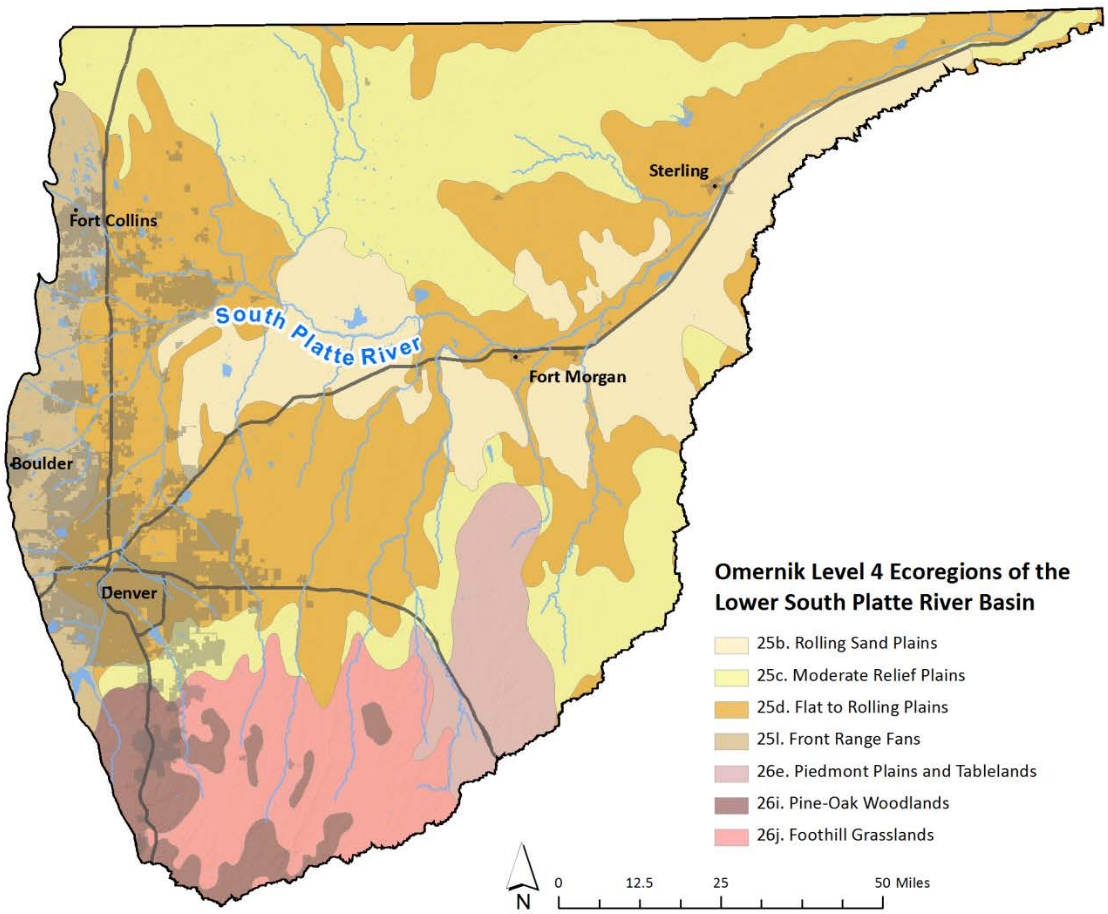


Figure 3. The Lower South Platte River Basin study area boundary.

2.3 Geology and Soils

Much of the basin east of the foothills is part of the Colorado Piedmont, a large gentle depressional basin worn by wind and rivers and underlain by shale. In the western and central Piedmont is the

Denver Basin, comprised of various layers of stacked aquifers separated by confining layers that stretch towards the east part of the study area and end partway through Morgan County (CDWR 2014). The very northern and eastern portions of the basin give rise to the High Plains, separated by an escarpment and by still having the Tertiary mantle that eroded from the Colorado Piedmont. Underneath the High Plains and west of the Denver Basin's aquifers lies the western edge of the large Ogallala aquifer that spans from Nebraska to Texas. The very western portions of the study area transition to sedimentary foothills and hogback ridges. The sandy and loamy soils underneath the South Platte's floodplain and its southern tributaries also form a surface alluvial aquifer, formed by glacial outwash closer to the Rocky Mountains that moved east from stream processes and flood deposition. A large percentage of the surface soil in the plains, particularly near and south of the South Platte River, originated from historic dunes or other wind-blown sources. North of the river, soils have high calcium carbonate content and are higher in percent clay.

2.4 Climate

The climate of the Lower South Platte basin is characterized by cold Colorado winters with average daily minimum temperatures 10–15°F and hot summers with average daily maximum summer temperatures >85 °F (WRCC 2014, 30-yr averages). During the 2012 and 2013 summer field seasons, daily highs exceeding 100°F were not uncommon. The Colorado plains are situated in the rainshadow of the Rocky Mountains, producing a semi-arid climate and vegetation communities tolerant of drought. Precipitation events in the plains are often short duration, very localized, and with high intensity sporadic events contributing much of the annual rainfall in this region (Lauenroth and Burke 2008). The central portions of Weld and Morgan counties receive the lowest precipitation (12–14 inches/year), and the eastern portions up the study area receive up to 20 in./year. The western-most study area receives more precipitation associated with the mountains, up to 24 in./year (WRCC 2014). Evaporation rates throughout the plains are high and are exacerbated by frequently windy conditions.

2.5 Hydrology

Prior to European settlement, the South Platte River used to be a mile wide and an inch deep, characterized by heavy spring pulses and floods, and by early summer the river would dry down. Tributary rivers to the South Platte historically flooded more frequently and with more energy than they do presently. Today, the river still has heavier flow in the spring, timed with the mountain snowmelt, but the channel is no longer braided, and moves much less water in the spring. Large reservoirs, numerous groundwater wells, extensive ditch networks, and intensive water management law account for every drop of water at times during the summer. Still, in many years, there are periods of time with no call on the river. Today, the channel continues to flow through the summer, due to extensive hydrologic alterations throughout the basin.

The changes in the timing and flow rates of the South Platte River are the result of complex interactions between human alterations and land use: the role of water laws ranging from interstate compacts to individual appropriation law and augmentation rights; to the effects of climatic fluctuations and change. These social, political, and environmental dynamics are closely intertwined, and have shaped water management of the South Platte basin. As a result, water availability in the basin for humans is so different from a natural state, it is difficult to tease out what the state of the river would be before the influence of the heavy human use that exists today. Instead we briefly outline the history of water usage in the basin to describe its dynamic nature and to help elucidate how the existing condition of water availability in the basin is influenced by human management.

As early as the 1860's, new settlers dug small irrigation ditches along the South Platte, and over the next 30 years continued to expand more ditches into a network further and further from the river. Prior Appropriation became law in 1876, meaning that the most senior water rights get the priority call on the river. In the 1880's, impoundments, transbasin diversions, and irrigation well construction redistributed the seasonality of river flow. Return flow from irrigation seepage had an additive impact on river levels, which no longer drew down completely later in summer. Combined with construction of reservoirs in the 1900's, irrigation and impoundment seepage raised the water table in lowlands and uplands adjacent to the floodplain. In the meantime, in 1923, Colorado and Nebraska created the interstate "South Platte River Compact" setting a minimum amount of river flow from Colorado to Nebraska, and prohibiting withdrawals that interfere with that minimum flow. Groundwater well expansion multiplied as settlement populations grew, especially during droughty times in the 1930's and 1950's. Wells were now extracting enough water to offset the once higher water table from seepage in regions. In 1969, a law was passed that required water users wells to replace any lost water, including groundwater, to senior users following augmentation plans. In more recent years, a system was developed using recharge ponds as an augmentation plan option to recharge the groundwater to more senior water users so less senior users could irrigate their land. Aside from recharge purposes, some landowners have managed their recharge ponds for the second goal to provide wetland wildlife habitat.

In addition to influencing wetland wildlife habitat, the many years of hydrology management throughout the basin has influenced the potential wetland vegetation along the river corridor. Some theorize that woody riparian vegetation (cottonwood galleries in particular) did not populate the floodplain until the water table was raised due to irrigation return flow. Another hypothesis on woody persistence today along the floodplain is that the managed river carried less water and floods had less energy, reducing the braided network of channels that change position with flood events, to one main channel. As the channel hardened and less frequently flooded the entire floodplain zone, the surrounding floodplain became more hospitable to tree establishment after less frequent flood events (Wohl 2013). Regardless, the South Platte floodplain used to be much more dynamic and subject to more extensive and frequent flooding, so while we don't know how the wetlands and riparian vegetation communities were expressed on the floodplain in those conditions, they were likely much different than today.

Less study has been done on the intermittent and ephemeral tributaries to the South Platte. The hydrology of these ecosystems is inherently more dynamic and locally variable. Land use and water accounting is less intensive off of the South Platte River, but perennial flow is not as common except in the western-most tributaries, so water diversions and impoundments may have a larger proportional impact on the existing available water. Many of these impoundments created functional wetlands and ponds for human and agricultural water supply in wetter years, but with recent drought in the 2000's, some of these impoundments have become non-functional at holding water, while they still prevent flow past their berms downstream.

2.6 Land Ownership and Land Use

Historically, nomadic Native Americans utilized the South Platte Basin's plains for hunting and seasonal living for at least hundreds of years. By the early 1800's, permanent settlements in the basin were made by trappers and explorers, often coexisting with Native Americans. Once gold was discovered in the mountains to the east in the 1860's, settlers were often travelling via the Overland Trail along the South Platte River, and the river valley became populated.

The basin encompasses a large area land area and a wide variety of land uses. The majority of the human population in the basin is located in the Front Range Corridor from the state line to southern Douglas County, and the high concentration of people in this region causes urban impacts on the landscape and its water resources. For instance, up to 100% of the South Platte River flow downstream of Denver is wastewater in some areas (Dennehy et al. 1998). The majority of the land area, however, is rural and agricultural. Ranching is the most widespread land use across all land area, but many other common land uses range from dry-land farming (mostly wheat), to irrigated farming (corn is one of the primary crops), energy (oil/gas) extraction, wildlife areas for recreation and habitat (hunting and fishing), and urban and suburban development.

Most of the basin is privately owned, and public parcels are patchy and often owned by the state land board and leased to private individuals or entities (Figure 4). The largest contiguous parcels of public lands are owned by CPW as state wildlife areas along the South Platte River or state parks around reservoirs; or are on the Pawnee National Grassland, owned by the USDA USFS. There are also numerous public lands along the Front Range owned by city and county lands. Along with most of the private land not already used for agriculture, most of the public lands are grazed with livestock.

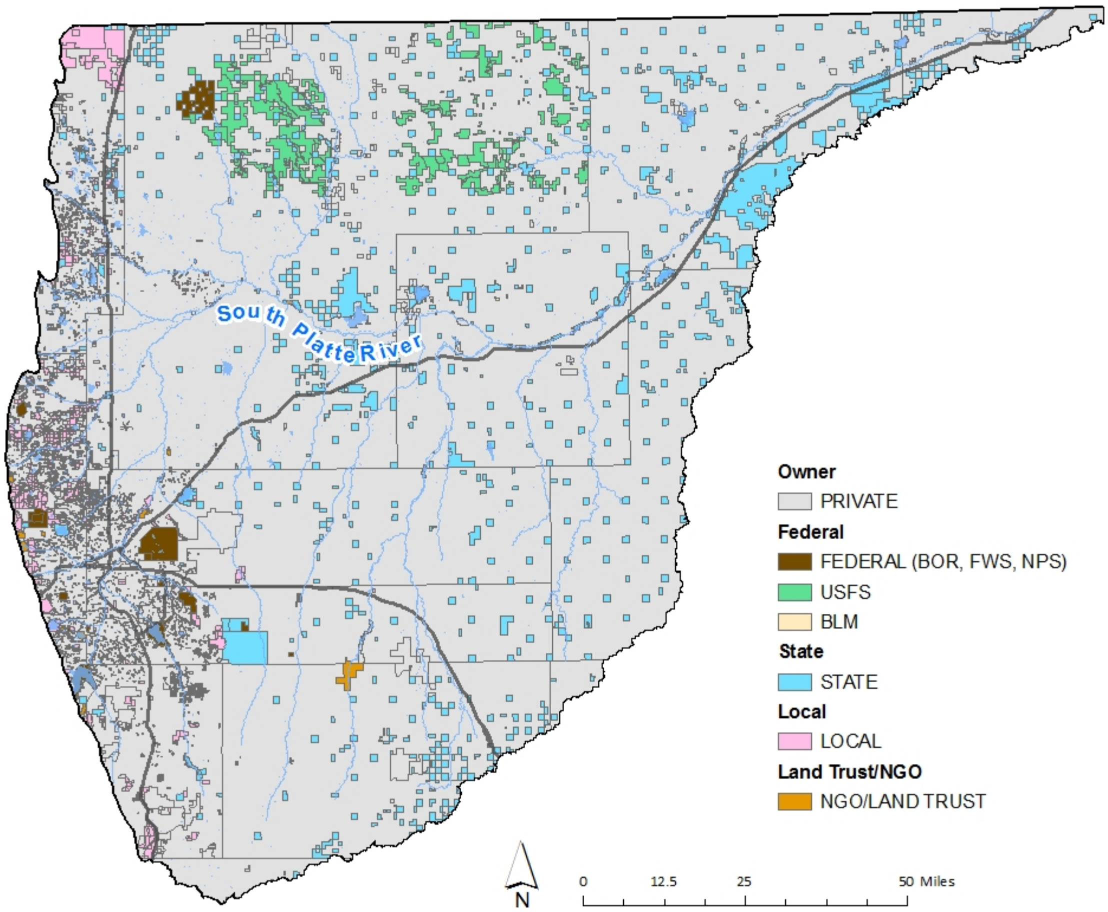


Figure 4. Land ownership in the Lower South Platte River Basin.

3.0 Methods

3.1 Wetland Mapping and Accuracy Assessment

To quantify the extent and distribution of wetlands in the Lower South Platte basin, a digital map of wetlands was created by converting original NWI paper maps into digital polygonal data and assessing the accuracy of those data.

3.1.1 Conversion of Original NWI Paper Maps to Digital Data

The geographic scope of the digital conversion included all 193 U.S. Geologic Survey (USGS) quads within the study area that lacked digital data in the NWI national dataset at the start of the project (Figure 4). For each quad, scans of original NWI paper maps were converted to digital data following CNHP's wetland mapping procedures (Appendix B) and adhering to the federal wetland mapping standard (FGDC 2009), to the extent possible. Wetland mapping data were not updated or corrected in this process, except in cases where the original code was considered invalid. The purpose of the digital conversion was to convert a large quantity of hard copy data into digital polygons in an efficient and cost effective manner. All newly converted digital data were submitted to the NWI program for incorporation into the national dataset.

To create a seamless data layer of wetlands throughout the study area, the newly converted NWI mapping was merged with NWI mapping already in a digital format (primarily along the Front Range corridor). Mapping in quads along the edge of the study area were clipped to the study area boundary. This clipped dataset was used for all other tasks within the project and was the basis of determining the extent of wetlands in the basin.

3.1.2 Accuracy Assessment of NWI Mapped Wetlands

To assess the accuracy of the NWI maps, a random selection of points were compared to independent photo interpretation of current aerial imagery. Accuracy assessment points were selected through a Generalized Random Tessellation Stratified (GRTS) sample design executed using the 'spsurvey' package in R version 2.14.0 (R Foundation for Statistical Computing 2011). A set of 1200 accuracy assessment points were distributed across the entire study area, spanning quads that converted to digital data through this project and quads that were already in a digital format. The total number of 1200 points was selected as a target that would provide effective coverage of the major mapping classes, but could be examined within a reasonable amount of time.

Accuracy assessment points were allocated between mapping classes (NWI System and Class combinations) using unequal probability selection criteria based on their relative abundance (Table 2). Of the 17 individual NWI mapping classes within the study area, a subset of the classes represented a majority of the mapped area. For map classes that represent <1% of the mapped wetlands, 20 points were evaluated. For map classes that represent 1–10% of the mapped wetlands, 50 points were evaluated. For map classes that represent >10% of the wetland mapping, 150 points were evaluated. The remaining 190 points were distributed across area mapped as uplands in order to determine if major wetland areas were missed in the NWI mapping.

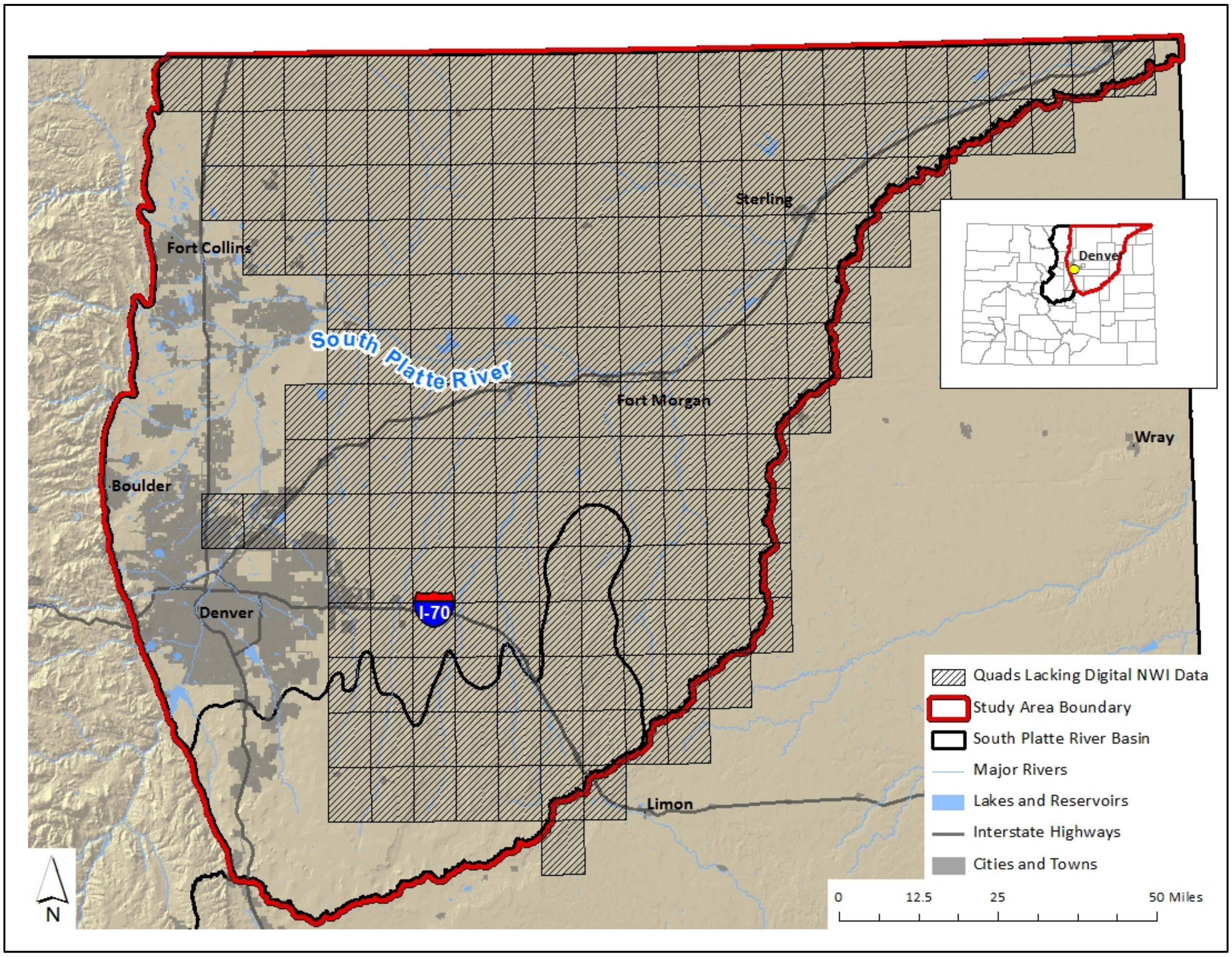


Figure 5. Quads lacking digital NWI data in the Lower South Platte Basin study area.

Each of the selected accuracy assessment points was examined using multiple data sources and assigned a NWI code based on interpretation of current information. The accuracy assessment evaluation and coding was done independent of the original code, meaning the interpreter did not know what original code was assigned to the accuracy assessment point. The primary data source used for the accuracy assessment evaluation was the most recent digital aerial photography available from the U.S. Department of Agriculture (USDA)'s National Agricultural Imagery Program (NAIP). For all areas of the Lower South Platte Basin, the most recent NAIP imagery is from summer 2011. In addition to the 2011 imagery, older NAIP image dates (2009 and 2005) was used to inform the classification, but the final classification was based on 2011 imagery. USGS topographic maps, soil survey data, hydrography data, land use data, and other ancillary data sources were also used to aid interpretation. Once all accuracy assessment points were classified, the independent classification was compared with the original classification. Results from the independent photo interpretation were summarized by into an error matrix that separated errors of omission, errors of commission, and overall accuracy following the method described in Congalton & Green (1999) and Lea & Curtis (2012).

Table 2. Allocation of accuracy assessment points among NWI mapping classes.

NWI System/Class	*NWI Acres*	*Percent of NWI Acres*	*Points*
Palustrine Wetlands			
PAB	1,150	0%	20
PEM	84,096	33%	150
Pf	4,801	2%	50
PFO	42,820	17%	150
PSS	8,972	4%	50
PUB	10,419	4%	50
PUS	6,123	2%	50
Lakes and Lakeshores			
L1UB	47,146	19%	150
L2AB	151	0%	20
L2UB	2,108	1%	20
L2US	2,002	1%	20
Rivers, Streams, Canals			
R2UB	11,173	4%	50
R2US	2,166	1%	20
R3UB	33	0%	20
R3US	17	0%	20
R4SB	29,000	11%	150
R4US	1,384	1%	20
Upland	NA	NA	190
Grand Total	253,561	100%	1200

3.2 Assessment of Wetland and Riparian Condition

The assessment of wetland and riparian condition was conducted in two separate phases: 1) sampling targeted, reference condition sites and 2) sampling randomly selected sites. For both phases, the sampling effort was divided between wetland and riparian areas in general, as mapped by NWI, and three priority wildlife habitat types: warm water slough, moist soil units, and recharge ponds. There were several reasons to devote specific sampling effort to these types.

- These three habitat types were identified as the most important habitat types within the study area over which land managers have considerable control.
- A significant portion of restoration and management dollars invested in the basin has been associated with these habitat types.
- Each of these habitat types represent a relatively small portion of the entire wetland and riparian resource and were not specifically identified by attributes of the sample frame (NWI mapping), meaning they would likely receive few sample points in the random draw.

- In addition, much of the work to restore or create these habitat types had taken place since the NWI mapping for the study area was originally created in the 1970s. Because of this, many occurrences of these types may not have been included in the sample frame.

Throughout this report, the sampling effort is described separately for reference and random sites and for general NWI-based sites and priority habitats.

3.2.1 Survey Design and Site Selection

The following paragraphs detail elements of the survey design for both the reference and random sample. Elements include the target population, sample size, sample frame, and selection criteria. The survey design follows principles outlined by the EPA's EMAP program (Stevens & Olsen 2004; Detenbeck et al. 2005).

Target Population

In general, the target population for both phases was all vegetated wetland and riparian areas mapped by the USFWS's NWI Program within the Lower South Platte River Basin. The target population did not include deep water lakes or stream channels, though we report out the acreage of these features. A minimum size criterion of 0.1 hectares was also implemented. For safety reasons, we excluded areas with water > 1 m deep from field sampling.

In past basinwide wetland condition assessments, the target population has been restricted to wetlands and did not incorporate non-wetland riparian areas (Lemly et al. 2011; Lemly & Gilligan 2012). Preliminary fieldwork in the Lower South Platte Basin revealed that the original NWI mapping included significant areas that would today be considered riparian areas and not wetlands. This was particularly the case along the floodplain of the South Platte River itself, but also along many smaller tributaries. The results from the accuracy assessment of NWI mapping (Section 4.2) further substantiate this early conclusion.

There was no way to systematically remove the non-wetland riparian areas from the sample frame for phase 2 (the random sample). In many instances, small scale herbaceous wetlands were imbedded within large polygons mapped by NWI as forested wetlands, but which were primarily dry cottonwood galleries. The actual wetlands were not consistently attributed and did not correspond with any other GIS data source available. Screening via desktop image analysis or in-field reconnaissance would have been both time consuming and would have resulted in many dropped sample points, which would have reduced the confidence of our estimates. In addition, riverine ecosystems in the Great Plains can intergrade between zones of wetland, riparian area, and stream channel/sandbar in a mosaic-fashion, without abrupt changes in ecosystem process. The entire wetland/riparian/channel mosaic functions as a unit to deliver important ecosystem services. For these reasons, all areas that matched either USFWS definition were evaluated for both reference and random sites. In our final analysis, we specifically note the proportion of our study points that were wetlands vs. riparian areas.

The operational definitions used in this project were from the USFWS. The definition of wetlands is from Cowardin et al. (1979):

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

The definition of riparian areas is from USFWS (2009):

"Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermitted lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one of both of the following characteristics: 1) distinctively different vegetation species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland."

In order to determine when an area meets the wetland definition, standard wetland identification and delineation techniques were used, based on materials produced by the ACOE and NRCS, including the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region* (ACOE 2008) and the *Indicators of Hydric Soils in the United States* (NRCS 2010).

It is important to note that standard delineation techniques have been developed based on a different definition of wetland used by the ACOE and the EPA for regulatory purposes under Section 404 of the Federal Clean Water Act (ACOE 1987):

"[Wetlands are] those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

The primary difference between the USFWS and the ACOE definitions is that the ACOE definition requires positive identification of all three wetland parameters (hydrology, vegetation, and soils) while the USFWS definition requires only one to be present. In addition, the USFWS definition also includes non-vegetated areas and deep water habitats, which were excluded from this study.

Though the target population was expanded to include riparian areas and non-target attribute classes (lakes and stream channels) were removed, the remaining sample frame for the random sample still included non-target areas. Non-target areas included lands converted to non-riparian upland, areas now under development, or obvious map errors. Non-target areas were rejected through desktop review or on-site evaluation.

When sampling moist soil unit and recharge pond priority habitats, both as reference and random sites, the target population definitions above did not apply. Moist soil units and recharge ponds are both created features that hold water during certain times of the year, often in the spring or the fall and not always during the active vegetation growing season. As such, they do not always meet the definition of either wetland or riparian area, which largely depend on vegetative indicators or indicators of soil changes related to vegetation. For these habitats, the target population was based on their known mapped distribution (see Sample Frame below). If the habitat was mapped as a moist soil unit and/or recharge pond, was confirmed on the ground to be a moist soil unit and/or recharge pond by the land managers, met the size and water depth criteria articulated above, then the site was sampled, whether it was a wetland or not. The only reason for rejecting these sites, besides lack of access, was that some sites within the recharge pond sample frame were actually large reservoirs and bigger than the concept of the recharge pond habitat type.

Subpopulations

The target population was classified into subpopulations based on two different classification systems. The first was the Ecological Systems classification (Comer et al. 2003), which uses biotic and abiotic factors to classify repeated patterns on the landscape. We defined six main Ecological System groups based on one or more wetland and riparian Ecological Systems found in the basin (Table 3). A key to Ecological Systems in the Lower South Platte River Basin is presented in the field manual (Lemly & Gilligan 2013). The second classification system was wildlife habitat types (Table 4), as defined through the wildlife habitat research conducted in Objective 2 (see Appendix A, which includes definitions and a key to wildlife habitat types). There is not a one-to-one relationship between Ecological Systems and wildlife habitat types. In some instances, more than one habitat type may occur within one Ecological System..

Because elements within the sample frame (NWI polygons) are not attributed according to either the Ecological System classification or wildlife habitat types, these subpopulations were part of the survey design *a priori*. Individual estimates of condition were calculated *post hoc* for subpopulations where sufficient data were collected.

Table 3. Ecological System subpopulations of the Lower South Platte River Basin.

Subpopulation	***Ecological System(s)***
Foothills riparian	
	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
Plains riparian	
	Western Great Plains Riparian
Plains floodplain	
	Western Great Plains Floodplain
Playas	
	Western Great Plains Closed Depression Wetland
	Western Great Plains Saline Depression Wetland
Marshes	
	Western North American Emergent Marsh
Wet meadows	
	Irrigation Influenced Wet Meadows
	Rocky Mountain Alpine-Montane Wet Meadow
	Rocky Mountain Subalpine-Montane Fen

Table 4. Wildlife habitat types of the Lower South Platte Basin.

Wildlife Habitat Types	
Natural wetlands	*Impoundments and other human-created wetlands*
Beaver pond	Irrigation ditch
Emergent marsh	Gravel pit
Playa	Moist soil unit*
Riparian wetland – shrub-scrub	Recharge pond*
Riparian wetland – herbaceous plants	Reservoir
Sandbar	Sewage lagoon
Stream channel	Stock pond
Warm water slough*	Urban runoff pond
Wet meadow	

*Priority wildlife habitat types

Sample Size

For reference site sampling, the target sample size was 30–40 sites. Reference sites represented both Ecological System groups and the three priority wildlife habitat types (Table 5). A minimum of three points per class was targeted. For classes with higher variability, up to six or eight points were targeted. Though not a large number, three per class allowed us to understand the degree of variability within each class, but also ensured sampling the entire set of points within one field season (summer 2012) with a crew of two people. A handful of the reference sites were revisited during summer 2013 to assess inter-annual variability (see Section 5.0).

Table 5. Allocation of reference sites.

Ecological System Subpopulations and Habitat Types	***Points***
Foothills riparian	4
Plains riparian	5
Plains floodplain	6
Playas	8
Wet meadows (incl. fens)	3
Marshes (habitat types used as proxy)	NA
Warm water sloughs	3
Moist soil units	4
Recharge ponds	3
Grand Total	36

For the random sample, the target sample size was also divided between general condition sites and priority habitats. For general condition sites, 75 sample points were distributed randomly within the NWI mapping, with the goal of sampling at least 50 points. A sample size of 50 is recommended by EPA statisticians for use in large-scale assessments of aquatic resources, as it provides ~10% precision with 90-95% confidence.[5] The goal of the general random sample was to estimate condition of all wetland and riparian acres, not necessarily by wetland type, so the overall sample size of 50 was sufficient for this purpose. For priority habitat sites, 30 sample points were dedicated to the three types (10 to warm water sloughs and 20 between moist soil units and recharge ponds). Though ten sample points does not provide high precision for each habitat type, these points did provide a coarse estimate of condition and of the range of variability.

Sample Frame

For reference sampling, sites were selected by hand from any wetland, riparian area, or priority habitat in the study areas, regardless of NWI mapping, and were not drawn from a sample frame.

For general condition random sites, the sample frame was based on the digital version of NWI polygons converted from paper maps (see Section 3.1). From the NWI dataset, all polygons that represent deep water lakes and river/stream channels (NWI codes that begin with L or R) were eliminated. Because of extreme variation in the size of individual polygons, target sample points were selected from within any area of wetland mapping and not from polygon centroids. All estimates made during analysis are for wetland area, not percent or number of individual wetlands.

For priority habitat random sites, 30 sites were selected (10 warm water sloughs and 20 between moist soil units and recharge ponds). These habitats occur primarily along or near the floodplain of the South Platte River. Two separate sample frames were designed for the habitat types, one for warm water sloughs and one for moist soil units and recharge ponds. By using a separate sample frames for these types, he data collected in these sites could not be incorporated into the overall estimate of wetland condition, These sites were primarily used to assess habitat value. The sample frames for priority habitats were developed as follows.

Warm water sloughs: At the start of the project, there was no digital spatial representation of warm water sloughs for the study area. However, sloughs are specifically located within a narrow band along the South Platte River floodplain, from the confluence of the Cache la Poudre at the town of Greeley east to the state line. To approximate the coverage of these features, the most recent aerial photography of the floodplain corridor was scanned by a CNHP Wetland Mapping Specialist and as many warm water sloughs as possible were delineated (Figure 6). The goal was not to make a definitive map of these features, but a workable approximation from which we could select sample points. In addition to the photo interpretation, we conducted one aerial flyover of the South Platte floodplain during the winter of 2012–13. An important aspect of warm water sloughs is that they are not frozen during the coldest months of the year because they are fed from groundwater that maintains above freezing temperatures. By flying over the floodplain, we were able to verify that the delineated features were indeed warm water sloughs.

[5] Recommendations for sample designs available at: http://www.epa.gov/nheerl/arm/surdesignfaqs.htm.

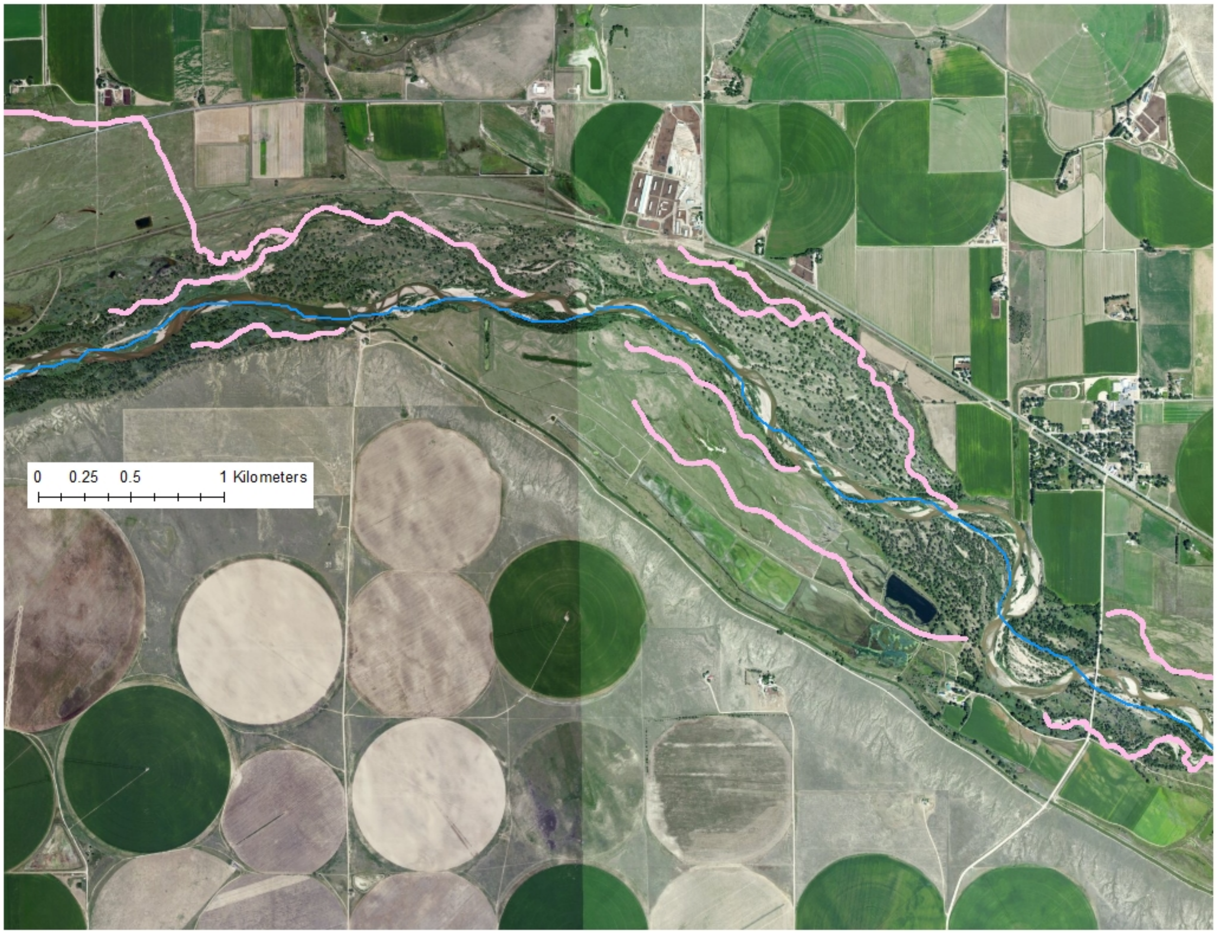


Figure 6. Example screen shot of the new warm water slough mapping used as a sample frame.

Moist soil units and recharge ponds (collectively called managed wetlands): Moist soil units represent wetlands that are actively managed for wildlife use. Water levels are closely controlled and desired plant populations are managed for with seeding and manual treatment. Recharge ponds are managed to hold water on the South Platte River floodplain and release it back to the river via groundwater recharge to augment base flows. They are filled in the fall and winter, when demand for irrigation water is low, but because the rate of transmission if slow, the water augments spring and summer flows, when demand for irrigation water is high. While these definitions describe two distinct management regimes, there are many wetlands along the Lower South Platte corridor that are managed for the dual benefit of wildlife and recharge, blurring the distinction between the two types. Because these two types represent two ends on a continuous gradient, we combined spatial data that depict these two types into one sample frame and sampled 20 points from this frame. A GIS shapefile of recharge ponds decreed by the Colorado Division of Water Resources (CDWR) was the base layer, which was supplemented with data on moist soil units compiled from land managers. The final target list included seven sites singularly managed as recharge ponds or moist soil units and six dual purpose sites.

Selection Criteria

For reference sampling, sites were hand selected based on consultations with wetland professionals within the basin and from examination of aerial photography. Sites were selected to represent the best available examples of each Ecological System group and each of the three priority wildlife habitat types.

For the general random sample, target points were selected through a GRTS survey design using the 'spsurvey' package in R version 2.14.0 (R Foundation for Statistical Computing 2011). The survey design selected 75 base sample points and a 200% oversample (150 points) using a one-stage, equal probability survey design stratified by Omernik Level 4 ecoregions. Stratifying the target sample points enforced a wider geographic distribution, which in turn targeted a more diverse array or wetland types. We considered using NWI classes as multidensity categories for unequal probability selection, but the NWI classes are not consistently applied across the study area and do not help achieve spread either geographically or between the subpopulations of interest.

The study area contains seven Level 4 ecoregions. Mapped wetland acres are not distributed evenly among the ecoregions, but heavily concentrated along the South Platte floodplain. To reduce the number of strata, the three Level 4 ecoregions within the Southwest Tablelands Level 3 ecoregion were combined into one stratum, as this far southern end of the study area contains few wetland acres. An even number of sample points was selected per stratum (Table 6). The initial distribution of sample points is illustrated in Figure 7. This map *does not* represent actual points sampled.

For the priority habitat random sample, target sample points were also selected based on GRTS survey design executed in R. The unstratified, equal probability survey design selected 10 or 20 base sample points and a 200% oversample (20 or 40 points) within the two separate sample frames.

Table 6. Potential distribution of sample points by Level 4 ecoregion.

Ecoregional Strata	*Target # of Sample Points*
25b. Rolling Sand Plains	15
25c. Moderate Relief Plains	15
25d. Flat to Rolling Plains	15
25l. Front Range Fans	15
26. Southwest Tablelands	15
Total	75

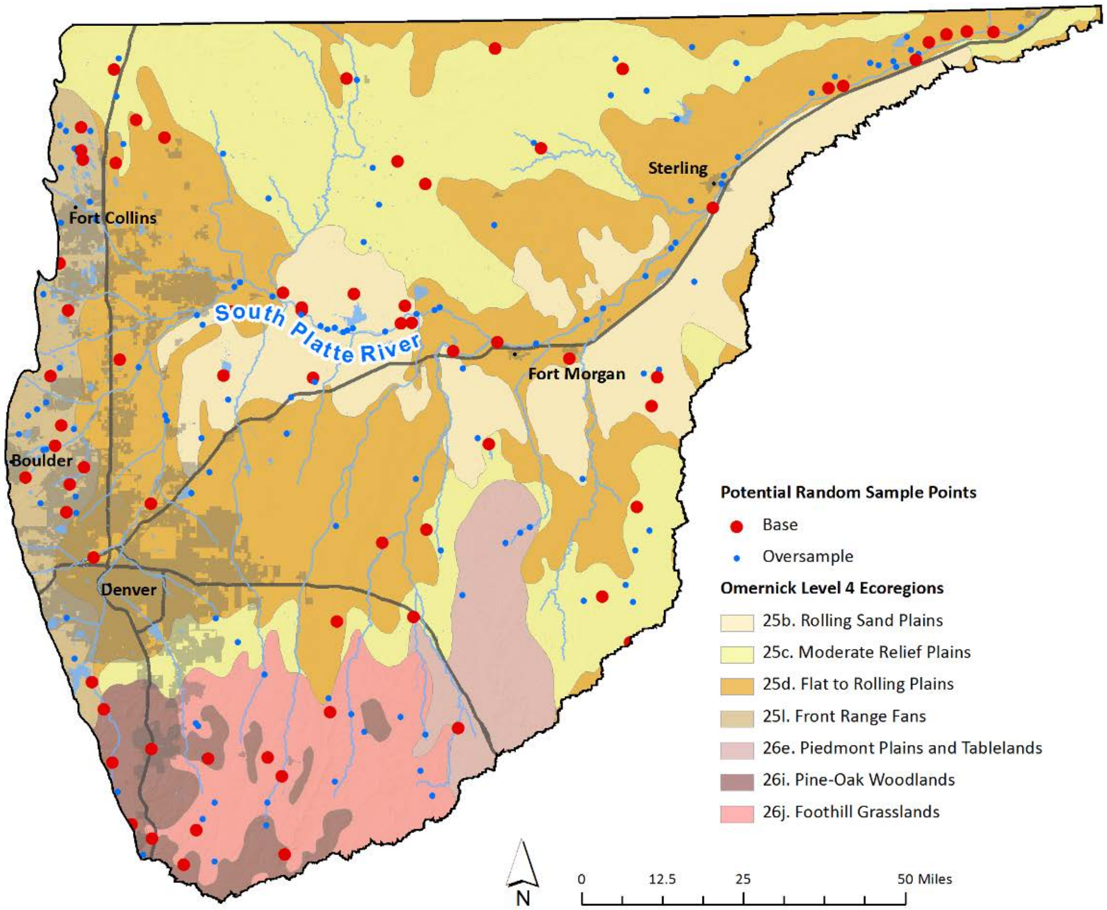


Figure 7. Omernik Level 4 ecoregions of the Lower South Platte River Basin and initial distribution of sample points by ecoregion. This map *does not* represent actual points sampled.

3.2.2 Field Methods

The basic field methods used for this project were developed at CNHP with previous EPA Region 8 funding and have been further refined through basinwide wetland condition assessments in the Rio Grande Headwaters basin (Lemly et al. 2011), North Platte River basin (Lemly and Gilligan 2012), and the northern Front Range (Lemly et al. 2013). Field protocols are based on the Ecological Integrity Assessment (EIA) framework (Faber-Langendoen et al. 2008, Lemly and Rocchio 2009a), which borrows from established wetland assessment methods such as the California Rapid Assessment Method for Wetlands (CWMW 2012) and the Ohio Rapid Assessment Method (Ohio EPA 2001). Data analysis also relies on the Floristic Quality Assessment for Colorado Wetlands (Rocchio 2007).

In approximately 30% of sample sites, the EIA method were carried out with intensive data collection methods, commonly referred to as Level 3 (see Section 1.2.1). At this level, vegetation data were collected using a modification of vegetation protocols from EPA's 2011 National Wetland

Condition Assessment (NWCA; EPA 2011). At the remaining sites, vegetation data were collected using more rapid field methods. Each method is explained in detail below. See Appendix C for a copy of the field form. The full field manual is available upon request (Lemly & Gilligan 2013).

Site Evaluation

Field data collection relies on the identification and establishment of an assessment area (AA) within the target population. In order to establish an AA, field crews first verified that each sample point met the target population and size and water depth criteria. For reference sites, sample points were hand selected; therefore, crews could establish the AA in any portion of the selected wetland, or even a neighboring wetland, provided it met the target population and appeared to be in good condition. They were not constrained by a certain distance from the initial waypoint. For random sites, crews were constrained to 60 m of the provided sample point. If an AA could not be established, it was dropped from the study.

Defining the Wetland Assessment Area

The assessment area (AA) is the boundary of the wetland (or portion of the wetland) targeted for sampling and analysis. At each sample point determined to meet the target population, an AA was defined as all wetland or riparian area of the same Ecological System type (or priority habitat type) in a 0.1–0.5 ha area surrounding the target point. Where possible, the AA was delineated as a 40-m radius circle around the point. However, the size and shape of the AA varied depending on site conditions. Prior to field visits, a set of two field maps was made for each targeted sample point. The field maps outline the potential AA boundary (40-m radius from the sample point), and a 100-m and 1-km buffer around the AA.

Once at the target sample point, field crew members will determine the appropriate dimensions of the AA. This determination was made by first estimating the approximate boundaries of the wetland or riparian area within the potential AA. Readily observable ecological criteria such as vegetation, soil, and hydrological characteristics were used to define wetland boundaries, regardless of whether they met jurisdictional criteria for wetlands regulated under the Clean Water Act. In general, protocols for establishing the AA in this project closely matched those developed for the EPA's NWCA. Extensive details on AA establishment can be found in the *2011 National Wetland Condition Assessment Field Operations Manual* (EPA 2011). The most significant difference between protocols from the NWCA and the Lower South Platte project is that the target population for this project includes non-wetland riparian areas, as mapped in NWI, and priority habitat types. Secondarily, crews in this project delineated Ecological System boundaries and adjusted the AA accordingly.

Classification and Description of the AA

Once the AA was established, standard site variables were collected from each sample location. This includes:

- UTM coordinates at four locations around the AA
- Elevation, slope, and aspect
- Place name, county, and land ownership
- Ecological System classification (Comer et al. 2003)
- Cowardin classification (Cowardin et al. 1979)

- HGM classification (Brinson 1993)
- Vegetation zones within the AA
- Wildlife habitats within the AA
- Description of onsite and adjacent ecological processes and land use
- Description of general site characteristics and a site drawing
- Several photographs of the AA boundary, vegetation modules, soil pits, and any notable features.

Vegetation Data Collection – Level 3

If the target sample point was selected for intensive Level 3 sampling, a sampling plot was used to collect vegetation data. In past basinwide assessments, we used a modification of the Flexible Plot or Carolina Vegetation Survey (CVS) method (Peet et al. 1998). Starting in 2012, we moved to the vegetation protocols developed for EPA's NWCA. This change was made to be more consistent with data collected around the country and to reduce subjectivity in plot placement. The NWCA method is just as flexible as the CVS method; crews are still able to adapt the plot layout to best fit within the AA. However, the NWCA method is less subjective and includes more guidance on how to lay out the plot in a variety of situation.

A fully documented description of the NWCA vegetation protocols can be found in the *2011 National Wetland Condition Assessment Field Operations Manual* (EPA 2011). A brief description is included here for reference. Several modifications to the protocols have been made for this project in the interest of time; those are also described here. The NWCA field protocol was developed for a crew of four people to carry out in one full field day. The crews for this project were two people, so protocols were pared down to fit the field day.

The standard arrangement of the vegetation plot was five 100 m^2 modules[6] distributed adjacent to four plot placement lines established along the cardinal axes (Figure 8). Modules were laid out to the left of the plot placement lines when facing from the AA center to the outer edge. Modules were numbered 1 through 5, beginning with the module closest to the center and radiating out in a clockwise direction from south to east, according to the following guidelines:

- To avoid the trampled area at the AA center, the Module 1 was located approximately 2 m from the AA center along the south plot placement line.
- Module 2 was located 10 m beyond Module 1, also along the south plot placement line.
- Module 3 was located 15 m from the AA center along the west plot placement line.
- Module 4 was located 15 m from the AA center along the north plot placement line.
- Module 5 was located 20 m from the AA center along the east plot placement line.

The standard vegetation plot layout could be modified in a number of different ways to best fit the AA. The *NWCA Field Operations Manual* has extensive detail on various alternative plot layouts. We followed all of the NWCA guidance in this project. The only difference was that, in the interest of time and to be consistent with our past vegetation protocols, we intensively sampled only four of

[6] In the *NWCA Field Operations Manual,* each module is referred to as a separate vegetation plot. We are using the term plot to refer to the entire vegetation sampling unit within an AA. We use the term module for the 100 m^2 sub-unit to be parallel with our past data collection protocols.

the five modules. Once all five were laid out, the field crew decided which modules to sample, prioritizing modules that included new species over modules that were similar to modules already sampled. The module that was not sampled intensively was considered the “residual” module. GPS waypoints and photographs were taken at the southeast-most corner of all five modules.

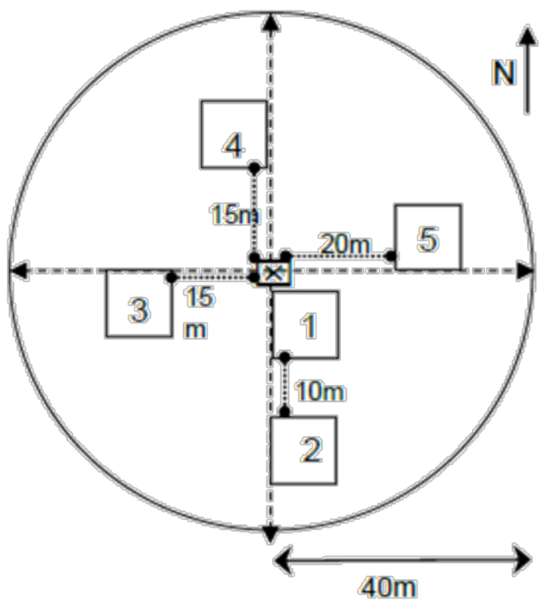


Figure 8. Schematic of the standard vegetation plot layout. Five subplots or modules are arranged along the cardinal axes.

Floristic measurements including presence/absence and abundance (i.e., cover) of all vascular plant species were made within the four selected modules using the field form in Appendix C. Within the NWCA protocol, presence/absence data is collected in a series of nested quadrats. For this project, presence/absence data was collected for the entire module instead of nested quadrats, again in the interest of time. However, sampling began in one 1-m^2 corner of the module to focus the field crew’s search. Once all species in that corner were identified, the crew moved throughout the entire module and noted all species encountered. Any unknown species were entered on the field form with a descriptive name and all unknown species were collected by the field crew to be identified later. Nomenclature for all plant species followed Weber and Wittmann (2012a, 2012b).

When all species within a module were identified, cover was visually estimated for the module using the following cover classes (Peet et al. 1998).

1 =	trace (one or two individuals)	6 =	>10–25%
2 =	0–1%	7 =	>25–50%
3 =	>1–2%	8 =	>50–75%
4 =	>2–5%	9 =	>75–95%
5 =	>5–10%	10 =	>95%

After sampling each of the intensive modules, the remaining (i.e. residual) module was walked to document presence of any species not recorded in the intensive modules. Percent cover of these species was estimated over the entire 500-m^2 vegetation plot. In addition to vascular species presence/absence and cover, several elements of ground cover as well as vertical vegetation strata were estimated for each module following the field form.

Vegetation Data Collection – Level 2

If the target sample point was selected for rapid Level 2 sampling, vegetation data were collected in a plotless sample design. All species present within the AA were identified and listed on the field form and the overall cover within the AA was visually estimated using the same cover classes as the Level 3 plots. The search for species was limited to no more than one hour to minimize the amount of time spent at the site. Several metrics were calculated from the species list (e.g., % non-native species, FQA indices, etc.).

Soil Profile Descriptions and Water Chemistry

At least two soil pits were dug within the AA. The pits were placed in or near vegetation plots, within vegetation types captured by the plot. If the vegetation and soil surface appeared relatively homogenous, only two pits were necessary. If there was variability within the vegetation and soil, up to four soil pits were dug to assess the dominant site soil type and capture the range of variation within the site. Among the pits dug, crews noted which was the most representative of the larger AA. Soil pits were dug with a 40-cm sharp shooter shovel to one shovel length depth (35 to 40 cm), when possible. A bucket auger was used to examine the soil deeper in the profile if needed to find hydric soil indicators. Because it is difficult to dig soil pits in areas with deep standing water, crews concentrated on areas near the water's edge if standing water is a significant part of the AA.

Following guidance in the *ACOE Regional Supplement* and the *NRCS Field Indicators of Hydric Soils in the United States* (NRCS 2010), crews identified and described each distinct layer in the soil pit. Crews measured and recorded the depth of each distinct layer. For each layer, the following information was recorded: 1) color (based on a Munsell Soil Color Chart) of the matrix and any redoximorphic concentrations (mottles and oxidized root channels) and depletions; 2) the soil texture; and 3) any specifics about the concentration of roots, the presence of gravel or cobble, or any usual features to the soil. Based on the characteristics, crew identified which, if any, hydric soil indicators occurred at the pit.

Water table measurements were recorded for each soil pit. Prior to taking measurements, the crew allowed the pit to sit at least 15 minutes and up to one hour to allow the water table to equilibrate. Once the pit equilibrated as much as possible, the crew measured the distance to saturated soil and to free water. Basic water chemistry parameters were measured at up to four locations in the AA, where water was accessible. At each location, the crew measured pH, conductivity, and temperature using a using a Hanna Instruments hand-held meter (Model # HI98129).

Ecological Integrity Assessment Metrics

For every sampled wetland, a Level 2 rapid EIA field form was filled out according to HGM Class and Ecological System. EIA metrics used in the South Platte River basin are shown in Table 7. Metric narrative ratings and scoring formulas are included in the field manual (Lemly and Gilligan 2013).

Table 7. EIA categories, attributes, and metrics used for the northern Front Range demonstration study.

Ecological Categories	*Key Ecological Attributes*	*Metrics*
Landscape Context	Landscape Connectivity	Landscape Fragmentation Riparian Corridor Continuity[1]
	Buffer	Buffer Extent Buffer Width Buffer Condition
Biotic Condition	Species Composition	Relative Cover Native Plant Species Absolute Cover Noxious Weeds Absolute Cover Aggressive Native Species Mean C
	Community Structure	Regeneration of Native Woody Species[2] Litter Accumulation Structural Complexity
Hydrologic Condition	Hydrology	Water Source Alteration to Hydroperiod Hydrologic Connectivity Bank Stability[1]
Physiochemical Condition	Physiochemistry	Water Quality – Turbidity / Pollutants Water Quality – Algal Growth Substrate / Soil Disturbance

[1] Metric recorded in Riverine HGM wetlands only.

[2] Only applied to sites where woody species are naturally common.

Wildlife Habitat Metrics

Based on literature reviews and expert interviewed conducted under Objective 2 of this project, a series of wildlife habitat metrics were developed for use in the field. See Appendix A for the final results of this research. The final two pages of the field form (Appendix C) include the wildlife habitat metrics collected for this project. These metrics were collected within each habitat type within the AA.

4.0 Results: Wetland Mapping and Accuracy Assessment

4.1 Wetland Mapping

Results of the complete digital wetland mapping of the Lower South Platte basin, including the extent of wetland acreage by NWI system/class, hydrologic regime, NWI modifier, irrigation, land ownership, and Level IV Ecoregions, provide a coarse quantification of wetland resources in the study area. The study area itself covers 8,417,519 acres. Original NWI mapping contained 253,611 acres of wetlands and water bodies, representing approximately 3% of the total land area (Figure 9; Table 7).

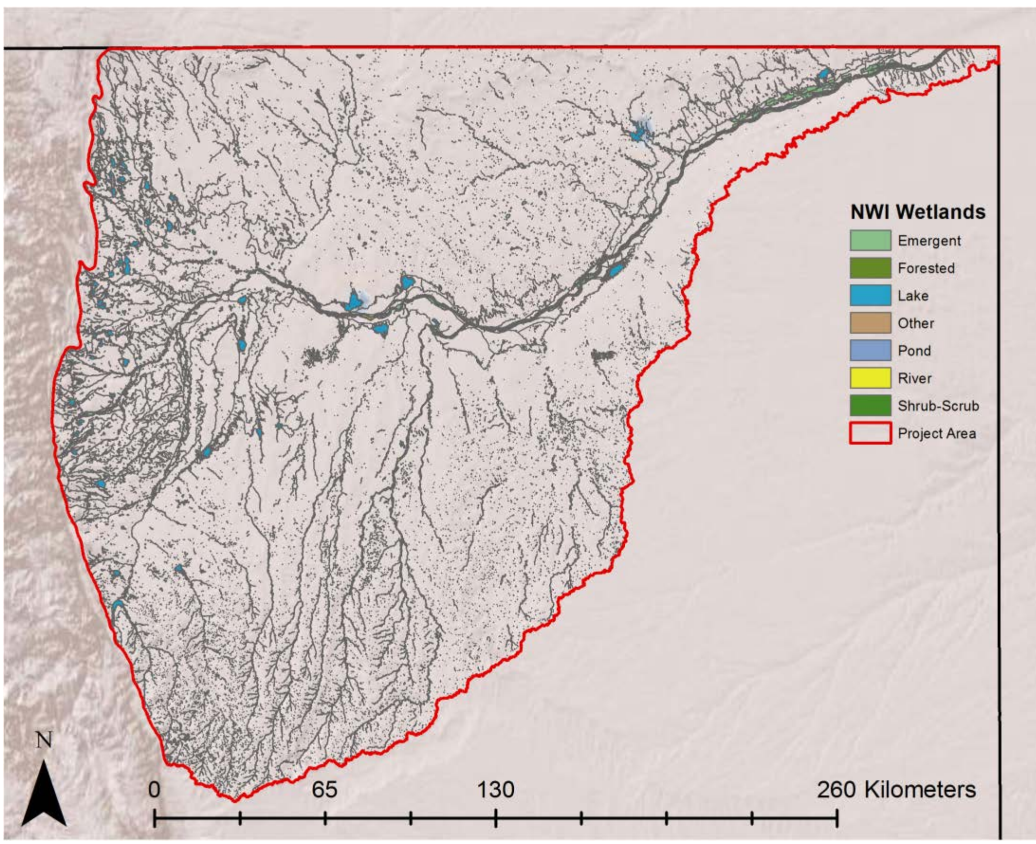


Figure 9. Digital NWI wetlands mapped in the South Platte in Colorado

4.1.1 Wetland Acres by NWI Group

Within the Lower South Platte basin of Colorado, herbaceous wetlands were overwhelmingly the largest mapped group at 84,138 acres, representing 33% of the total mapped features (Table 7; Figure 10). The second largest group was lakes, both natural and manmade, with 51,409 acres

(20% of all mapped NWI acres). Many of the lakes in the study area are artificially created reservoirs, primarily used for water storage. Rivers / streams / canals and forested wetlands each made up another 17% of mapped acres. Though the majority of the rivers in the area are within their natural channels, the 43,785 acres of river is artificially elevated due to the extensive network of artificially dug irrigation canals.

With lakes and rivers removed to specifically highlight wetlands, herbaceous wetlands accounted for 53% of wetlands, with forested wetlands making up 27%. Herbaceous wetlands primarily represent wet meadows (both natural and irrigated), marshes, and playas. The extensive acreage of forested wetlands mapped in the study area is a result of early mapping methods. As explained in the accuracy assessment (see Section 4.2), forested wetlands were overmapped by 350%. Most of the mapped acres are not true wetlands. Forested wetlands are not as common in Colorado as they are in other parts of the country, as our tree species are not adapted to large expanses of wet ground. Ponds made up 4% of the overall mapped area and 7% of the mapped wetlands specifically, which is higher than would be expected naturally due the creation of berms in drainages and artificially dug irrigation and stock ponds.

Table 8. NWI acreage mapped in Colorado's Lower South Platte basin.

NWI Group	*All Acres*	*% Wetlands and Water bodies*	*% Wetlands*
Herbaceous Wetlands	84,138	33%	53%
Shrub Wetlands	8,972	4%	6%
Forested Wetlands	42,862	17%	27%
Ponds	11,569	5%	7%
Other Wetlands	10,927	4%	7%
Total Wetlands (excl. Lakes & Rivers)	**158,468**	**62%**	**100%**
Lakes and Shores	51,409	20%	-
Rivers/Streams/Canals	43,785	17%	-
Total Wetlands & Waterbodies	**253,661**	**100%**	**NA**

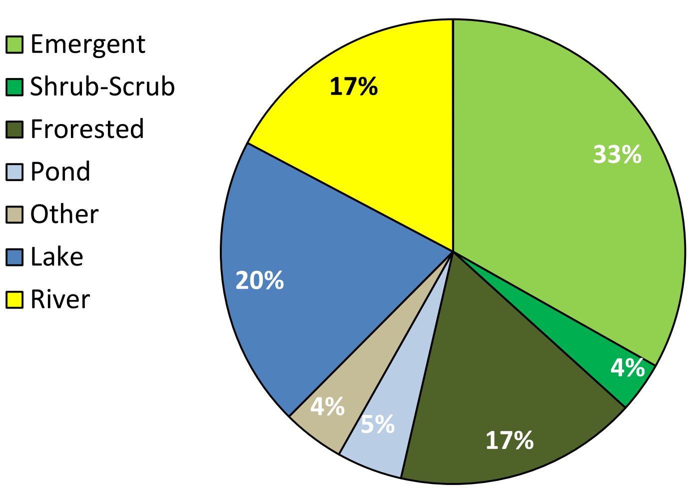


Figure 10. Percent of mapped NWI acres by group.

4.1.2 Wetland Acres by Hydrologic Regime

The most prevalent wetland hydrologic regimes of the NWI mapped acres were temporarily flooded (50%), seasonally flooded (19%), and permanently flooded (14%) (Table 8). Both temporarily flooded and seasonally flooded wetlands rely on overbank flooding from adjacent rivers and streams, accumulation of storm runoff in drainages, or flood irrigation to deliver water to the wetlands. These wetlands are only wet from a few weeks to a few months a year, and may be dry towards the end of the growing season. Permanently flooded wetlands were 14% of the total mapped area, but a negligible percent of mapped wetlands. Generally, the permanently flooded, intermittently exposed, and semi permanently flooded regimes are associated with waterbodies rather than wetlands.

Table 9. NWI Wetland and waterbody acreage mapped in the South Platte by hydrologic regime code.

NWI Code	*Hydrologic Regime*	*All NWI Acres*	*% All Acres*	*Wetland Acres Only*	*% Wetland Acres*
A	Temporarily Flooded	125,719	50%	101,906	64%
B	Saturated	680	0%	680	0%
C	Seasonally Flooded	46,995	19%	35,883	23%
F	Semipermanently Flooded	9,525	4%	9,137	6%
G	Intermittently Exposed	26,559	10%	3,439	2%
H	Permanently Flooded	36,723	14%	0	0%
J	Intermittently Flooded	2,576	1%	2,531	2%
None	No hydrologic regime (Pf)	4,883	2%	4,883	3%
Total		**253,661**	**100%**	**158,468**	**100%**

4.1.3 Wetland Acres by Extent Modified and Irrigated

The NWI classification includes several modifiers that describe alteration from human and beaver activity. The four modifications mapped in the South Platte boundary were: 1) excavated, 2) dammed and impounded, 3) beaver influenced, and 4) farmed. In total, only 5% of both total mapped acres and wetlands were modified (Table 9), however, modification was not distributed evenly. Of all NWI groups, the “other” group was the most modified, with 44% being farmed. These primarily represent small farmed playas on the plains. Twenty percent of ponds and 7% of lakes were modified by either excavation or impoundment. Rivers were primarily un-modified, with a small portion modified by excavation (1%) due to the creation of irrigation canals, though this is likely undermapped.

Though 95% of wetlands were not coded with a modifier for excavation, damming, or beavers, irrigation (not captured in the mapping attribution) has a large influence on wetlands in Colorado. Within the South Platte area, 5% of all mapped NWI features and 7% of mapped wetlands were located on irrigated lands. Herbaceous wetlands were the most common wetland type on irrigated lands, making up 11% of all mapped herbaceous wetlands and 70% of all irrigated wetlands. Pond wetlands accounted for 4% of all irrigated wetlands. Though ponds accounted for only 4% of irrigated wetlands, it is reasonable to assume that a large portion of the 20% modified ponds were created for irrigation and agricultural purposes.

Table 10. South Platte NWI Wetland and waterbody groups mapped by modifier and extent irrigated. All NWI acres shown, with totals for wetlands (excluding lakes and rivers) and all NWI acres.

Wetland Type	*No Modifier*		*Excavated*		*Dammed / Impounded*		*Beaver Influenced*		*Farmed*		*Irrigated Wetlands*[1]		
	Acres	*% of Class*	*Acres*	*% of Class*	*Acres*	*% of Class*	*Acres*	*% of Class*	*Acres*	*% of Class*	*Acres*	*% of Class*	*% of Irrigated Wetlands*
Herbaceous	82,501	99%	76	0%	402	0%	1	0%	27	0%	9,193	11%	85%
Shrub	8,308	97%	2	0%	298	3%	0	0%	0	0%	129	1%	1%
Forested	41,946	100%	6	0%	117	0%	0	0%	0	0%	733	2%	7%
Ponds	6,666	80%	1,297	11%	1,011	9%	1	0%	0	0%	479	4%	4%
Other	5,353	52%	88	1%	369	3%	0	0%	4,803	44%	309	3%	3%
Wetlands (excl. Lakes & Rivers)	**149,884**	**95%**	**1,470**	**1%**	**2,196**	**1%**	**2**	**0%**	**4,830**	**3%**	**10,844**	**7%**	**100%**
Lakes	47,518	92%	1,141	2%	2,749	5%	0	0%	0	0%	106	0%	-
Rivers/Streams/Canals	43,509	99%	276	1%	0	0%	0	0%	0	0%	2,093	5%	-
Wetlands & Waterbodies	**240,997**	**95%**	**2,887**	**1%**	**4,945**	**2%**	**2**	**0%**	**4,830**	**2%**	**13,043**	**5%**	**-**

[1] Irrigated lands from the Colorado Decision Support System (CDSS 2013).

4.1.4 Wetland Acres by Landownership

The distribution of wetlands by landowner highlights the importance of private lands for the wetland resources in the South Platte. Private lands make up 88% of the entire Lower South Platte basin in Colorado, and 80% of all NWI acres and 83% of wetlands were located on private land (Table 10; Figure 11). Very little of the South Platte basin is federally owned (3%), with the U.S. Forest Service owning 2% and the Bureau of Land Management and the U.S. Fish and Wildlife Service each owning less than one percent. The State of Colorado owns 6% of the study area, mostly managed by the State Land Board (SLB). Of those acres owned by the State, SLB lands were generally drier, with only 3% of both mapped NWI acres and wetlands. Lands managed by Colorado Parks and Wildlife (CPW), however, were proportionally much wetter. Though CPW manages less than one percent of the basin, they manage 7% of mapped wetlad acres, mostly on large State Wildlife Areas established for waterfowl habitat and recreational opportunities. Other ownership groups were small in both the percent of study area owned as well as mapped wetlands, though municipalities (cities, counties, join city/county ownership) own 6% of all mapped NWI acres and 4% of mapped wetlands.

Table 11. NWI Wetland and waterbody acreage mapped in the South Platte by grouped land owner.

Grouped Owner[1,2]	*Total Land Area within South Platte*		*Total NWI Acres within South Platte*		*Wetland Acres Only*	
	Acres	*% of South Platte*	*Acres*	*% of NWI Acres*	*Acres*	*% of Wetlands*
Federal Lands	**249,148**	**3%**	**6,039**	**2%**	**2,770**	**2%**
Bureau of Land Management	1,511	0%	597	0%	134	0%
Misc. Federal	35,162	0%	3,818	2%	1,233	1%
U.S. Fish and Wildlife Service	19,971	0%	618	0%	483	0%
U.S. Forest Service	192,504	2%	1,006	0%	919	1%
State Lands	**537,417**	**6%**	**24,795**	**10%**	**16,012**	**10%**
Colorado Parks and Wildlife	36,451	0%	17,736	7%	11,758	7%
State Land Board	499,523	6%	7,005	3%	4,221	3%
Misc. State	1,443	0%	54	0%	33	0%
Other						
Cities	115,467	1%	6,892	3%	4,145	3%
Counties	52,462	1%	3,500	1%	1,743	1%
Joint City / County	17,388	0%	5,262	2%	787	0%
Spec / Metro / School Districts	9,780	0%	2,536	1%	400	0%
Non-Govern. Organizations	13,089	0%	1,805	1%	423	0%
Private	7,422,713	88%	202,831	80%	132,188	83%
Total	**8,417,464**	**100%**	**253,661**	**100%**	**158,468**	**100%**

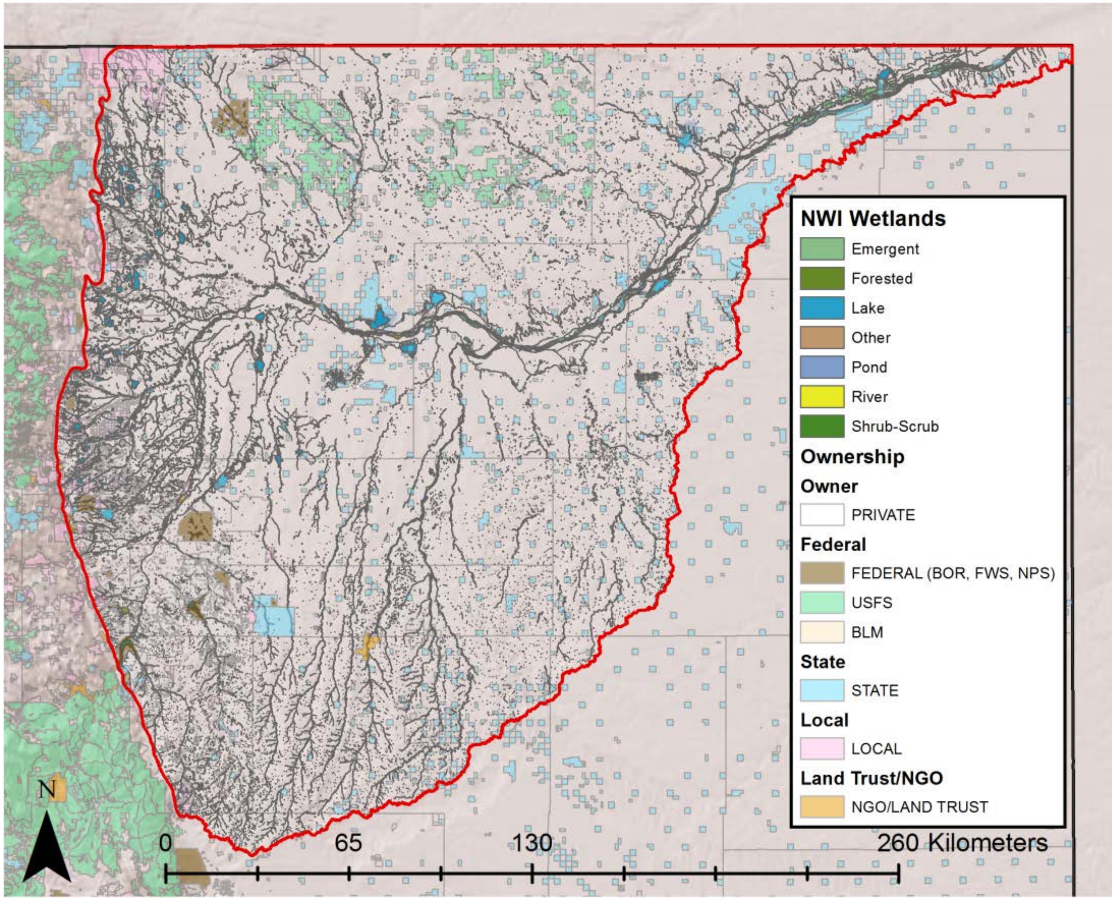


Figure 11. Wetlands and Land Ownership in the Lower South Platte Basin.

4.1.5 Wetland Acres by Ecoregion

Analyzing mapped wetlands by ecoregion shows the spatial distribution of wetlands within the Lower South Platte basin. The High Plains Level III Ecoregion had the most mapped NWI acres (90%), but this share is similar to the total amount of land area within the Ecoregion (84%) (Table 11). That more wetlands were mapped in the High Plains Ecoregion is expected, as it contains the South Platte River and its floodplains. Within the High Plains Ecoregion, herbaceous wetlands were primarily mapped in the Flat to Rolling Plain Level IV Ecoregion, which contains most of the South Platte floodplain. The High Plains Ecoregion contained 91% of all mapped forested wetlands, mostly in the Flat to Rolling Plains, though it is important to note that forested wetlands mapped throughout the study are may better fit within the new Riparian mapping system, if they were mapped with the updated classification system. Also of not, the High Plains Ecoregion included 100% of mapped lakes.

The Southwestern Tablelands Ecoregion is drier and has less NWI acres (10%) than its total land area (16%). This ecoregion contained 41% of mapped shrub acres, however. The Foothills Grasslands Level IV Ecoregion represents only 8% of the project area, but has 26% of shrub wetland acres, generally located along small creeks and drainages.

Table 12. Wetland acreage in South Platte by Level II / Level IV Ecoregion and NWI system / class.

Level III / IV Ecoregion	*South Platte Land Area*		*South Platte NWI Acres*		*Percent of South Platte Wetlands within Ecoregion by NWI System / Class*						
	Acres	*%*	*Acres*	*%*	*Herb*	*Shrub*	*Forest*	*Pond*	*Other*	*Lakes*	*Rivers*
25: High Plains	**7,030,133**	**84%**	**229,242**	**90%**	**94%**	**59%**	**91%**	**89%**	**83%**	**100%**	**81%**
25b: Rolling Sand Plains	1,207,764	14%	26,576	10%	11%	4%	10%	5%	6%	16%	8%
25c: Moderate Relief Plains	2,182,354	26%	19,805	8%	11%	8%	3%	6%	22%	2%	10%
25d: Flat to Rolling Plains	3,143,819	37%	144,454	57%	62%	41%	72%	53%	48%	43%	57%
25l: Front Range Fans	496,195	6%	38,406	15%	11%	6%	6%	25%	7%	40%	6%
26: Southwestern Tablelands	**1,378,356**	**16%**	**24,218**	**10%**	**6%**	**41%**	**9%**	**11%**	**17%**	**0%**	**19%**
26e: Piedmont Plains and Tablelands	393,985	5%	4,369	2%	1%	3%	3%	1%	5%	0%	1%
26i: Pine-Oak Woodlands	326,721	4%	5,194	2%	2%	11%	0%	4%	2%	0%	4%
26j: Foothill Grasslands	657,650	8%	14,655	6%	2%	26%	6%	7%	9%	0%	14%

4.2 Accuracy Assessment

To assess the accuracy of the digital NWI mapping, 1000 random points were selected throughout the study area. This assessment showed clear trends in the mapping that should be taken into account whenever these data are used. The accuracy assessment (AA) was conducted with two levels of precision. At the highest level of precision, only the NWI mapping class at the exact AA point was evaluated. At the second level of precision, the closest NWI mapping class within a 100 m buffer was evaluated. As the original mapping was created at a coarse scale, this allowed for some shifting of the original polygons. Many wetlands did fall just beyond the AA point and, in those cases, it was fairly clear that the mapping was accurately representing the wetland feature, but the polygon was not in the precise location. To take into account the instances when the mapping at the AA point was both accurate and precise *and* the instances when the mapping was accurate but not precise, the "buffer" analysis takes into account whether the point was correctly attributed either precisely at the point or within the buffer. This is the most conservative approach that gives the most benefit of the doubt to the original mapping.

Even with the buffer analysis, the overall accuracy of the map was only 46.8% (90% CI = 44.2–49.5%). Without the buffer analysis, the accuracy was a mere 32.9% (90% CI = 30.6–35.3%). The most significant source of discrepancy was within the forested wetland class (Table 12; Figure 12). Only 22% of forested wetland points evaluated in the AA were accurately mapped; this represents a 353% over-mapping of forested wetlands. The majority of incorrectly mapped forested wetlands were classified as Riparian forested or Riparian shrub (Rp1FO or Rp1SS) with the AA analysis. These represent the expansive dry cottonwood gallery forests of the South Platte floodplain. The Riparian mapping system was not in place at the time that the original mapping was created, but was developed to account for the importance of non-wetland riparian areas in the Western U.S. The original mapping likely incorporated the cottonwood galleries into the Palustrine Forested (PFO) class because they are clearly evident on the landscape, but, yet, do not actually meet the definition of wetland. Estimates based on the AA buffer analysis predict that there are fewer than 10,000 acres of actual forested wetlands in the basin (down from 42,839 acres), but there are 31,056 acres of non-wetland riparian habitat.

Herbaceous wetlands were also grossly overmapped in the original NWI mapping. The final estimate of herbaceous wetland acres based on the buffer analysis (38,012 acres) was less than half the original acreage mapped (84,133 acres; 121% overmapped). Nearly all of the incorrectly mapped herbaceous wetlands were classified as upland in the AA analysis. It is difficult to say if this is because the original NWI mapping was not accurate, or if there has been a systematic drying in the basin since the original mapping was created.

All but one of the AA classes evaluated in this analysis were overmapped, though lakes and rivers were more accurate than true wetland acres. The only AA class that was undermapped was ponds, slough, and playas, which included PAB, PUB, and PUS mapping classes. This AA class represented a diverse set of small scale wetland types that each represented too small an area to analyze separately. Many of these small scale wetlands were either incorporated in larger, generalized polygons in the original mapping or were missed all together.

The final estimate of wetland acres in the study area (not including waterbodies or riparian areas) is less than half the original mapped acreage, 75,243 acres instead of 158,458 acres. The magnitude of this difference strongly underscores the need for new, updated wetland mapping on the plains in order to use the data for any kind of management decision.

Table 13. Estimates of wetland and waterbody acres based on the AA analysis.

AA Category	Estimate of Acres			Difference between Buffer and Original	
	Original	AA Point	Buffer	Acres	% Change[1]
Herbaceous	84,133	28,944	38,012	-46,121	45%
Shrub	8,978	5,785	5,961	-3,018	66%
Forested	42,839	6,755	9,453	-33,386	22%
Farmed	4,804	1,952	2,312	-2,492	48%
Ponds/Sloughs/Playas	17,704	19,147	19,506	1,801	110%
Total Wetlands	**158,458**	**62,584**	**75,243**	**-83,215**	**47%**
Lakes	51,443	46,994	48,719	-2,724	95%
Rivers	43,798	24,816	34,728	-9,070	79%
Riparian	--	35,184	31,056	31,056	--
Total NWI (incl. Rip)	**253,661**	**169,577**	**189,746**	**-63,952**	**75%**
Upland Predicted	--	84,122	63,952	63,952	--

[1] The percent change represents the final estimate divided by the original, or the percent of the original that remains in that mapping class.

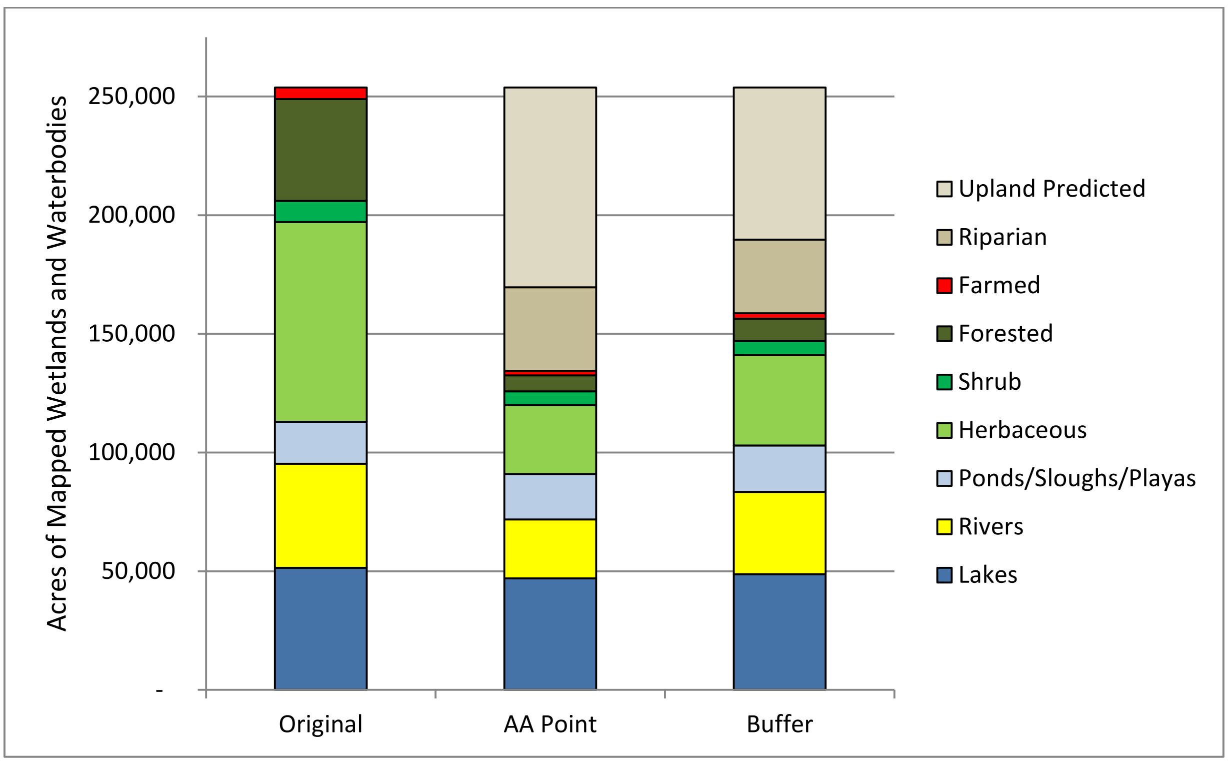


Figure 12. Estimates of wetland and waterbody acres based on the AA analysis.

5.0 RESULTS: ASSESSMENT OF WETLAND CONDITION

5.1 Level 1 Assessment of Wetland Condition

Results from the Level 1 Landscape Integrity Model (LIM) for the Lower South Platte basin show that although only 34% of the project area is severely stressed, 60% of wetlands in the project area fall into the severe stress category. A further indication of the seriousness of threats to wetland resources in this basin is that 0% of wetlands experience no stress and 7% experience low stress. (Table 13; Figure 13; Figure 14). Certain wetland types are more affected by modeled stressors than others. Most herbaceous and forested wetlands, which account for the largest shares of all wetlands, fall within higher stress classes. Nearly all ponds also fall into higher stress categories.

Modeled stress on wetlands also shows strong geographic patterns (Table 14). Wetlands in the High Plains Level III Ecoregion experience more stress than those in the Southwest Tablelands. Within the High Plains, landscape stressors are concentrated in both the Flat to Rolling Plains and the Front Range Fans Level IV Ecoregions. The Flat to Rolling Plains contains the South Platte floodplain and associated agricultural activity, while the Front Range Fans contains the major population centers of the Front Range, including portions of Denver, Boulder and Fort Collins.

Modeled stress is generally distributed similarly across land owners, with a few notable exceptions (Table 15). Wetlands owned by municipalities face high stress, as these wetlands are located in or around urban development. Wetlands owned by the U.S. Forest Service experience proportionally lower modeled stress. Most of these wetlands are within the Pawnee National Grassland, a large undeveloped stretch of the plains. One major stressor not accounted for in the model, however, is grazing. Many areas of the Pawnee are grazed and the level of stress on these wetlands would be higher if grazing was taken into account.

Table 14. Wetland LIM stressor class for wetlands by major wetland type. Percentages are given for NWI mapped acres in all cases except the bottom row, which shows stressor classes for all area within the basin.

NWI Group	***1: No Stress***	***2: Low Stress***	***3: Moderate Stress***	***4: High Stress***	***5: Severe Stress***
Herbaceous Wetlands	0%	9%	12%	18%	61%
Shrub Wetlands	0%	6%	18%	29%	46%
Forested Wetlands	0%	4%	12%	21%	63%
Ponds	0%	5%	8%	11%	76%
Other Wetlands	1%	13%	22%	28%	36%
Total Wetlands (excl. Lakes & Rivers)	**0%**	**7%**	**13%**	**20%**	**60%**
Lakes and Shores	2%	26%	17%	17%	39%
Rivers/Streams/Canals	0%	8%	18%	21%	53%
Total Wetlands & Waterbodies	**1%**	**11%**	**14%**	**19%**	**55%**
Entire South Platte Basin	**2%**	**24%**	**21%**	**19%**	**34%**

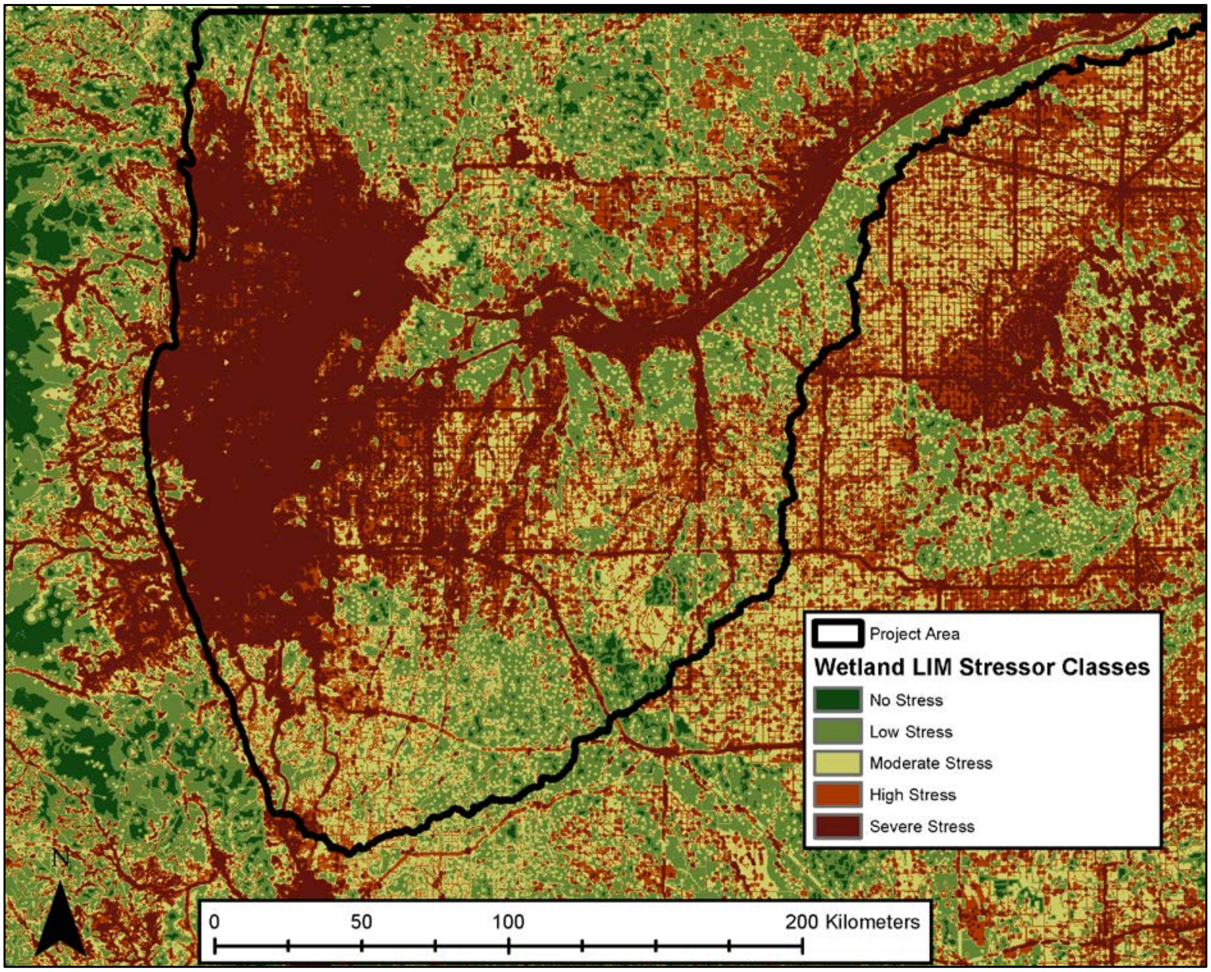


Figure 13. Map of Wetland LIM stressor classes across the North Platte River Basin

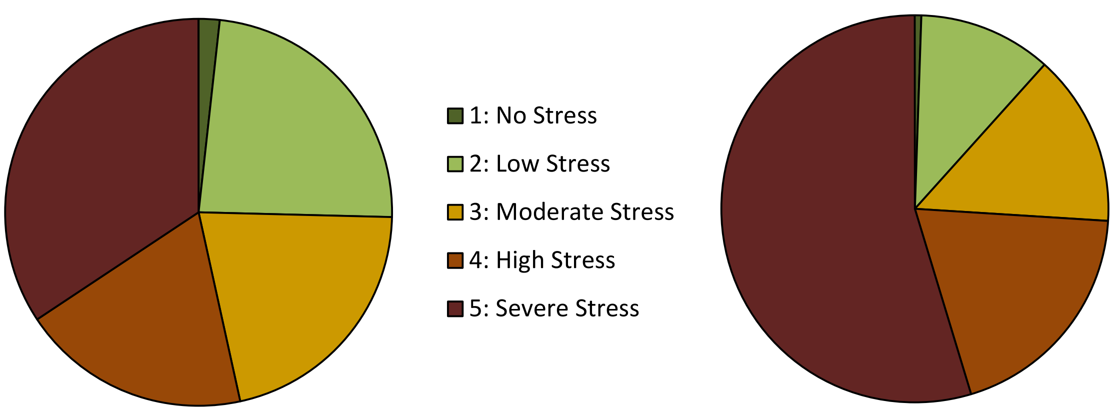


Figure 14. Comparison of LIM stressor classes for the entire South Platte River Basin (left) and all NWI acres within the basin (right).

Table 15. Wetland LIM stressor class for wetlands by ecoregion. Percentages are given for NWI mapped acres in all cases except the bottom row, which shows stressor classes for all area within the basin.

Level III / IV Ecoregion	*1: No Stress*	*2: Low Stress*	*3: Moderate Stress*	*4: High Stress*	*5: Severe Stress*
25: High Plains	**1%**	**11%**	**12%**	**18%**	**58%**
25b: Rolling Sand Plains	2%	28%	17%	17%	35%
25c: Moderate Relief Plains	2%	31%	26%	21%	20%
25d: Flat to Rolling Plains	0%	7%	10%	19%	64%
25l: Front Range Fans	0%	3%	9%	16%	71%
26: Southwestern Tablelands	**0%**	**15%**	**33%**	**30%**	**22%**
26e: Piedmont Plains and Tablelands	1%	16%	29%	27%	26%
26i: Pine-Oak Woodlands	0%	8%	27%	32%	33%
26j: Foothill Grasslands	0%	17%	36%	30%	16%
All Wetlands and Waterbodies	**1%**	**11%**	**14%**	**19%**	**55%**
Entire South Platte Basin	**2%**	**24%**	**21%**	**19%**	**34%**

Table 16. Wetland LIM stressor class for wetlands by major landowner. Percentages are given for NWI mapped acres in all cases except the bottom row, which shows stressor classes for all area within the basin.

Grouped Owner[1,2]	*1: No Stress*	*2: Low Stress*	*3: Moderate Stress*	*4: High Stress*	*5: Severe Stress*
Federal Lands	**1%**	**18%**	**21%**	**26%**	**34%**
Bureau of Land Management	1%	25%	25%	28%	21%
Misc. Federal	0%	11%	20%	27%	42%
U.S. Fish and Wildlife Service	0%	3%	9%	44%	44%
U.S. Forest Service	5%	54%	30%	8%	4%
State Lands	**2%**	**19%**	**18%**	**23%**	**39%**
Colorado Parks and Wildlife	2%	16%	15%	24%	43%
State Land Board	1%	27%	23%	20%	27%
Misc. State	0%	0%	0%	3%	97%
Other					
Cities	1%	7%	4%	4%	84%
Counties	0%	3%	12%	13%	72%
Joint City / County	0%	28%	22%	17%	32%
Spec / Metro / School Districts	0%	4%	12%	19%	65%
Non-Govern. Organizations	0%	9%	27%	21%	43%
Private	0%	10%	14%	19%	57%
Total	**1%**	**11%**	**14%**	**19%**	**55%**
Entire South Platte Basin	**2%**	**24%**	**21%**	**19%**	**34%**

5.2 Level 2/3 Assessment: Characterization of Sampled Wetlands

5.2.1 Implementation of the Survey Design

During the summers of 2012 and 2013, 122 wetland, riparian, and non-wetland priority habitat sites were sampled to assess the condition and habitat value of mapped wetlands in the Lower South Platte Basin. Twelve sites were revisited once or twice during these years to detect variability in site conditions and habitat values of the more dynamic site types across seasons and years. A total of 137 successful site visits were conducted for this study. During 2012, 36 sites were surveyed with Level 3 condition and habitat assessments as reference sites for either the condition or habitat assessment study goals (Table 16). In 2013, 86 new sites were surveyed with habitat assessments, and also with Level 2.5 or 3 condition assessments when sites were wetlands or riparian areas, as part of the probabilistic random condition or habitat sample frames (Table 17).

Table 17. Sampled reference sites by condition or habitat assessment and ownership.

Sample Year[1]	2012	2013	2012	2013	All Years
Landowner	**Condition Sample**		**Habitat Sample**		**Total**
City/County Parks	5	0	0	0	5
Colorado Parks and Wildlife	7	0	4	2	13
Federal	8	0	0	0	8
State Land Board	2	0	0	0	2
Public Subtotal	**22**	**0**	**4**	**2**	**28**
Private	4	0	4	0	8
Reference Sites Sampled/Year	**26**	**0**	**8**	**2**	**36**
Total Reference Sites	**26**		**10**		**36**

[1] First sample year reported for sites visited both years.

Table 18. Random sites sampled in 2013 by condition or habitat sample frames and ownership.

Landowner	Condition Sample	Habitat Sample	All Sample Frames
City/County Parks	8	0	8
Colorado Dept. of Transportation	1	0	1
Colorado Parks and Wildlife	2	7	9
Federal	2	0	2
State Land Board	2	1	3
Public Subtotal	**5**	**8**	**23**
Private	45	20	65
Total Random Sites	**60**	**28**	**88**

Together, each of these sites were sampled for one of the four sample frames for the South Platte study: 1) reference condition ecological systems (reference condition), 2) ambient condition NWI-mapped wetlands (random condition), 3) reference wildlife habitat value in priority wetlands managed for wildlife habitat (reference habitat), and 4) ambient wildlife habitat value in priority wetlands (random habitat). Two additional random habitat sites were incidentally on the same wetlands as reference habitat sites surveyed in 2012. These fell into both habitat sample frames, and contributed to the total of 88 random wetlands surveyed in 2013.

Much of the land in the basin is privately owned, and a large number of the study sites sampled were located on private lands. Many landowners granted permission to survey sites on their land only once we communicated that their site locational information did not need to be disclosed for the study. This helped reduce the percentage of landowners who refused site access, and likely reduced some sampling bias. However, for this reason, private site locations cannot be shown on a study area map. Sites for the condition sample frames were spread widely across the study area, falling along rivers, intermittent and ephemeral streams, and in isolated wetlands (Figure 15). Sites for the habitat sample frames were clustered along or near the South Platte floodplain.

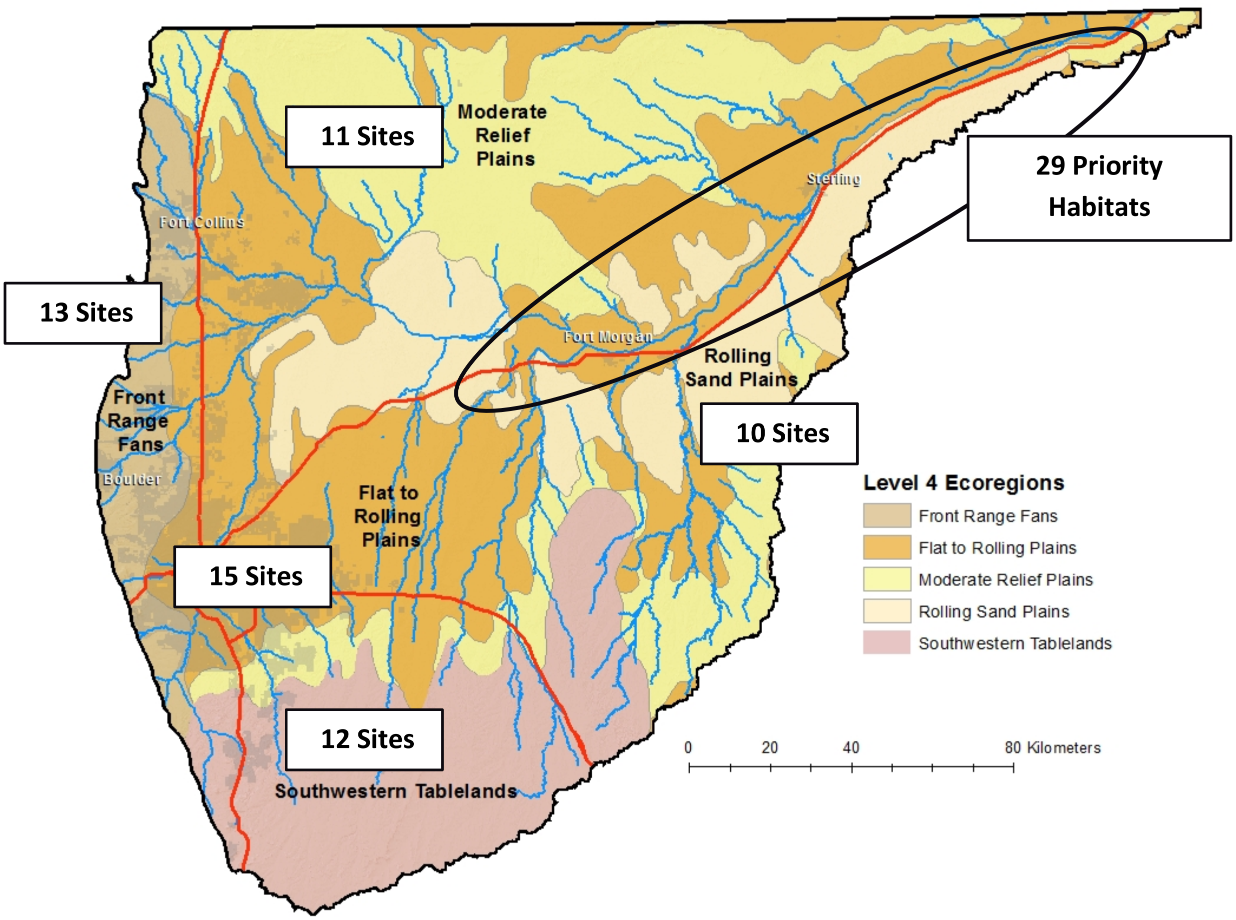


Figure 15. Density of sites sampled in the Lower South Platte River Basin.

For the random condition sample, ownership of the final survey points was skewed more heavily towards public ownership than the initial set of target points evaluated (Figure 16). The increased skew was primarily due to difficulties obtaining site access on private lands. Targeted points in the habitat sample frame had a lower dropped site rate than for randomly mapped NWI wetlands, with the exception of recharge pond habitats (Table 18). This was in part because a higher proportion of priority habitat points were located on CPW lands, and for those on private lands, many landowners were already familiar with CPW's interest in wildlife value of those habitat types when permission was requested. Recharge ponds had the highest habitat sample drop rate because of both site permission issues and because various reservoirs may receive some recharge credit, but are too large to be classified as recharge pond habitats over reservoirs.

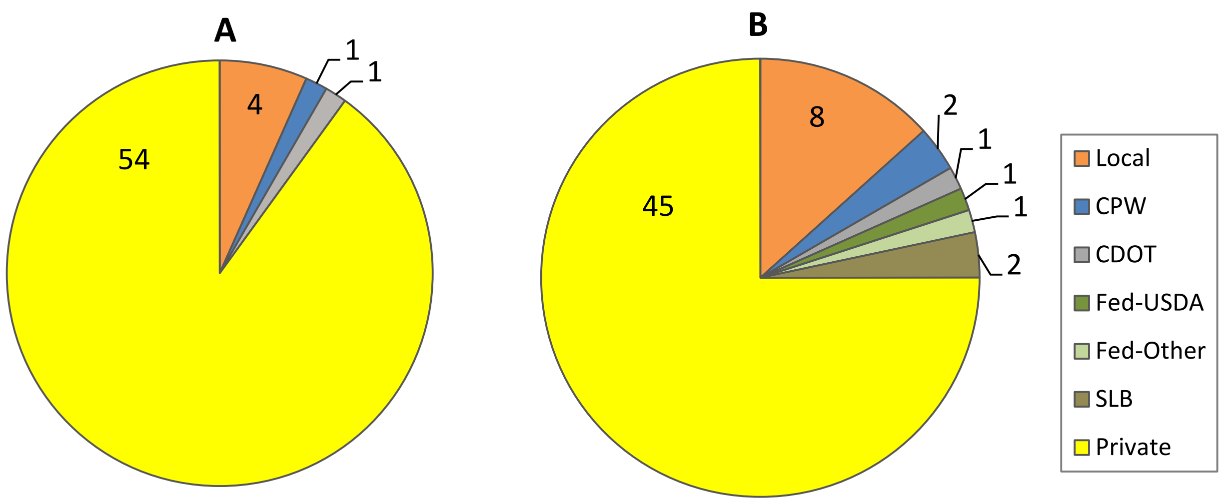


Figure 16. Comparison of land ownership between the first 60 target random condition points evaluated (A) and the 60 wetland points sampled after points were dropped from design (B).

Aside from no access, there were several reasons for dropping non-target points, as listed below (Table 18):

1. ***Size:*** For the ecoregion sample, the wetland at the point did not meet the minimum area or width criteria. For the habitat sample, the recharge pond was too large and was situated on a reservoir.
2. ***Farmed***: The point was not mapped in GIS as farmed**,** but evaluation of aerial photography or landowner discussion indicated the site was likely farmed with row crops. Some of the farmed sites may still pond water, but condition assessment metrics would not be very useful with a vegetation cover of wheat or corn. Other farmed sites were converted to farmland with fill and would also fit into the 'dry' drop category.

3. ***Dry***: For the random sample, the desktop screen of the mapped wetland did not show an aerial photo color signature characteristic of a wetland (n=4); or upon field reconnaissance, the wetland did not meet the wetland or riparian criteria (n=5). Some of these 'dry wetlands' may have dried in recent years because of changes in local hydrology after the NWI original mapping in the 1970s. For the habitat sample, dry indicates that the mapping was inaccurate because no target priority habitat was located at or within 60m from that point. This definition differs from the random sites, as the target habitats did not have to meet the USFWS definition of wetland or riparian. The only dry habitat features encountered were in the constructed wetland categories.
4. ***Deep water:*** The point was located in deep open water >1 m, and was not within 60m distance of a wetland that met the sample frame with shallower water.
5. ***Logistics***: One of the three points was dropped because it was located in a feedlot holding pond, and exposure to the site water would be unsafe to the field crew. The other two sites were dropped because permissions were obtained to survey points further down the random sample list order first, and once permission was obtained to survey the sites, the minimum number of target sites were already sampled and time did not allow for further sampling.

Table 19. Number of wetland points evaluated, skipped, and surveyed by random condition and habitat strata.

Random Strata	**All Evaluated Random Points**			
Ecoregion: (Condition of NWI wetlands)	**# Points Evaluated**	**# Dropped**	**# Surveyed**	**% Evaluated Points Surveyed**
25b: Rolling Sand Plains	37	27	10	27%
25c: Moderate Relief Plains	27	16	11	41%
25d: Flat to Rolling Plains	37	22	15	41%
25l: Front Range Fans	30	17	13	43%
26 Southwestern Tablelands	36	25	11	31%
Ecoregion Total	**167**	**107**	**60**	**36%**
Priority Habitat				
Moist Soil Unit	8	1	7	88%
Recharge Pond	13	8	5	38%
Recharge Pond/ Moist Soil Unit	7	1	6	86%
Warm Water Slough	14	4	10	71%
Habitat Total	**42**	**14**	**28**	**67%**

Causes for site access refusals and non-target site classification varied by ecoregional strata (Table 18; Table 19). NWI mapping in the Southwest Tablelands ecoregion was the least reliable. The survey rate of evaluated sites was 31%, and lack of access was still the primary dropped-site cause. However, one quarter of all the evaluated tablelands sites were dropped because they were non-target. In addition, many sites surveyed in the Southwest Tablelands ecoregion only marginally met the FWS wetland criteria. Targeted random points in the Rolling Sand Plains ecoregion included a number of wet meadows surrounded by new oil and gas development, with oil wells were more densely concentrated there than in other ecoregions. Eight of the points in this ecoregion were specifically not granted survey access due to recent oil/gas development or were owned by energy companies who declined access. This may present some bias in the wetland condition results away from landscapes with heaver oil/gas development impacts. One-half (eight) of the dropped sites in the Moderate Relief Plains ecoregion appeared to be playas. These playas were dropped due to permission issues or because they were actively cropped and non-target. About 15% of the 107 dropped random condition sites appeared to be playas, with another eight probable playas dropped from other ecoregions. (Numbers of dropped wetland types are approximate because wetlands that had experienced conversion were challenging to type without site visits). Playas consisted of only 7% of the random surveyed sites, so playas were likely underrepresented in the surveyed random points. Pitted and farmed playa points did fall into the random sample, but none of these were surveyed due to permission issues and because actively cropped playas were non-target. Therefore, the surveyed playa sites are skewed towards better condition than if the first random playa points were sampled.

Table 20. Cause of rejection for all random points evaluated but not surveyed.

Sample Frame Stratification	**Rejected Cause**		**Non-Target Detail**				
Ecoregional Strata	**No Access**	**Non-Target**	**Size**	**Farmed**	**Dry (desktop/field)**	**Deep Water**	**Logistics**
25b	24	3	-	2	1/0	-	-
25c	13	3	-	2	0/1		-
25d	17	5	-	3	1/0	1	-
25l	11	6	-	-	1/0	3	2
26	16	9	4	2	1/2	-	-
Habitat Strata							
MSU	1	-	-	-	-	-	-
RP13	4	4	3	-	0/1	-	-
RPMSU	-	1	-	-	0/1	-	-
WWS	3	1	-	-	-	-	1
All Strata	**89**	**32**	**7**	**9**	**9**	**4**	**3**

5.2.2 Classification of Sampled Wetlands/Riparian Areas

Sampled reference wetlands included most targeted wetland types, with the exception of floodplain riverine HGM wet meadows (Table 20). Besides wet meadows, the targeted sample size of four or more reference condition wetland types were sampled in the basin. The two sampled reference wet meadows were supported by groundwater with a slope HGM, and were located on the western edge of the basin on the edge of the foothills. Although we had hoped to find natural reference condition wet meadows along the South Platte floodplain corridor, where floodplain wet meadows existed, they were either degraded or their primary water source was irrigation. It is possible that before intensive water management on the floodplain, riverine wet meadows were an important wetland type in that region of the basin. However, lack of reference examples of this wet meadow ecosystem makes it difficult to use the study data to speculate about this ecosystem. Smaller patch wet meadow patches (generally < 0.1 ha) were located within the plains floodplain ecological systems in relatively undisturbed landscapes. The plains floodplain ecosystem is inherently a mosaic of herbaceous, shrub, and woody vegetation, so these small wet meadow patches were highly interspersed with taller vegetation. Where these small natural riverine wet meadow patches were observed within the non-irrigated and more contiguous floodplain landscapes, they were only marginally wet, transitioning between scattered sedges and mesic forbs to upland grasses and weeds. In addition to the targeted reference wetland types, a fen was surveyed (initially targeted as wet meadow) on Soapstone Prairie in the NW study area. This fen had soil pits with >80 cm of peat, and was situated in a landscape of seeps and springs. It is possible that more fens exist in these seep/spring zones along the northwestern to southwestern regions of the study area. Three of each targeted priority habitat types were sampled

Table 21. Sampled reference sites by sample frame and ecological system.

Sampled reference wetland/riparian/habitats	# Reference Sites Surveyed	Total # Reference Site Visits
Playa	8	16
Plains Floodplain	6	7
Plains Riparian	5	5
Foothills Riparian	4	4
Wet Meadow	2	2
Fen	1	1
Total Reference Condition	**26**	**35**
Moist Soil Unit	3	6
Recharge Pond	3	5
Recharge Pond/ Moist Soil Unit	1	1
Warm Water Slough	3	3
Total Reference Habitat	**10**	**15**
Total Reference Sites/Visits	**36**	**50**

The random wetlands surveyed encompassed the range of common ecological systems (wetland types) in the study area (Table 21). The only known wetland type missed in the random condition sample were fens, but in the Lower South Platte Basin, these were uncommon if not rare. Floodplain and riparian systems were the most common sampled in the random condition assessment. The random condition ecoregional sample frame strata resulted in sampling a relatively lower proportion of targeted mapped wetlands along the South Platte floodplain than the actual proportion of mapped wetland acreage that occurs along the floodplain. This sampling stratification was to ensure a spatial spread in sample points that would allow sampling of enough of the common wetland types present throughout the basin. As a result, while the most common sampled ecological system was Plains Riparian, Plains Floodplain was likely the most common NWI-mapped wetland/riparian ecological system in the basin.

Marshes were the most common wetland types sampled in the habitat sample. Marshes were also the most frequently sampled wetland type across all sample frames for this study. This was because most of the priority habitat features would classify as marsh ecological systems when in their wet state. Some of the reference and random priority habitats did not meet any wetland criteria at the time of the site visit. For these, if they receive irrigation at all, it is applied outside of the growing season. These sites did not meet criteria for any ecological system, and were assigned 'no class' in Table 21.

Table 22. Sampled sites by sample frame and ecological system.

Sample Frame	Plains Riparian	Plains Floodplain	Irrigated Wet Meadow	Marsh	Foothills Riparian	Playa	Foothills Wet Meadow	Fen	No Class	Total
Random Condition	16	11	10	9	7	4	3			60
Reference Condition	5	6			4	8	2	1		26
Random Habitat			1	15					12	28
Reference Habitat				10					1	11
Total Sites	**21**	**17**	**11**	**33**[1]	**11**	**12**	**5**	**1**	**12**[1]	**123**

[1] One habitat site in each of the marsh and 'no class' categories fell in both the reference and random sample frames. For those sites, the same site data was used for each sample frame.

Marshes were the most broadly distributed wetland type throughout the study area (Table 22 and Figure 17) for the random condition sample. They were sampled in all ecoregions except for the Southwest Tablelands. However, four of the eleven surveyed wetlands in the tablelands ecoregion were non-functioning impoundments, which used to be marshes when they were functioning wetlands. The only USFWS wetland criteria those former marshes met were hydric soils, and although these soils met regional wetland criteria, they were potentially relict. Lacking marsh vegetation, those sites fit the plains riparian ecological system classification, as an impounded wetland/riparian type of the larger plains riparian landscape.

Table 23. Sampled random condition sites by Ecological System and ecoregional strata.

Ecological System	25b	25c	25d	25l	26	Total
Western Great Plains Riparian	1	6	-	-	9	16
Western Great Plains Floodplain	3	-	8	-	-	11
Irrigation-Influenced Wet Meadow	3	-	5	2	-	10
North American Arid West Emergent Marsh	3	1	1	4	-	9
Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland	-	-	1	5	1	7
Rocky Mountain Lower Montane-Foothill Wet Meadow	-	-	-	2	1	3
Total	10	11	15	13	11	60
% of Random Sites	17%	18%	25%	22%	18%	100%

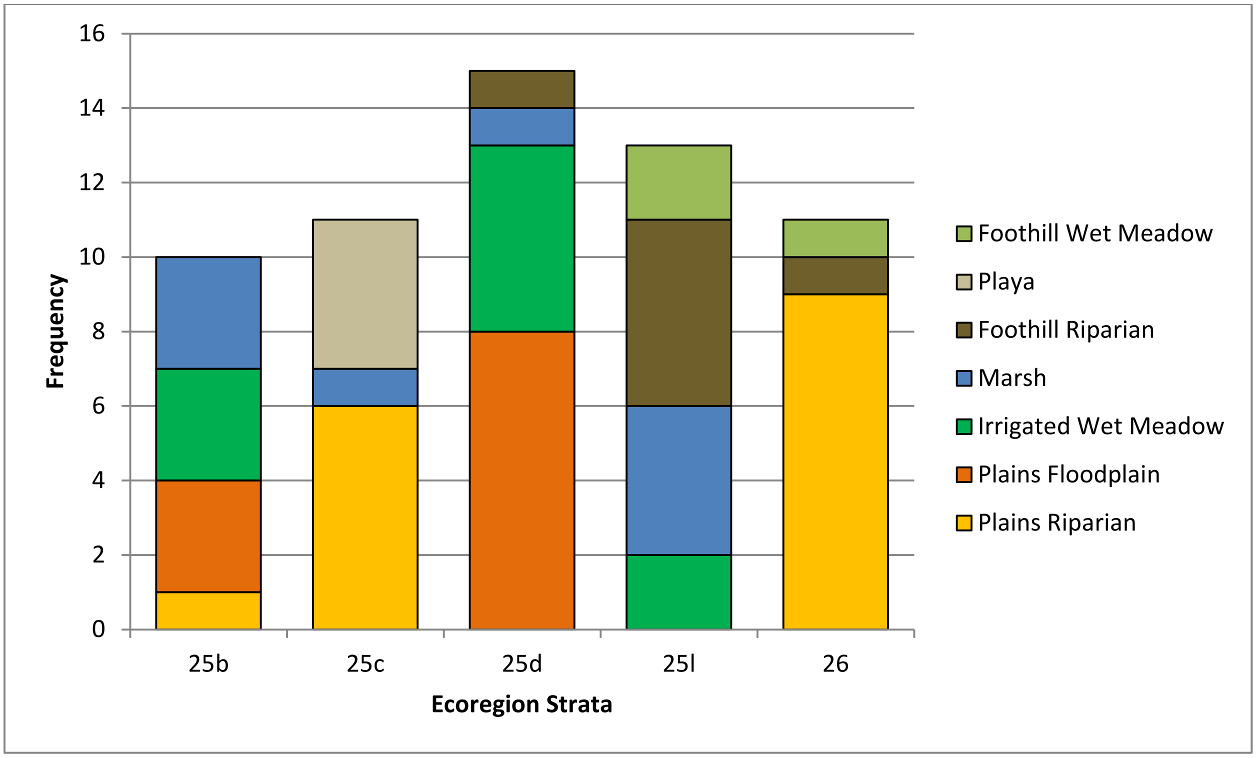


Figure 17. Sampled random condition sites by ecoregional strata and Ecological System.

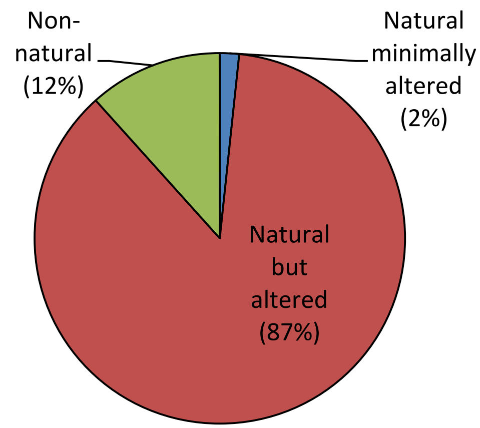
Marshes also classified into the broadest range of HGM classes, with random condition sites surveyed from all HGMs except for slope (Tables 23 and 24). Along with the riverine, depressional, and slope HGM wetland classes that could potentially occur naturally in the basin, 7 of the 60 random sites fell into a slope-like novel irrigation-fed HGM class, and 1 wetland situated on a reservoir fell into lacustrine fringe. Although there were likely a number of naturally-occurring wetland and riparian areas throughout the basin in the past, most of these wetland/riparian features are now altered by hydrology management influences. Only one of the 60 surveyed sites, a playa wetland, had no alterations to its water source. All riverine HGM sites fell within a landscape that likely historically also supported wetland/riparian hydrology. Now, the majority of wetland and riparian areas in the basin still receive some natural water sources, but are often dominated by altered hydrology sources. The remaining 12% of surveyed sites occurred outside of a landscape position that historically supported a wetland/riparian ecological system.

Table 24. HGM and Ecological System classification of sampled random condition sites.

HGM Class/Wetland-Riparian Source	Ecological System							Total	% of Total
	Plains Riparian	Plains Floodplain	Foothill Riparian	Irrigation-Influenced Wet Meadow	Foothill Wet Meadow	Marsh	Playa		
Riverine	**9**	**11**	**5**	**2**		**3**		**30**	**50%**
2) Natural feature, but altered or augmented	9	11	5	2		3		30	50%
Depressional	**7**		**2**	**1**		**5**	**4**	**19**	**32%**
1) Natural feature with minimal alteration							1	1	2%
2) Natural feature, but altered or augmented	7			1		4	3	15	25%
3) Non-natural feature			2			1		3	5%
Novel Irrigation-Fed (Most Similar to Slope)				**7**				**7**	**12%**
2) Natural feature, but altered or augmented				4				4	7%
3) Non-natural feature				3				3	5%
Slope					**3**			**3**	**5%**
2) Natural feature, but altered or augmented					3			3	5%
Lacustrine Fringe						**1**		**1**	**2%**
3) Non-natural feature						1		1	2%
Total	**16**	**11**	**7**	**10**	**3**	**9**	**4**	**60**	**100%**
% of Total	**27%**	**18%**	**12%**	**17%**	**5%**	**15%**	**7%**	**100%**	

Table 25. Wetland source sub-classification of sampled random condition sites.

Wetland Source	Count	% of Total
1) Natural feature with minimal alteration	1	2%
2) Natural feature, but altered or augmented	52	87%
3) Non-natural feature	7	12%
Total	**60**	**100%**



Vegetation in the North American Arid West Emergent Marsh ecological system (marsh) is characterized by having coarse, relatively tall, herbaceous stature (Figure 18). Common marsh species include cattail (*Typha* spp.), rushes (*Juncus* spp.), bulrushes (*Schoenoplectus* spp.), and spikerushes (*Eleocharis* spp.). Sampled marshes spanned a wide range of HGM water regimes from temporarily to semi-permanently flooded or saturated, and most sites experienced inundation during some part of the growing season. The only natural marshes sampled in the basin were the warm water sloughs located along the South Platte floodplain. Many of the other marshes were created intentionally by impoundments and/or irrigation, or unintentionally via irrigation seepage.

Figure 18. Photographs of marshes in the Lower South Platte River Basin. Top left: reference warm water slough. Top right: reference moist soil unit. Bottom left: random condition marsh. Bottom right: random recharge pond.

The Western Great Plains Riparian ecological system (Figure 19) includes woody and herbaceous wetlands and riparian areas. These are located along tributary rivers, streams, and intermittent creeks flow towards the South Platte River in the plains portion of the basin. In a natural setting, these ecosystems are classified in the riverine HGM, however, they were frequently impounded and converted to depressional systems. Vegetation varies from open cottonwoods to a mixture of herbaceous wetland and mesic and upland shortgrass prairie species that tolerate flashy water regimes, with the flooding leaving behind small ponds to slowly dry down in micro-depressions over the course of the summer.

Figure 19. Photographs of plains riparian sites in the Lower South Platte River Basin. Top photos: reference condition. Bottom photos: random condition.

The Western Great Plains Floodplain ecological system (Figure 20), includes wetlands and riparian areas located along the South Platte River and within its larger floodplain zone in the plains portion of the study area. These ecological systems encompass a mosaic of cottonwood (*Populus deltoides*) galleries, small *Spartina* spp. swales, *Salix* or *Symphorocarpus* shrublands, and mesic meadows off of the river. Soils are often sandy. On the river, annual vegetation populates sandbars and portions of the riverbed that don't flood for very long host aquatic plants and slower moving shallow streamlets. These ecological systems fall in the riverine HGM.

Figure 20. Photographs of plains floodplains in the Lower South Platte River Basin. Top photos: reference condition. Bottom photos: random condition.

The Western Great Plains Closed Depression (Figure 21), or playa, ecological system includes isolated, precipitation-fed, shallow clay-lined depressional wetlands surrounded by a landscape of shortgrass prairie. Most of the playas in the study area are wet only ephemerally, though a few are wet seasonally. Plant community composition changes substantially between their wet and dry phase, and their vegetation is naturally low in cover, especially in the central most frequently-wetted zones. Dry cover is often wheatgrass (*Pascopyrum smithii*), with sparse *Ambrosia tomentosa* occupying the lowest zone, and wet cover is often *Eleocharis* spp.

Figure 21. Photographs of playas in the Lower South Platte River Basin. Top photos: reference condition (left: dry, right: wet). Bottom photos: random condition.

The Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland ecological system (foothills riparian; Figure 22) supports the wetland and riparian ecosystems fed by streams coming from the foothills. Vegetation in these ecological systems can have a cottonwood overstory, but also frequently possess more complex vertical vegetation layers than the plains riverine ecological systems. *Salix exigua* is a common understory shrub, along with shrubs in the Rosaceae family.

Figure 22. Photographs of foothills riparian areas in the Lower South Platte River Basin. Top photos: reference condition. Bottom photos: random condition.

The Rocky Mountain Lower Montane-Foothill Wet Meadow ecological system (foothills wet meadow; Figure 23) includes herbaceous wetlands situated in the foothills. These are primarily groundwater-fed from a high water table, and are situated at or near a break in slope. Diverse low statured graminoids and forbs comprise wet meadow vegetation.

Figure 23. Photographs of foothills wet meadows in the Lower South Platte River Basin. Top photos: reference condition. Bottom photos: random condition.

The Rocky Mountain Subalpine-Montane Fen (Figure 24) ecological system is similar to the wet meadow ecosystem above, but is characterized having organic soils for a depth of at least 40 cm. The peat is able to develop from very stable, saturated soil hydrology. Fens have not been characterized as a lower elevation ecological system in Colorado, but because only one fen was observed in the study area, we reference its standard ecological system name from higher elevations. The fen vegetation had high cover of *Carex simulata* and *Carex nebraskensis*.

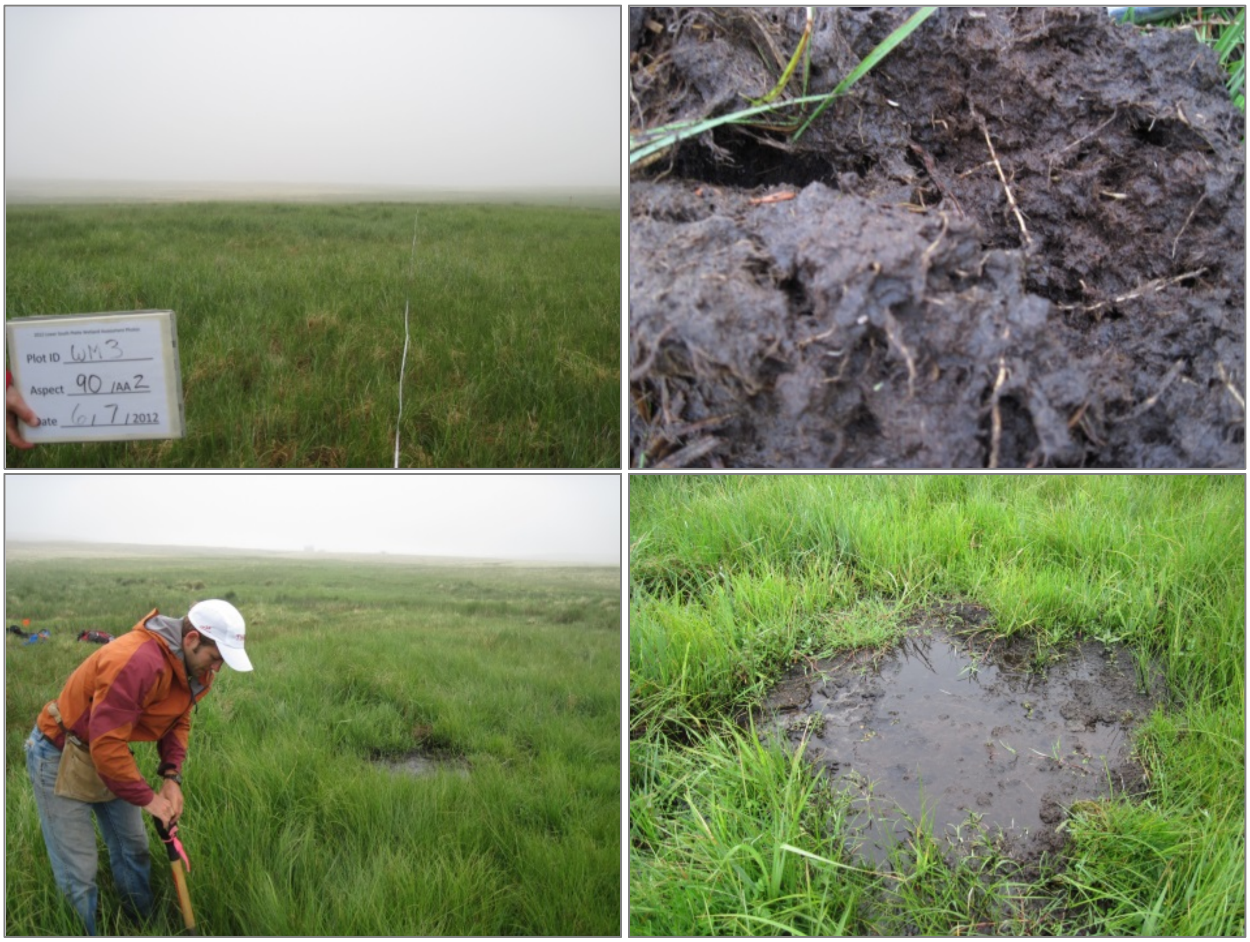


Figure 24. Photographs of the one reference fen sampled.

The irrigation-influenced wet meadow ecological system (Figure 25) is a human influenced, hybrid ecological system between plains floodplain, and foothills wet meadow. Hydrology does not always fit well into a single HGM, as these ecosystems can be fed by either or both surface flood irrigation or subsurface irrigation seepage. Their plant communities are typical of wet meadow species, and when in good condition, their plant communities may be similar to the foothills wet meadow. *Distichlis spicata* (saltgrass) and *Critesion jubatum* (foxtail barley) were common dominant species in this ecological system.

Figure 25. Photographs of irrigated wet meadows in the Lower South Platte River Basin, all sampled for random condition.

5.2.3 Characterization of Vegetation

The high number of wetland and riparian ecological systems present throughout the basin, coupled with high variability in site wetness, vegetative physiognomy, and condition across sampled sites lent to high species diversity across sites. A total of 602 unique plants were identified to species in the sites sampled from all study frames. Some sites had high within-site species diversity as well, while sites trended towards monocultures. The most diverse site sampled was a reference condition foothills riparian site which supported 90 different plant species. The site that held the lowest species diversity was a reference condition playa which only supported 7 species during its inundated phase.

The most widespread plant species observed in the basin's NWI-mapped wetland/riparian areas are detailed in Table 25. These fourteen species are characteristic of the Lower South Platte basin's wetland and riparian acreage - together they comprised approximately 50% of the total plant cover recorded in the random wetland condition sites. The species vary from obligate wetland species to noxious weeds such as cheatgrass (*Anisantha tectorum*) that establish in once-wet areas that are in the process of converting to upland or subject to other stress. All of these common plants have a moderate to high ability to withstand disturbance, as indicated by their low C-values, which is in part response to the presence of human-related stressors in the basin, and the basin's long history of multiple land uses. However, the low C-values of the native species are also indicative of the natural disturbance regimes inherent to the wetland and riparian areas of northeast Colorado's plains. Cottonwood (*Populus deltoides*) thrives of off floods that clear a substrate then create moist soil conditions for successful establishment; and smartweed (*Persicaria amphibia*) frequently colonizes sandbars and ephemeral streambeds where it can persist successfully with fluctuating water conditions ranging from flooded, to saturated, to dried-down. Wheatgrass (*Pascopyrum smithii*), can be the dominant species on a playa during dry periods, but can also withstand flooding while the playa is ponded and vegetated with the wetland obligate *Eleocharis macrostachya* (a common spikerush that also covered >1% of randomly surveyed acreage in the basin).

The most frequently encountered plant species in the surveyed wetlands and riparian areas across the study area were often even more weedy or able to tolerate moderate-high disturbance than the plants that occupied the highest cover in the random surveys (Table 26). Only three of those species were wetland indicator species for the Great Plains Region, and those three were often observed in marginal wetlands. These species were all observed in at least one-third of the randomly sampled sites, with the most common species, prickly lettuce (*Lactuca serriola*), observed at 42 of the 60 sites. Four of the most common species were Colorado noxious weeds, and two of the other non-natives - burningbush/kochia (*Bassia sieversiana*) and smooth brome *(Bromopsis inermis)* can spread aggressively. Given the large basin study area, and the high diversity in types of sites surveyed, these species are prolific throughout (and likely outside of) the wetlands and riparian areas of northeast Colorado.

Noxious weeds were abundant throughout wetlands, riparian areas, and priority habitats across the study area (Table 27), with 38 Colorado state-listed weeds documented in surveyed sites. Two additional watch-listed species were also documented in multiple sites. Cheatgrass, canada thistle (*Breea arvensis*), bindweed *(Convolvulus arvensis)*, poison hemlock *(Conium maculatum)*, and broadleaved pepperweed (*Cardaria latifolia*) were all observed repeatedly with patches of high cover across sampled sites. Many of the other weeds were present in high cover within in smaller patches of the assessment area, or dominated sites that had sparser cover overall. The high abundance of noxious weeds present in surveyed sites indicated that a lot of the wetland vegetation in the basin was under high stress.

Table 26. Plant species with the highest total percent cover across all random wetlands and riparian areas surveyed for the condition assessment.

Scientific Name	Common Name	% Cover of Surveyed Area	Wetland Indicator Status[1]	Native Status	C-Value
Distichlis stricta	saltgrass	7.6	FACW[2]	Native	4
Populus deltoides	plains cottonwood	6.0	FAC	Native	3
Salix exigua	narrowleaf willow	5.9	FACW	Native	3
Pascopyrum smithii	western wheatgrass	4.5	FACU[2]	Native	5
Typha angustifolia	narrowleaf cattail	4.5	OBL	Native	2
Anisantha tectorum	cheatgrass	4.5	---	Non-native	0
Chenopodium album	lambsquarters	3.2	FACU	Non-native	0
Juncus arcticus	mountain rush	3.0	FACW	Native	4
Breea arvensis	Canada thistle	2.5	FACU	Non-native	0
Schoenoplectus pungens	common threesquare	2.1	OBL	Native	4
Bromopsis inermis	smooth brome	1.9	UPL	Non-native	0
Typha latifolia	broadleaf cattail	1.7	OBL	Native	2
Phalaroides arundinacea	reed canarygrass	1.5	FACW	Native	2
Persicaria amphibia	longroot smartweed	1.5	OBL	Native	4

[1] Wetland Indicator Status based on the 2013 National Wetland Plant List for the Great Plains region. OBL = obligate wetland species, found in wetlands 99% of the time; FACW = facultative wetland species, found in wetlands 67–99% of the time; FAC = facultative species, found in wetlands 34–66% of the time; FACU = facultative upland species, found in uplands 67–99% of the time; UPL = obligate upland species, found in uplands 99% of the time.

[2] *Distichlis stricta* is a wetland indicator species in the Great Plains, but not in the Arid West region (FAC). *Pascopyrum smithii* is a FAC species in the Arid West region. Random sites were located in both regions, though more of the study area is located in the Great Plains region.

Table 27. Twenty most common plant species encountered in Lower South Platte random wetlands and riparian areas surveyed for the condition assessment.

Scientific Name	Common Name	# Site Observations	Wetland Indicator Status	Native Status	C-Value
Lactuca serriola	prickly lettuce	42	FAC	Non-native	0
Pascopyrum smithii	western wheatgrass	38	FACU	Native	5
Breea arvensis	Canada thistle	36	FACU	Non-native	0
Bassia sieversiana	burningbush	33	FACU	Non-native	0
Chenopodium album	lambsquarters	29	FACU	Non-native	0
Critesion jubatum	foxtail barley	29	FACW	Native	2
Bromopsis inermis	smooth brome	27	UPL	Non-native	0
Anisantha tectorum	cheatgrass	26	---	Non-native	0
Populus deltoides	plains cottonwood	25	FAC	Native	3
Distichlis stricta	saltgrass	23	FACW	Native	4
Rumex crispus	curly dock	23	FAC	Non-native	0
Taraxacum officinale	common dandelion	23	FACU	Non-native	0
Thlaspi arvense	field pennycress	23	FACU	Non-native	0
Asclepias speciosa	showy milkweed	22	FAC	Native	3
Ambrosia psilostachya	Cuman ragweed	20	FACU	Native	3
Carduus nutans	nodding plumeless thistle	20	FACU	Non-native	0
Convolvulus arvensis	field bindweed	20	---	Non-native	0
Glycyrrhiza lepidota	American licorice	20	FACU	Native	3
Helianthus annuus	common sunflower	20	FACU	Native	1
Juncus arcticus	mountain rush	20	FACW	Native	4

Table 28. Noxious weed species encountered in Lower South Platte wetlands, riparian areas, and priority habitats. Cover data applies to all sample frames.

Scientific Name	Common Name	CO Noxious Status	# Sites	Ave. % Cover	Min. % Cover	Max. % Cover
Breea arvensis	Canada thistle	List B	66	3.13	0.03	37.50
Anisantha tectorum	cheatgrass	List C	46	9.13	0.03	85.00
Convolvulus arvensis	field bindweed	List C	36	2.21	0.03	37.50
Conium maculatum	poison hemlock	List C	33	3.15	0.03	37.50
Verbascum thapsus	common mullein	List C	30	0.50	0.03	1.50
Cardaria latifolia	broadleaved pepperweed	List B	28	2.45	0.03	37.50
Carduus nutans ssp. macrolepis	nodding plumeless thistle	List B	28	1.35	0.10	17.50
Elaeagnus angustifolia	Russian olive	List B	25	2.43	0.03	9.00
Tithymalus uralensis	Russian leafy spurge	List B	19	4.43	0.13	17.50
Dipsacus fullonum	Fuller's teasel	List B	15	3.25	0.10	17.50
Cardaria draba	whitetop	List B	13	3.54	0.50	17.50
Tribulus terrestris	puncturevine	List C	12	3.38	0.03	17.50
Elytrigia repens	quackgrass	List B	11	7.76	0.38	36.88
Phragmites australis	common reed	Watch List	10	3.13	0.50	10.00
Arctium minus	lesser burdock	List C	7	0.57	0.13	1.50
Cichorium intybus	chicory	List C	6	0.48	0.10	1.50
Cynoglossum officinale	gypsyflower	List B	6	1.11	0.13	3.50
Tamarix ramosissima	saltcedar	List B	6	2.27	0.50	7.50
Onopordum acanthium	Scotch cottonthistle	List B	5	0.70	0.50	1.50
Cirsium vulgare	bull thistle	List B	4	0.36	0.03	0.50
Linaria vulgaris	butter and eggs	List B	4	3.04	0.03	11.50
Sonchus uliginosus	moist sowthistle	List C	4	0.50	0.50	0.50
Acosta diffusa	diffuse knapweed	List B	3	0.33	0.13	0.50
Acroptilon repens	hardheads	List B	3	1.17	0.50	2.13
Hypericum perforatum	common St. Johnswort	List C	3	0.30	0.03	0.75
Anthemis cotula	stinking chamomile	List B	2	0.44	0.38	0.50
Cyperus esculentus	yellow nutsedge	List B	2	0.13	0.13	0.13
Dipsacus laciniatus	cutleaf teasel	List B	2	8.76	0.03	17.50
Potentilla recta	sulphur cinquefoil	List B	2	0.38	0.25	0.50
Sonchus arvensis	field sowthistle	List C	2	0.69	0.50	0.88
Sphaerophysa salsula	alkali swainsonpea	Watch List	2	6.44	1.50	11.38
Abutilon theophrasti	velvetleaf	List C	1	0.50	0.50	0.50
Artemisia absinthium	absinthium	List B	1	1.50	1.50	1.50
Cylindropyrum cylindricum	jointed goatgrass	List B	1	1.50	1.50	1.50
Erodium cicutarium	redstem stork's bill	List C	1	0.38	0.38	0.38
Hesperis matronalis	dames rocket	List B	1	17.50	17.50	17.50
Hibiscus trionum	flower of an hour	List B	1	0.50	0.50	0.50
Leucanthemum vulgare	oxeye daisy	List B	1	0.50	0.50	0.50
Linaria genistifolia ssp. dalmatica	Dalmatian toadflax	List B	1	0.50	0.50	0.50
Panicum miliaceum	broomcorn millet	List C	1	0.50	0.50	0.50

5.3 Level 2/3 Assessment: Floristic Quality Assessment

Vegetation surveys were conducted in all sampled wetlands and riparian areas, though the intensity of the protocols varied between Level 2.5 and Level 3 sites. Overall floristic quality results are reported only for the random condition assessment sites, as these were randomly sampled across the entire basin. Mean C metrics are used in site condition scores, so are reported on for various sample frames to describe the relationships between Mean C and ecological system across the basin.

5.3.1 Mean C

Mean C values observed in the Lower South Platte Basin were much lower on average than values observed in other Colorado basin-wide surveys. This was not surprising given the high cover of non-natives and noxious weeds in the basin – many wetlands and riparian areas in the basin supported degraded plant communities. Across all sample frames, site Mean C's in the reference and random habitat sample frames tended to be on the lower half of the spectrum of the range of site Mean C's observed in the basin, with values spanning from 0.5 to 2.9 (Figure 26). Random condition sites supported a broader range of 0.89 to 3.74, and a higher average Mean C across the sample frame. We were surprised to find that all four of the plains floodplain reference condition sites and one of the reference foothill wet meadows scored Mean C's below 2.0. The highest site Mean C in the basin was from the reference fen, with a value of 4.52.

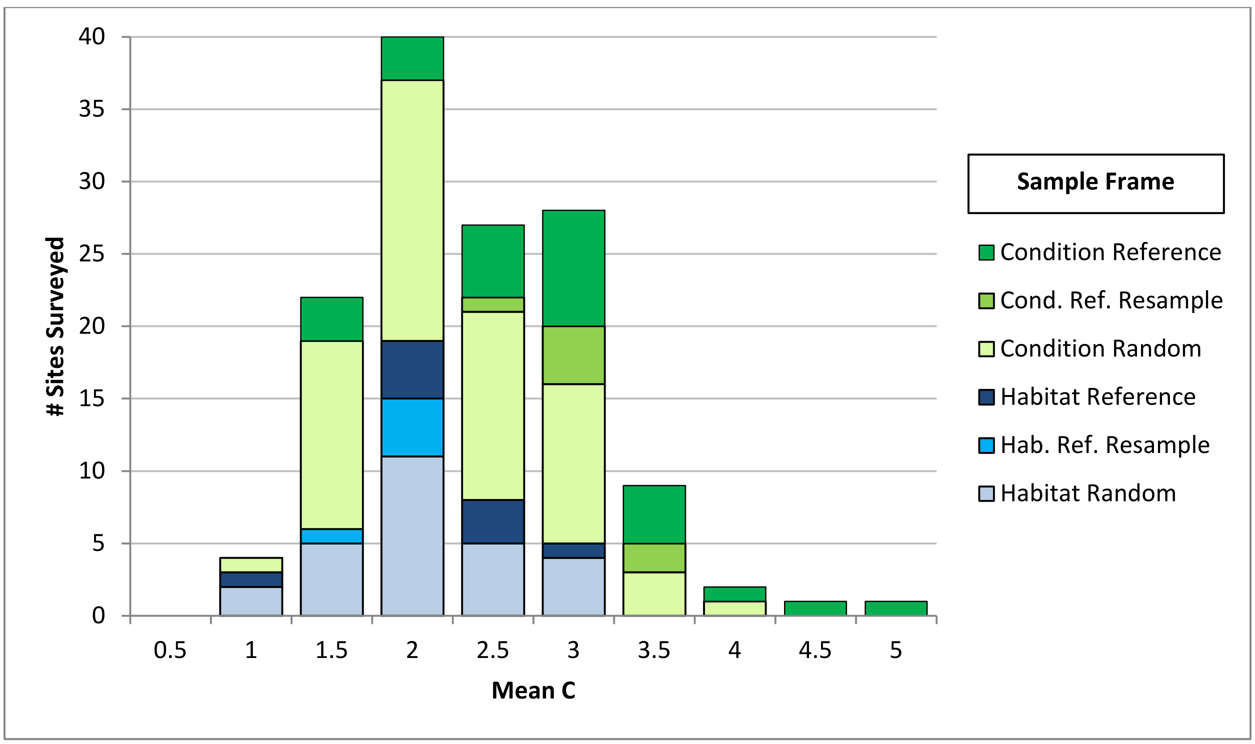


Figure 26. Frequency of Mean C values for all sites sampled and sample frames. Number under each bar represents the upper bound of the bin. Resampled sites are reported separately because Mean C varied widely between samples.

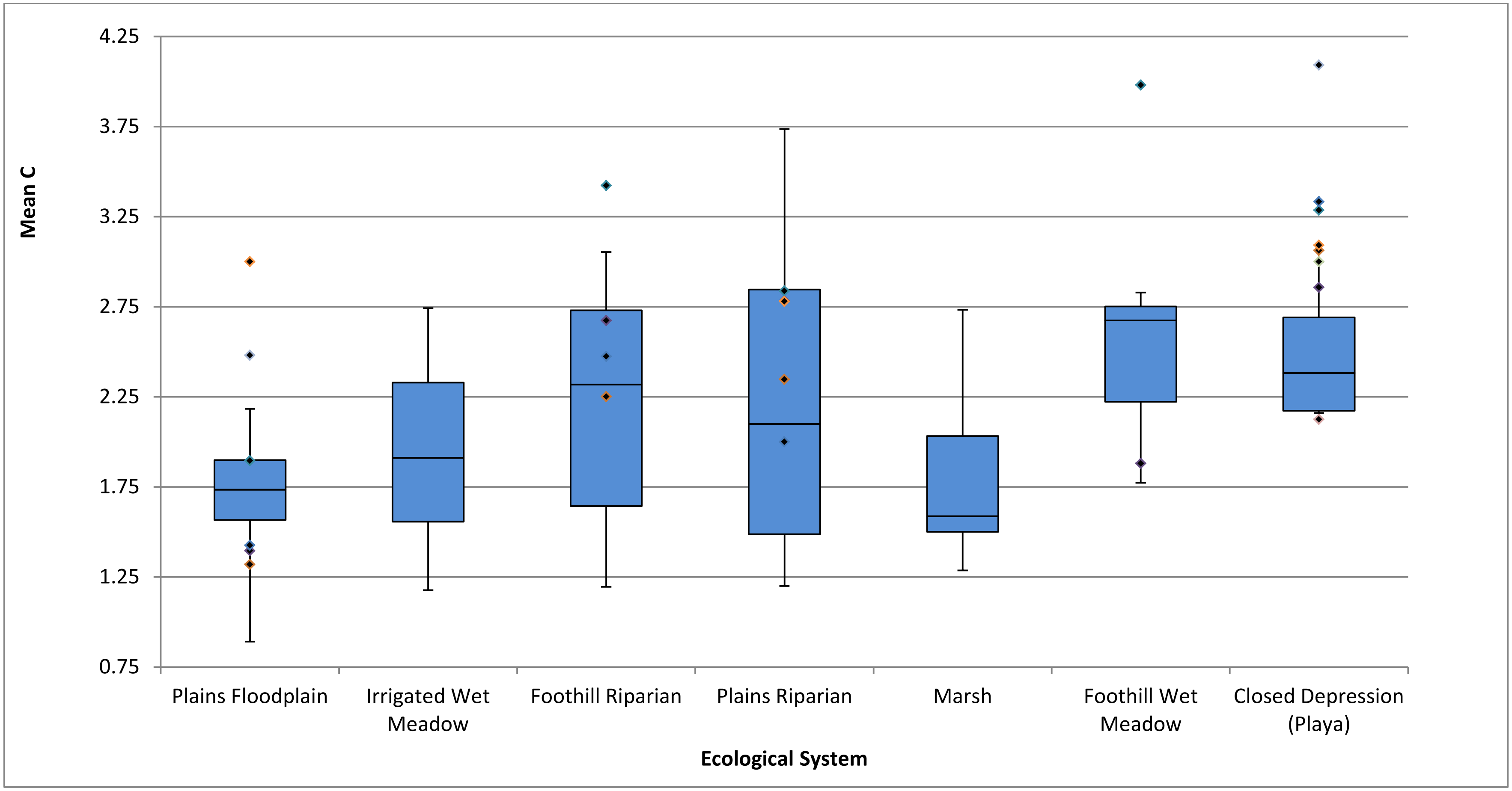


Figure 27. Range of Mean C scores by Ecological System for random condition sites, and their comparison with reference condition sites. Boxplots represent random sites - with filled boxes representing 75th percentile to 25th percentile. Horizontal line represents the median. Whiskers extend to highest and lowest observed values. Each diamond point represents a reference condition site. Highest value observed is reported for reference sites that were visited > once.

Further analysis of reference versus random condition sites revealed that the reference site Mean C values for most of the ecological systems spanned the range of random condition site values, instead of the highest values (Figure 27), particularly in the Western Great Plains ecological systems. This indicated that the Mean C may be a less reliable measure of site biotic response to anthropogenic disturbance and stress in the Western Great Plains ecological systems, considering that most of the reference sites were in better condition than the random sites.

Mean C values in the plains floodplain reference sites were highly variable, and comparison of reference sites to random sites indicated that Mean C's in this system did not seem at all related to site biotic condition. The three reference plains floodplain sites located on the South Platte River, chosen as reference for having the higher levels of site complexity and lesser anthropogenic disturbance, had Mean C values far below the median for the random site Mean C's. The plains floodplain site in the cottonwood gallery scored at the 3rd quartile of random sites, and the high scoring plains floodplain sites were in the *Symphoricarpos* (snowberry) shrub and herbaceous floodplain zone, farthest from influence by the South Platte River. These dynamics may be related to increasing levels of natural disturbance resulting in lower Mean C's. The range of scores may also be reflective of the high physiognomic patch diversity and corresponding variation in vegetation inherent to plains floodplain wetland and riparian areas. Plains riparian ecological systems also showed a lack of relationship between better condition reference site Mean C's and the range of condition observed from random sites. This ecological system also has high variability across sites in physiognomy and in how much water the wetlands/riparian areas receive.

The irrigated wet meadow sites had a similar and slightly higher Mean C median and range compared with the plains floodplain site values. As many irrigated wet meadows were located within the South Platte floodplain, it was not surprising their values were similar. They also shared a similar Mean C range to the foothill wet meadows, with a lower mean and minimum. This also made sense because potential wet meadow vegetation is strongly influenced by hydroperiod. While highly functioning irrigated wet meadows can be very similar in community composition to natural groundwater supported wet meadows, as irrigation practices cause a wet meadow's hydroperiod to deviate from natural seasonality, the biota can become stressed and more plants tolerant of disturbance will outcompete wet meadow plants that are sensitive to disturbance.

Playa ecological systems appear to have a positive relationship between Mean C and condition in Figure 27, but only the highest Mean C's are shown for reference sites with revisits in the graph. When all reference site revisits are considered, Mean C values for the playa sites don't show consistent trends with playa random vs. reference condition (Table 28). Of the three resurveyed playa reference sites observed with visible change in vegetation cover and moisture (surveyed in both wet/moist and dry conditions), these scored substantially different Mean C's when surveyed in wetter vs. drier state, not necessarily higher or lower when wetter. Also, one of the smallest playas that appeared to pond less frequently, with less bare ground and more wheatgrass, scored the highest, and another of the smallest reference sites, located in a remote seemingly undisturbed location, scored the lowest of all playa sites. A larger playa sample size and more revisits may help detect trends in Mean C and playa condition. However, dynamics observed from this study do indicate that variability in playa Mean C can be influenced by other factors not related to to playa condition. The four randomly surveyed playas fell in a more disturbed landscape context than all of the eight reference playas, but they did not fall into the lowest spectrum of potential playa condition that includes actively farmed and pitted playas.

Table 29. Variation in Mean C Values of Sampled Playas.

Site Code and Survey Year	Mean C	Native Mean C	Cover-weighted Mean C	Sample Frame
S01-Dry 2012	3.08	4.11	3.06	Reference
S03-Dry 2012	2.86	3.33	3.14	Reference
S03-Moist 2012	2.80	3.50	3.12	Reference
S03-Dry 2013	2.73	3.75	3.27	Reference
S04-Dry2012	3.29	3.83	3.91	Reference
S04-Wet 2012	2.60	3.55	3.49	Reference
S04-Moist 2013	3.06	3.77	3.59	Reference
S06-Dry 2012	3.00	3.55	4.30	Reference
S06-Wet2012	3.33	4.00	3.31	Reference
S06-Moist 2013	2.53	3.69	2.73	Reference
S07-Dry 2012	3.09	4.25	4.00	Reference
S07-Dry2012 #2	no observable change in vegetation - no species list recorded			
S08-Dry 2012	4.09	4.50	3.82	Reference
S08-Dry2012 #2	no observable change in vegetation - no species list recorded			
S17-Dry 2012	2.13	3.40	4.41	Reference
S20-Dry 2012	3.00	4.80	3.91	Reference
25c-222-Dry 2013	3.00	4.50	4.58	Random
25c-241-Dry 2013	2.59	3.38	3.80	Random
25c-242-Dry 2013	2.18	3.70	3.02	Random
25c-246-Dry 2013	2.16	3.18	3.54	Random

Mean C values in foothills riparian and marsh ecological systems did follow trends related to biotic condition. The foothills riparian woodland and shrubland ecological system had a positive relationship between site condition and Mean C in this basin, just as observed in wetlands sampled with EIA for the the 2011 Front Range watershed approach study (Lemly et al. 2013) situated in the Lower South Platte Basin Front Range Fans ecoregion. The foothills riparian random condition sites with Mean C values higher than the median value were similar in condition to those in the reference sites. Marsh ecosystems were also rated in the Front Range study and are better understood than the plains-specific ecological systems. No reference condition marsh sites were sampled for this study, and marsh sites had low Mean C's overall. The Mean C values of warm water slough marshes in the habitat sample fell within the same Mean C range as the condition random marshes. Warm water sloughs from the habitat sample were more natural in origin than the marshes sampled in the condition sample, however they also had issues with anthropogenic site impacts, cattail dominance, and noxious weeds. Many of the sampled marshes experienced high levels of anthropogenic disturbance, high cover of noxious weeds, and cattail dominance, so low Mean C site values seemed appropriate. With only five foothill wet meadows and one fen sampled for this study, there were too few sites of these wetland types to make assumptions about consistent positive relationships between Mean C and site condition. However, many of the higher elevation analogs of these ecological systems were surveyed using EIA in previous CNHP studies.

5.3.2 EIA Metric Development - FQA Metrics in Plains and Foothill Ecological Systems

For development of ecological integrity assessments specific to the basin's wetland types, Mean C was retained as an EIA biotic condition metric for five ecological systems: foothills riparian, marsh, wet meadow (foothill, and irrigated), and fen. Mean C value ranges were already developed for similar ecosystems to those based on field-testing in the mountains. Because high functioning lower elevation wetlands experience more natural disturbance and dynamism than their higher elevation wetland type counterparts where the Mean C scoring thresholds were assigned, the Native Mean C values from reference condition and good condition random sites were used to recalibrate Mean C scoring thresholds for these lower elevation ecological systems (Table 29). Other FQA variables were also evaluated with a scatterplot analysis to see if they showed stronger relationships with site condition than Mean C, but no stronger trends were detected from these variables.

Mean C was not retained as a biotic condition metric for the Western Great Plains-specific ecological systems: plains riparian, plains floodplain, and closed depression (playa). Instead, the other FQA metrics used in Colorado's EIA such as relative cover of native species, percent noxious, and percent aggressive native species, were weighted more heavily in the EIA biotic score for these ecological systems.

With only 60 random condition wetland/riparian sites sampled for this study across 7 different ecological systems, and with only a few reference sites surveyed from each ecological system, sites within the reference and random categories had highly variable plant composition, even when comparing sites within ecological system. Within-site temporal variability was also observed with site revisits, but revisits were not a central focal point of this study. This variability factor created challenges in both interpreting the utility of Mean C and other FQA metrics to assess overall site condition as has been done in other basins. As more wetland/riparian reference sites are surveyed in lower elevations, further examination of the new EIA biotic variable weights and scoring thresholds are needed, especially for the Western Great Plains ecological systems. In the future, EIA data from larger sample sizes of plains reference condition sites with multiple site revisits could help characterize the natural variability inherent to these ecosystems, along with the associated plant communities and indicator species that should occur in reference examples of plains wetlands/riparian areas.

Table 30. Means and standard deviations of all FQA metrics by Ecological Systems from random condition sites.

Ecological System	Plains Floodplain n=11		Plains Riparian n=16		Foothill Riparian n=7		Foothill Wet Meadow n=3		Irr. Wet Meadow n=10		Marsh n=9		Playa n=4	
FQA Metric	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total species richness	40.9	9.9	32.5	14.5	49.7	15.4	37.0	12.1	27.9	15.4	31.2	14.9	17.0	7.0
Native species richness	18.7	6.3	18.3	12.3	25.9	13.4	20.0	8.9	12.6	7.8	16.3	9.3	11.0	5.5
Non-native species richness	19.5	4.9	12.6	5.4	21.3	5.5	15.3	4.2	12.9	8.3	13.3	6.7	5.3	2.8
% Non-native	51.5	8.5	45.0	18.1	47.2	14.7	45.0	8.6	50.2	14.0	46.6	10.1	32.5	7.2
Mean C of all species	1.7	0.4	2.1	0.8	2.2	0.7	2.4	0.6	1.9	0.5	1.8	0.5	2.5	0.4
Mean C of native species	3.5	0.4	3.9	0.4	4.2	0.4	4.4	0.5	3.9	0.4	3.4	0.3	3.7	0.6
Cover-weighted Mean C of all species	2.2	1.0	2.2	1.3	2.4	0.8	2.9	0.9	3.1	0.8	2.2	0.6	3.7	0.7
Cover-weighted Mean C of native species	3.5	0.4	3.9	0.8	3.6	0.5	4.3	0.7	4.1	0.3	3.0	0.6	4.0	0.7
FQI of all species	10.4	2.9	12.0	6.6	15.1	6.4	14.4	5.3	9.4	3.6	9.7	4.4	9.4	1.6
FQI of native species	14.8	3.1	15.7	6.5	20.5	6.5	19.4	6.2	13.3	4.1	13.1	4.7	11.5	1.8
Cover-weighted FQI of all species	13.2	5.8	12.4	8.4	16.3	7.4	17.7	8.0	14.7	3.9	11.3	4.4	14.3	3.0
Cover-weighted FQI of native species	14.9	3.7	16.0	7.2	17.4	5.6	18.9	6.9	13.9	4.2	11.4	4.7	12.9	3.9
Adjusted FQI	24.1	3.9	28.2	6.0	30.0	5.9	32.8	5.6	27.3	4.4	24.6	4.0	30.2	4.6
Adjusted cover-weighted FQI	24.2	4.4	28.8	8.2	25.4	5.0	31.9	6.2	28.7	5.3	21.5	4.9	33.4	6.9

5.4 Level 2/3 Assessment: Ecological Integrity Assessment

5.4.1 EIA Scores of Sampled Wetlands and Riparian Areas for Condition Assessment

Level 2 condition scores were calculated for all of the random and reference condition wetlands and riparian areas sampled in the study area. EIA scores are translated into a 4-tiered ranking system of A, B, C, D at the site level and by site component rank: landscape integrity, biotic condition, hydrologic condition, and physiochemical condition. These ranks can be interpreted as:

A = Reference (no or minimal human impact)
B = Slight deviation from reference
C = Moderate deviation from reference
D = Significant or severe deviation from reference

Within the Lower South Platte basin, no random sites scored an A rank at the site level (Table 30 and Figure 28). More than half of the sites ranked as C's, and the remainder of sites had B and D ranks. Reference condition sites, on the other hand, most frequently ranked as B's. Their ranks ranged from A's to C's, with no D's. The only A-ranking reference wetlands occurred in playa ecological systems. Reference playas usually had no hydrologic modifications, and were set in a relatively contiguous landscape. The seven D-ranking sites most frequently occurred in either constructed wetlands such as impounded plains riparian areas, or unnatural wetlands such as irrigated wet meadows and depressional marshes. Emergent marshes were the lowest scoring wetland types, with no sites ranking above a C. There were not any strong trends in site condition by ecoregion, except that no D-ranked sites were surveyed in the Moderate Relief Plains (Table 31 and Figure 29). However, a number of initially targeted heavily altered playas (farmed or pitted) were not sampled from this ecoregion, which would have likely ranked as D's if sampled.

The component condition ranks help explain the drivers of the overall EIA ranks, by examining the landscape context, biotic condition, hydrologic condition, and physiochemical condition ranks (Table 32). Except for biotic condition, reference condition sites ranked from reference to fair condition in the component ranks. Across random sites, the full range of ranks was assigned for all component categories. Over 25% of the random sites scored A's in landscape integrity. Although the study area is a working landscape with numerous land uses at the basin scale, east of the Front Range corridor, the basin is fairly rural. Many of the plains wetland and riparian ecological systems were situated in a contiguous landscape setting, with undeveloped land cover providing a buffer surrounding the surveyed wetland point. However, far fewer sites ranked even a B in biotic condition. Even where the landscape was contiguous, weeds were common, often in high cover, and the plant community composition indicated response to some stress. Three-quarters of the sites ranked as A's and B's in physiochemical condition. However, most random sites did not have surface water, and without water the physiochemical condition is based entirely on having an intact substrate. Most of the hydrologic ranks were B's or C's. We would have expected the hydrology to rank more similarly to the biota, given the intensive water management ubiquitous to the water-limited plains environment. Hydrology is a challenging metric to rate at the site-level in the plains. Many cumulative and non-point hydrologic stressors exist in the basin, but they may not be visible in the field if sites are not directly adjacent to ditches, head gates, or irrigated lands. The existing hydrology EIA metrics were also developed in the mountains, where alterations to hydrology were often more visible at a local scale. For future wetland/riparian surveys in the plains, there is a need to define and evaluate new potential hydrology EIA variables that may better suit the plains setting, and that are based on visible alterations to the site's hydrology.

5.4.2 Common Stressors Observed in Sampled Wetlands and Riparian Areas

Selected land uses both within the AA and within a 500m envelope surrounding the AA were noted to identify potential sources of stress affecting the condition of the basin's wetlands and riparian areas. Stressors were noted at most sites, and often a wide variety of multiple stressors were recorded. The most frequently noted stressors were development of roads and structures surrounding the sites (Table 33). Light to moderate grazing, and human land use and recreation were also common within and surrounding the AA's. Agricultural irrigation related stressors frequently impacted site hydrology within and surrounding the AA. Compaction and soil disturbance were common physiochemical stressors from human use or livestock.

Table 31. EIA ranks by Ecological Systems of reference and random sites in condition sample frames.

# Random Sites x Ecological System	A	B	C	D	Total
Western Great Plains Riparian	-	4	8	4	16
Western Great Plains Floodplain	-	4	7	-	11
Irrigation-Influenced Wet Meadow	-	3	5	2	10
North American Arid West Emergent Marsh	-	-	8	1	9
Foothill Riparian Woodland and Shrubland	-	3	4	-	7
Playa	-	3	1	-	4
Foothill Wet Meadow	-	2	1	-	3
Total Random	0	19	34	7	60
% of Random Sites	0%	32%	57%	12%	100%
# Reference Site Visits[1] x Ecological System					
Western Great Plains Riparian	-	5	-	-	5
Western Great Plains Floodplain	-	3	4	-	7
Foothill Riparian Woodland and Shrubland	-	2	2	-	4
Playa	4	6	-	-	10
Foothill Wet Meadow	-	1	1	-	2
Fen	-	1	-	-	1
Total Reference Visits	4	18	7	0	29
% of Reference Visits	14%	62%	24%	0%	100%

[1] Three reference sites were visited twice with full EIA recorded. EIA scores are tallied separately for these sites, as data/condition varied between visits.

Table 32. EIA ranks by ecoregional strata of random condition sites.

Ecoregion	A	B	C	D	Total
25d	0	5	9	1	15
25l	0	3	8	2	13
25c	0	6	5		11
26	0	3	5	3	11
25b	0	2	7	1	10
Total	0	19	34	7	60
% of Sites	0%	32%	57%	12%	100%

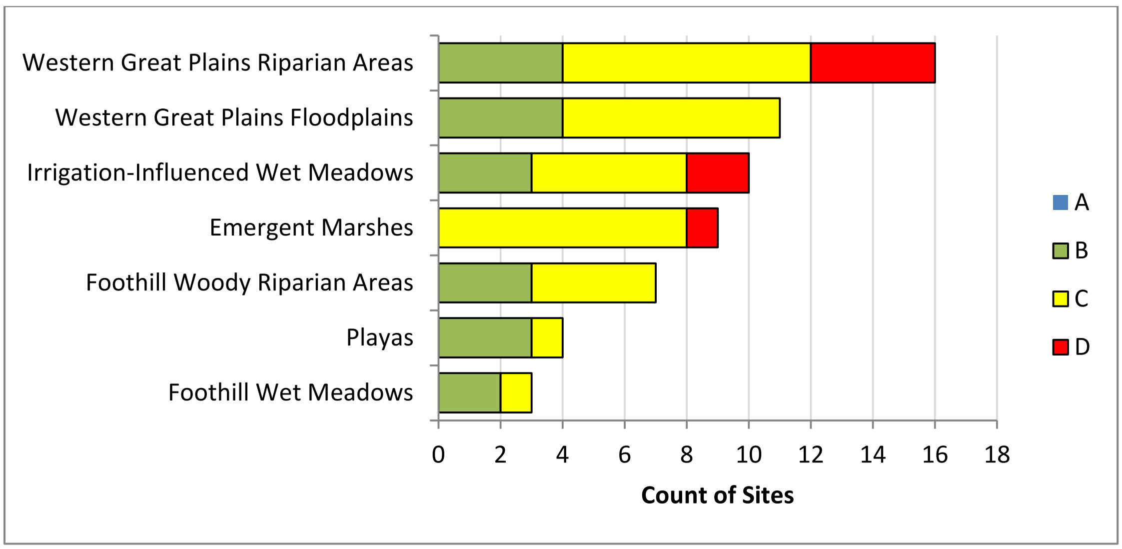


Figure 28. EIA ranks by Ecological Systems of random condition sites.

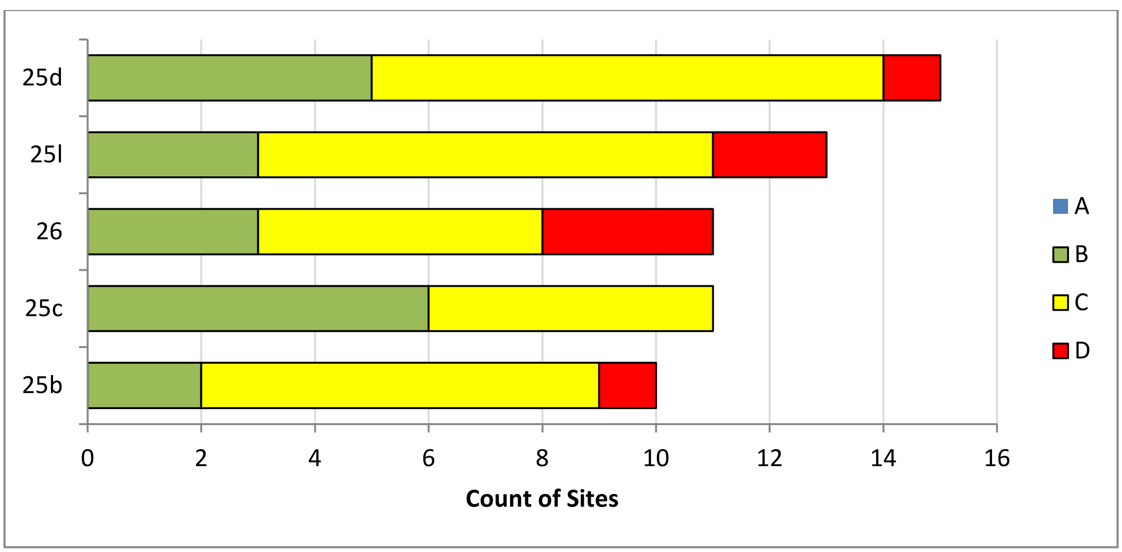


Figure 29. EIA ranks by ecoregional strata of random condition sites.

Table 33. Component EIA ranks by Ecological Systems in condition sample frames.

Condion Sample Frame	Random Sites					Reference Site Visits[1]				
Component Rank x Ecological System	**A**	**B**	**C**	**D**	**Total**	**A**	**B**	**C**	**D**	**Total**
Landscape Context										
Western Great Plains Riparian	5	7	3	1	16	3	2	-	-	5
Western Great Plains Floodplain	4	5	2	-	11	2	4	1	-	7
Irrigation-Influenced Wet Meadow	2	4	2	2	10	-	-	-	-	-
North American Arid West Emergent Marsh	-	6	3	-	9	-	-	-	-	-
Foothill Riparian Woodland and Shrubland	1	2	3	1	7	-	3	1	-	4
Playa	2	2	-	-	4	7	3	-	-	10
Foothill Wet Meadow	2	1	-	-	3	1	1	-	-	2
Fen	-	-	-	-	-	-	1	-	-	1
Total	**16**	**27**	**13**	**4**	**60**	**13**	**14**	**2**	**0**	**29**
Biotic Condition										
Western Great Plains Riparian	-	3	3	10	16	-	2	3	-	5
Western Great Plains Floodplain	-	-	4	7	11	-	-	4	3	7
Irrigation-Influenced Wet Meadow	-	-	3	7	10	-	-	-	-	-
North American Arid West Emergent Marsh	-	-	2	7	9	-	-	-	-	-
Foothill Riparian Woodland and Shrubland	-	-	4	3	7	-	-	4	-	4
Playa	-	3	1	-	4	2	9	3	-	14
Foothill Wet Meadow	-	-	2	1	3	-	-	1	1	2
Fen	**-**	**-**	**-**	**-**	**-**	-	-	1		1
Total	**0**	**6**	**19**	**35**	**60**	**2**	**11**	**16**	**4**	**33**
Hydrologic Condition										
Western Great Plains Riparian	-	4	9	3	16	-	5	-	-	5
Western Great Plains Floodplain	-	9	2	-	11	-	4	3	-	7
Irrigation-Influenced Wet Meadow	-	5	2	3	10	-	-	-	-	-
North American Arid West Emergent Marsh	-	1	6	2	9	-	-	-	-	-
Foothill Riparian Woodland and Shrubland	-	2	4	1	7	-	3	1	-	4
Playa	-	2	1	1	4	6	4	-	-	10
Foothill Wet Meadow	-	1	2	-	3	-	2	-	-	2
Fen	**-**	**-**	**-**	**-**	**-**	**-**	1	-	-	1
Total	**0**	**24**	**26**	**10**	**60**	**6**	**19**	**4**	**0**	**29**
Physiochemical Condition										
Western Great Plains Riparian	1	7	7	1	16	3	2	-	--	5
Western Great Plains Floodplain	4	6	1	-	11	5	2	-	-	7
Irrigation-Influenced Wet Meadow	-	7	2	1	10	-	-	-	-	-
North American Arid West Emergent Marsh	4	4	1	-	9	-	-	-	-	-
Foothill Riparian Woodland and Shrubland	5	2	-	-	7	2	2	-	-	4
Playa	-	4	-	-	4	9	1	-	-	10
Foothill Wet Meadow	1	-	2	-	3	1	1	-	-	2
Fen	**-**	**-**	**-**	**-**	**-**	**-**	1	-	-	1
Total	**15**	**30**	**13**	**2**	**60**	**20**	**9**	**0**	**0**	**29**

[1] Three reference sites were visited twice with full EIA recorded. An additional four sites were visited a third time with just Biotic data recorded. EIA component scores are tallied separately for these sites, as data/condition varied between visits.

Table 34. Common recorded landscape, vegetation, hydrologic, and physiochemical disturbances observed by ecological system in random condition sites (continued on next page).

Stressor by Ecological System	Plains Rip. n=16	Plains Flood. n=11	Irr. Wet Meadow n=10	Marsh n=9	Foothill Rip. n=7	Playa n=4	Foothill Wet Meadow n=3	Total n=60
Landscape Stressors in 500m Envelope Surrounding AA								
Unpaved roads	15	10	7	8	5	2	3	50
Domestic or commercially developed buildings	8	3	5	6	6	1	3	32
Paved roads, parking lots, railroad tracks	4	6	6	6	5		2	29
Agriculture – tilled crops	6	9	4	3	2	1		25
Light grazing/browse by livestock/native ungulates	7	6	2	3	4	2	1	25
Light recreation or human visitation	4	6	2	5	4	2	2	25
Moderate grazing/browse by livestock/native ungulates	9	1	7	1		1	1	20
Water storage reservoirs - open water	1	1	4	3	3		1	13
Moderate recreation or human visitation	2	2	2		3		1	10
Intensively managed lawns/urban parks/golf courses	1		1	2	4			8
Stressors recorded in <10% of random sites	12	4	9	9	6	0	2	42
Other	12	4	9	9	6	0	2	42
Total	**69**	**48**	**49**	**46**	**42**	**9**	**16**	**279**
Mean # Landscape Stressors/Site	**4.3**	**4.4**	**4.9**	**5.1**	**6.0**	**2.3**	**5.3**	**4.7**
Vegetation Stressors in AA								
Light recreation or human visitation	3	5	1	2	4	2	2	19
Light grazing by livestock or native ungulates	8	3	2	2	3			18
Moderate grazing by livestock/native ungulates	6	1	**6**	1		1	1	16
Other	6	2	9	3	1	0	2	23
Total	**23**	**11**	**18**	**8**	**8**	**3**	**5**	**76**
Mean # Vegetation Stressors/Site	**1.4**	**1.0**	**1.8**	**0.9**	**1.1**	**0.8**	**1.7**	**1.3**

Stressor by Ecological System	**Plains Rip. n=16**	**Plains Flood. n=11**	**Irr. Wet Meadow n=10**	**Marsh n=9**	**Foothill Rip. n=7**	**Playa n=4**	**Foothill Wet Meadow n=3**	**Total n=60**
Hydrology Stressors Within and 500m Surrounding AA								
Agricultural runoff - observed or potential	4	4	6	3	2		2	21
Berms, dikes, levees - hold water in the wetland	8	2	3	3	3	1		20
Pumps/diversions/ditches move water into wetland	2		6	3	2	2		15
Dam / reservoir	1		2	2	4		2	11
Impoundment / stock pond	4		2	1	2			9
Pumps/diversions/ditches move water out of wetland	2	1	2	3	1			9
Observed or potential urban runoff		1	1	2	4			8
Flow obstructions into or out of wetland (lack of culverts)	4		1	1	1			7
Extensive ground water wells		3			2	1		6
Other	3	2	2	3	6	1	0	17
Total	**28**	**13**	**25**	**21**	**27**	**5**	**4**	**123**
Mean # Hydrology Stressors/Site	**1.8**	**1.2**	**2.5**	**2.3**	**3.9**	**1.3**	**1.3**	**2.1**
Physiochemical Stressors within AA								
Compaction and soil disturbance by human use	8	1	7	1			1	18
Compaction and soil disturbance by livestock/ungulates	5	1	1	1		2		10
Direct application of agricultural chemicals	1	1	3	2	1	1	1	10
Discharge or runoff from feedlots		3	3	1	1	1		9
Erosion	1	1		2		2	1	7
Filling or dumping of sediment	1		2	2	1			6
Other	4	2	4	3	3	0	2	16
Total	**40**	**18**	**40**	**24**	**12**	**12**	**10**	**154**
Mean # Physiochemical Stressors/Site	**2.5**	**1.6**	**4.0**	**2.7**	**1.7**	**3.0**	**3.3**	**2.6**

6.0 Results: Assessment of Wildlife Habitat

6.1 Mapped Acres of Wildlife Habitat

To understand the quantity of habitat available to priority wetland dependent wildlife species, a crosswalk between the habitat types and NWI codes was developed, allowing for mapped wetlands to be summarized by these habitat types (Table 34). The figures are rough estimates, however, given the inaccuracy of the NWI mapping, as explained in Section 4.2.

Table 35. Wetland acreage in the Lower South Platte River Basin by habitat types.

Habitat Types	NWI Codes	Acres	% of NWI Acres
Wet meadow (natural or irrigation-influenced) / Riparian wetland (herbaceous)	PEMA, PEMAd, PEMC, PEMCd, PEMB, PEMK, PEMKC, PEMKF	80,541	31.8%
Cottonwood galleries	PFO*	42,820	16.9%
Playas (including farmed playas)	PEMAf, PEMJ, Pf, PUSA, PUSAh, PUSAx, PUSC, PUSCh, PUSCx, PUSJ, PUSKA, PUSCK	13,259	5.2%
Riparian wetlands (woody)	PSS*	8,971	3.5%
Emergent marsh	PUBF, PUBG, PABF, PABG, PEME, PEMFd	7,406	2.9%
Stock ponds or other excavated / impounded wetlands (including some vegetated irrigation ditches)	PABFh, PABFx, PABGh, PABGx, PEMAh, PEMAx, PEMCh, PEMCx, PEMFh, PEMFx, PUCGh, PUBGx, PUBK, PUBKF, PUBKG	5,380	2.1%
Beaver ponds	PABGb, PEMFb	2	< 1%
Lakes and lake shores	All Lacustrine system codes	51,407	20.3%
Perennial rivers and streams	All R*UB and SB codes except R4SBCx, R4SBKA, R4SBKC	32,744	12.9%
Unvegetated irrigation canals	R4SBCx, R4SBKA, R4SBKC	7,426	2.9%
Sandbars	All R*US codes	3,567	1.4%
Total		253,661	100%

The most common habitat type mapped in the basin was wet meadow / herbaceous riparian wetland, with over 80,000 acres and 32% of all NWI acres mapped. Based on the accuracy assessment, however, up to half of these acres are likely incorrectly mapped. As the NWI classes encompassed in this habitat type are on the drier end of Palustrine Emergent, a good portion of them would be mapped as upland today, meaning the true acreage of this herbaceous habitat is closer to 40,000. Based on irrigated lands data, perhaps up to 10,000 of these remaining 40,000 acres are directly irrigated. After meadows, lakes are the most commonly mapped habitat, with over 50,000 acres, and this figure is reasonably accurate. Cottonwood galleries are the third most common habitat, with over 40,000 acres. This number is also reasonable accurate, though would be separated into ~33,000 acres of dry cottonwood stands and less than 10,000 of wet cottonwoods and associated shrubs.

6.2 Classification of Survey Sites by Habitat Type

In the field, sites were classified by habitat type along with the Ecological System and HGM classifications. Habitats are smaller patches than Ecological Systems and more than one habitat could occur within an individual site. This is especially true in the floodplain and riparian systems (plains floodplain, plains riparian, and foothill riparian sites), which were often a mosaic of habitat patches.

Within the random sites surveyed, there was a tight one-to-one relationship between meadows and playas in both the Ecological System and habitat classifications (Table 35). However, the nine sites classified as marshes within the Ecological System classification were broken out more specifically by habitat into warm water sloughs (2), emergent marsh (6), recharge pond/moist soil unit (1), and recreation pond (1), with generally one habitat patch per site. The only exception was a large marshy site that contained a warm water slough within it. The entire site was classifies as marsh in the Ecological Systems key, but the slough was called out as a separate habitat patch.

All three riparian systems included various habitat patches. Plains floodplain sites contained up to four patches per site, with an average of 1.5. The most common habitat was cottonwood gallery, found in 9 of 11 plains floodplain sites. This habitat was not considered particularly valuable for the priority species and was not assessed with the species-based indices (see Section 6.2). Other common habitats within the plains floodplain system included both woody and herbaceous riparian vegetation, sandbars, river channels, and warm water sloughs.

Within the plains riparian system (the smaller, tributary streams on the plains), the most common habitat type was stream channel (6 of 16 sites). These channels were often intermittent or ephemeral and were dry with mesic herbaceous vegetation at the time of sampling, but did have evidence of bed and bank. The second most common habitat patch was stock pond (5 of 16). These ponds were bermed depressions within the otherwise intermittent or ephemeral stream channels on the plains. Most were dry at the time of sampling, but were clearly meant to hold water whenever possible. Other habitat patches include open mesic vegetation, cottonwood gallery, and both woody and herbaceous riparian vegetation. These sites were less complex, in general, with 1.2 patches per site on average and a maximum of two patches.

The foothills riparian system was the most diverse in terms of habitat patches, with 1.7 patches per site on average and up to four patches in total. These sites were more likely to have woody riparian vegetation (5 out of 7 sites) and did contain some marsh vegetation, along with cottonwood, a sandbar, and a stream channel. One site was classified as a gravel pit because it was foothill riparian vegetation growing on the edge of a reclaimed gravel pond.

Table 36. Habitat types within random sample sties by Ecological System.

	Plains floodplain (n = 11)	Plains riparian (n = 16)	Foothills riparian (n = 7)	Marsh (n = 9)	Irrigation-influenced wet meadow (n = 10)	Natural wet meadow and fen (n = 3)	Playa (n = 4)	Grand Total
Natural habitat types								
Riparian wetland (woody)	2	1	5					8
Riparian wetland (herbaceous)	1	2						3
Sandbar	1		1					2
River / stream channel	2	6	1					9
Warm water slough	2			2				4
Cottonwood gallery	9	2	2					13
Open mesic vegetation		3						3
Emergent marsh			2	6				8
Wet meadow					10	3		13
Playa							4	4
Human-created habitat types								
Recharge pond / moist soil unit				1				1
Recreational pond				1				1
Gravel pit			1					1
Stock pond		5						5
Average habitat patches per site	1.5	1.2	1.7	1.1	1	1	1	
Max habitat patches per site	4	2	4	2	1	1	1	

In all, wet meadow and cottonwood gallery were the most common habitats encountered in the random sites, with thirteen patches each. River / stream channel was next with nine patches, while emergent marsh and riparian woody both had eight patches. There were five stock ponds, four warm water sloughs, and four playas. The rest of the habitats had three or few occurrences.

The habitat classification of the randomly selected priority habitats was more straightforward, as one might assume. All ten warm water sloughs were understandably considered warm water sloughs. Of the eighteen moist soil units and recharge ponds, one contained a warm water slough, which was called out separately. The rest were simply classifies as recharge pond / moist soil unit.

6.3 Assessment of Habitat Quality

In the field, sites were assessed for habitat quality based on the variables selected through the habitat research (see Appendix A). Raw data were collected on the same variables regardless of habitat, but different variables were used to assess habitat quality for different species. This was done through seventeen habitat indices developed through the habitat research and analyzed in an Access database. Each index applied to a specific set of habitats, depending on the habitat preference of the species. The only habitats not included in any index were cottonwood gallery and open mesic vegetation. These two habitat types occupied all of 13 out of 60 sites, meaning 22% of sites had no habitat value calculated by these indices. The following results present habitat value of the 60 random sites first, by priority species group, and then of the randomly selected priority habitats.

6.3.1 Dabbling Ducks

Three separate indices were developed for dabbling ducks: Duck Diurnal Marsh, Duck Diurnal Meadow, and Duck Nocturnal. Ducks occupy most of the habitat types surveyed in this project. During the day, they are found in any of the moist environments, only excluding cottonwood gallery and open mesic vegetation. This means that suitable duck diurnal habitat was found in 47 of the 60 random sites (78%). Diurnal habitat values were calculated for most habitats with the Duck Diurnal Marsh index, but wet meadows were evaluated separately with the Duck Diurnal Meadow index. Results from both are combined in Table 36 and Figure 30.

The overall value of diurnal duck habitat was moderate, with a score of 0.56 out of 1.00. Sandbars had the highest scores for diurnal duck habitat, but were found in only two sites. The one reclaimed gravel pit also had high habitat value. Warm water sloughs, wet meadows, and stock ponds each had at least one site with high habitat value. All other habitats had medium to low habitat value.

Suitable nocturnal habitat was found in fewer sites, 31 out of 60 (52%). Woody riparian areas, sandbars, and wet meadows were generally not considered nocturnal habitat. Overall nocturnal habitat value was also moderate, with a score of 0.52 (Table 37). The best nocturnal habitat was found in warm water sloughs and one stock pond (Figure 31).

Table 37. Index values for diurnal duck habitat.

Habitat Type	Mean	Max	Min	SD
Sandbar	0.90	1.00	0.80	0.14
Gravel pits	0.74	0.74	0.74	
Warm water slough	0.64	0.86	0.45	0.17
Wet meadow	0.63	0.73	0.47	0.07
Stock pond	0.59	0.83	0.52	0.14
Recharge pond / moist soil unit	0.54	0.54	0.54	
River / stream channel	0.53	0.61	0.48	0.05
Riparian wetland (herbaceous)	0.51	0.52	0.51	0.01
Playa	0.51	0.51	0.51	0.00
Emergent marsh	0.50	0.64	0.41	0.09
Recreational pond	0.50	0.50	0.50	
Riparian wetland (woody)	0.44	0.61	0.30	0.10
Overall	**0.56**	**1.00**	**0.30**	**0.13**

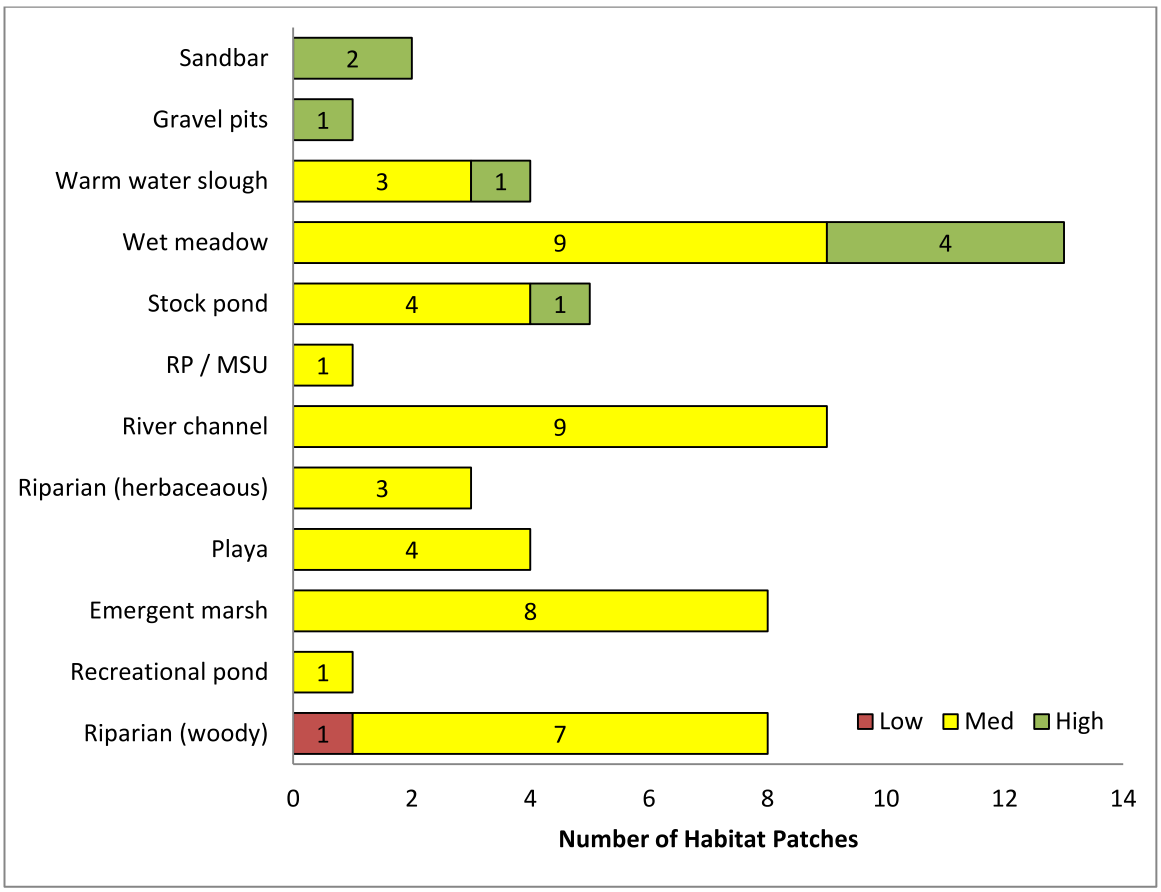


Figure 30. Index rank (High, Med, Low) for diurnal duck habitat.

Table 38. Index values for nocturnal duck habitat.

Habitat Type	Mean	Max	Min	SD
Warm water slough	0.62	0.76	0.45	0.14
Stock pond	0.57	0.73	0.52	0.09
Gravel pits	0.56	0.56	0.56	
River channel	0.52	0.61	0.48	0.04
Riparian wetland (herbaceous)	0.51	0.52	0.51	0.01
Playa	0.51	0.51	0.51	0.00
Recharge pond/Moist soil unit	0.50	0.50	0.50	
Recreational pond	0.50	0.50	0.50	
Emergent marsh	0.46	0.62	0.35	0.08
Warm water slough	0.62	0.76	0.45	0.14
Overall	**0.52**	**0.76**	**0.35**	**0.08**

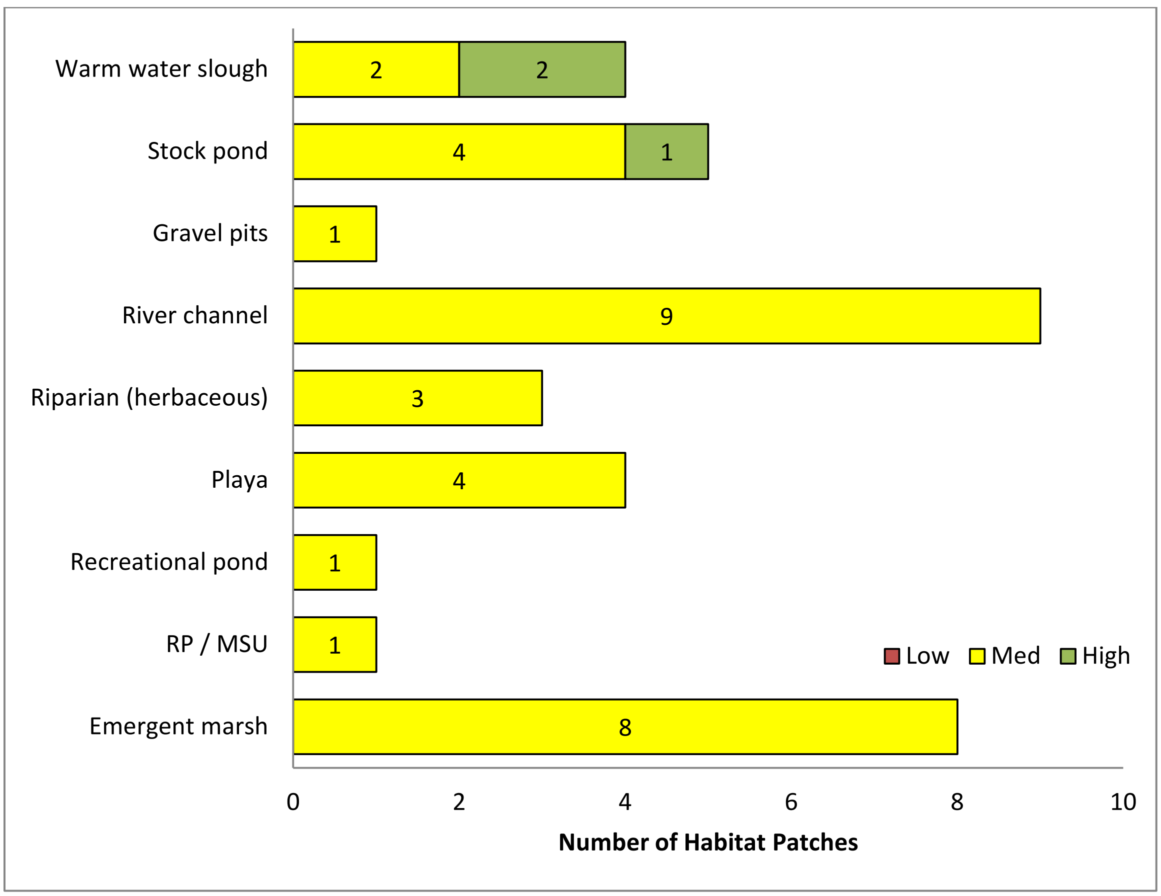


Figure 31. Index rank (High, Med, Low) for nocturnal duck habitat.

6.3.2 American Bittern

Habitat preferred by bitterns was found in 28 of 60 sites (47%), in five different habitat types (Table 38 and Figure 32). The best habitat was found in emergent marshes and warm water sloughs.

Table 39. Index values for American bittern habitat.

Habitat Type	Mean	Max	Min	SD
Emergent marsh	0.58	0.79	0.38	0.15
Warm water slough	0.60	0.71	0.54	0.08
Gravel pits	0.62	0.62	0.62	
Wet meadow	0.44	0.63	0.29	0.10
Riparian wetland (herbaceous)	0.41	0.46	0.38	0.05
Overall	**0.50**	**0.79**	**0.29**	**0.13**

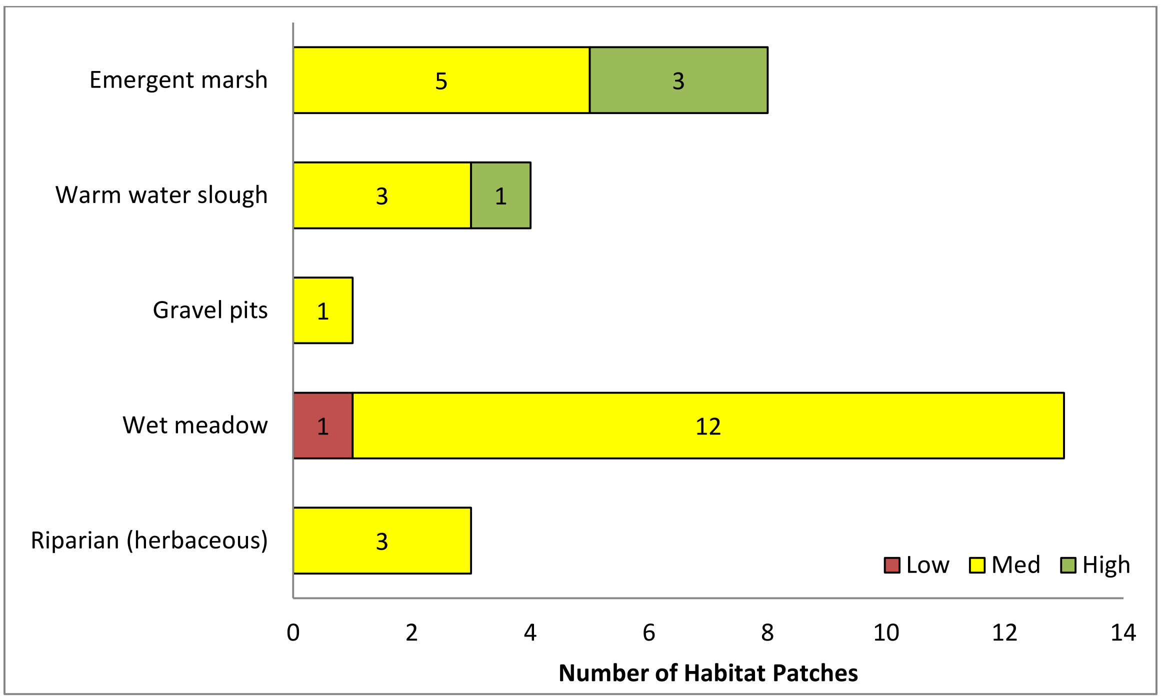


Figure 32. Index rank (High, Med, Low) for American bittern habitat.

6.3.3 Greater Sandhill Cranes

Habitat for greater sandhill cranes was evaluated separately for roosting and feeding. Feeding habitat was found in 22 of 60 sites (37%), in three different habitat types (Table 39 and Figure 33). Both emergent marshes and wet meadows had high habitat value scores for sandhill feeding and overall scores were very high (mean of 0.79). Roosting habitat was found in 12 of 60 sites (20%), in two different habitat types (Table 40 and Figure 34). Values for roosting habitat were not as high as feeding habitat.

Table 40. Index values for greater sandhill crane feeding habitat.

Habitat Type	Mean	Max	Min	SD
Emergent marsh	0.92	1.00	0.66	0.13
Wet meadow	0.62	0.89	0.33	0.23
Recharge pond / moist soil unit	0.44	0.44	0.44	
Overall	**0.79**	**1.00**	**0.33**	**0.23**

Table 41. Index values for greater sandhill crane roosting habitat.

Habitat Type	Mean	Max	Min	SD
Emergent marsh	0.56	0.96	0.33	0.21
Playa	0.46	0.66	0.39	0.14
Overall	**0.52**	**0.96**	**0.33**	**0.19**

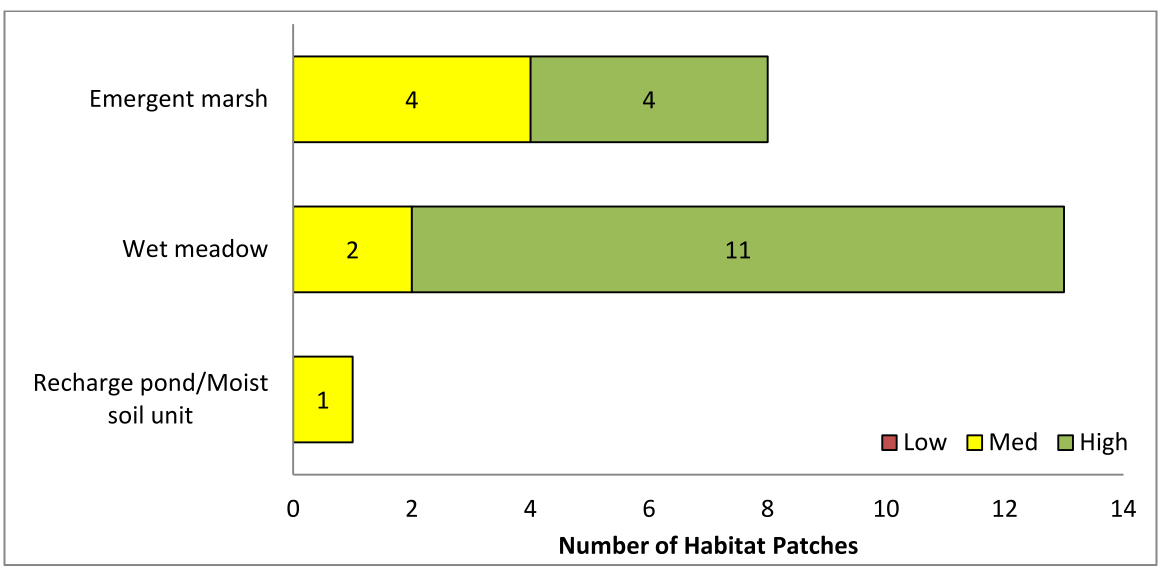


Figure 33. Index rank (High, Med, Low) for greater sandhill crane feeding habitat.

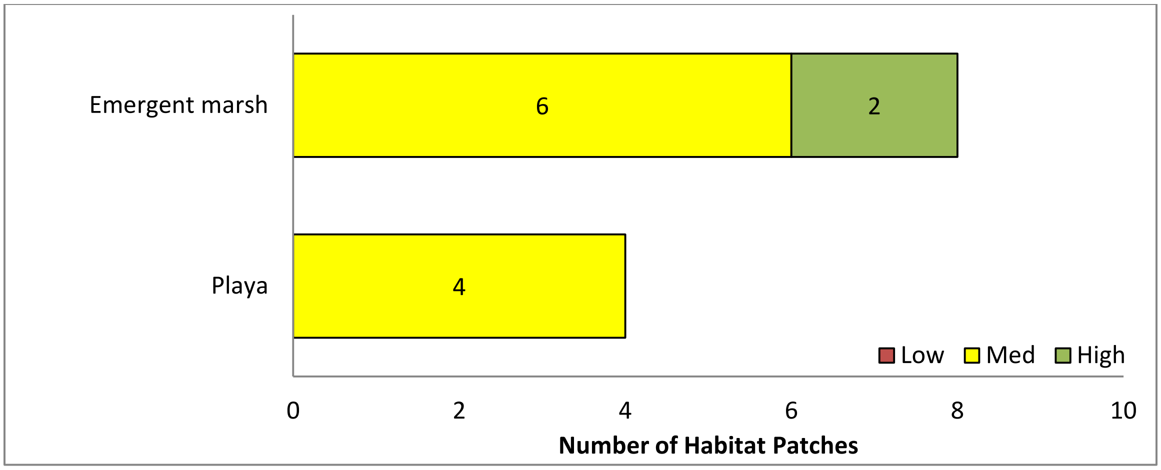


Figure 34. Index rank (High, Med, Low) for greater sandhill crane roosting habitat.

6.3.4 Long-Billed Curlew

Two habitats were evaluated for long-billed curlew, wet meadows and playas (Table 41 and Figure 35). These habitats were found in 17 of 60 sites (28%). The two habitats were evaluated with separate indices, but combined in the data below. Both habitats had high value for curlews.

Table 42. Index values for long-billed curlew habitat.

Habitat Type	Mean	Max	Min	SD
Playa	0.79	1.00	0.83	0.07
Wet meadow	0.93	1.00	0.43	0.17
Overall	**0.82**	**1.00**	**0.43**	**0.16**

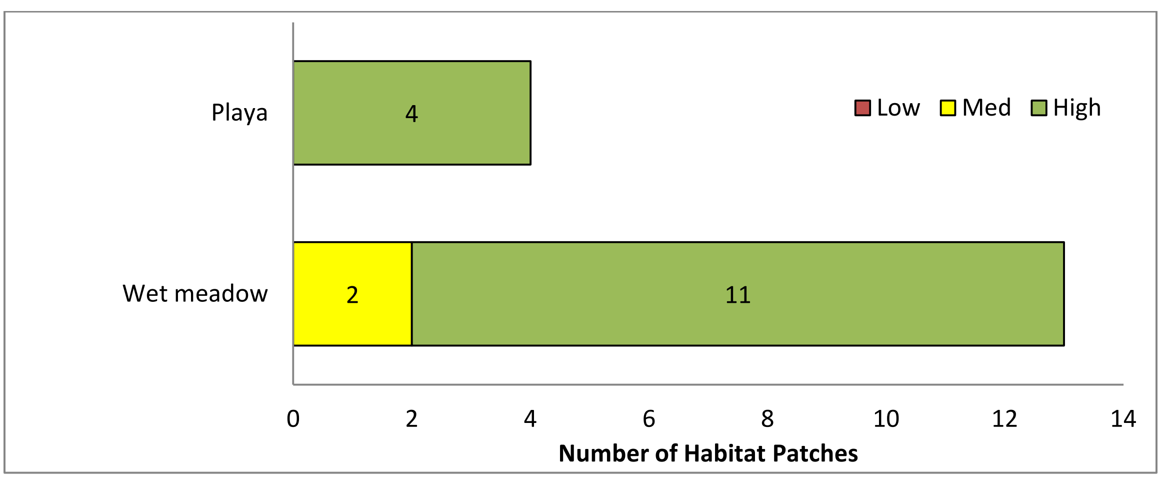


Figure 35. Index rank (High, Med, Low) for long-billed curlew habitat.

6.3.5 Piping Plover

Sandbars were the only habitats evaluated for piping plovers. Only two sandbars were surveyed in the random sites, representing only 3% of sites. Because sandbars are mapped as rivers within the NWI mapping, they were not specifically targeted, which may explain the low number of sandbars encountered. Even so, they still likely represent a small portion of the total wetland and riparian area within the basin. Of the two sandbars surveyed, one had medium habitat value and the other had high value (Table 42 and Figure 36).

Table 43. Index values for piping plover habitat.

Habitat Type	Mean	Max	Min	SD
Sandbar	0.64	0.67	0.60	0.05
Overall	**0.64**	**0.67**	**0.60**	**0.05**

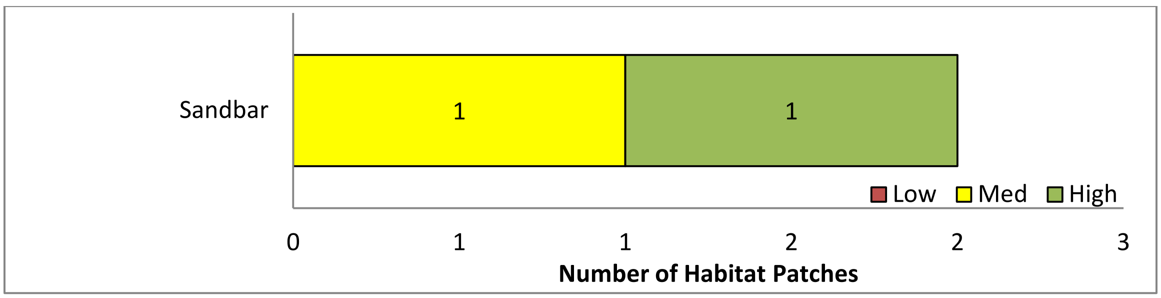


Figure 36. Index rank (High, Med, Low) for piping plover habitat.

6.3.6 Short-Earned Owl

The evaluation of short-eared owl habitat was focused on marshes, wet meadows, and plays. Most occurred in sites with a single habitat patch, but marsh habitat was also found in lower montane riparian areas. Habitat preferred by short-earned owls was found in 25 of 60 sites (42%). The best habitat was found in emergent marshes and warm water sloughs. Playas had consistently high values for short earned owl, and wet meadows had both high and medium values (Table 43 and Figure 37).

Table 44. Index values for short-earned owl habitat.

Habitat Type	Mean	Max	Min	SD
Playa	0.81	0.93	0.76	0.08
Wet meadow	0.69	0.86	0.47	0.12
Emergent marsh	0.43	0.81	0.21	0.19
Overall	**0.62**	**0.93**	**0.21**	**0.20**

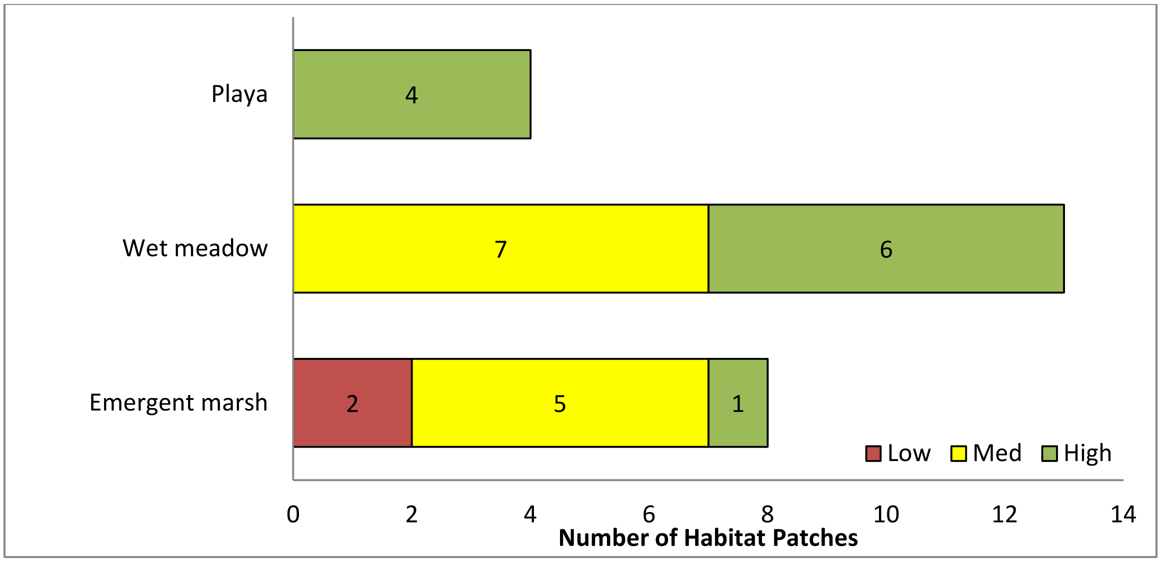


Figure 37. Index rank (High, Med, Low) for short-earned owl habitat.

6.3.7 Frog Guild

Two frogs were included as priority species, the northern leopard frog and the plains leopard frog. Their habitat needs were similar enough that they were combined in the habitat indices. Their needs during different phases of their lives, however, were very different. This led to the creation of three indices for the frog guild: Frog Feeding, Frog Breading, and Frog Wintering (Tables 44, 45, 46 and Figures 38, 39, 40). Breeding habitat was found in 29 of 60 sites (48%), feeding habitat was found in 42 sites (70%), and wintering habitat was found in 13 sites (22%). The value of breeding habitat was generally moderate, with a mean score of 0.54. Feeding habitat generally ranked high, with a mean of 0.78. Wintering habitat, however, ranked relatively low, with a mean of 0.32.

Table 45. Index values for frog feeding habitat.

Habitat Type	Mean	Max	Min	SD
Playa	0.91	1.00	0.82	0.10
Stock pond	0.89	1.00	0.76	0.11
Recharge pond/Moist soil unit	0.88	0.88	0.88	
Wet meadow	0.87	1.00	0.70	0.10
Riparian wetland (herbaceous)	0.84	1.00	0.70	0.15
Riparian wetland (woody)	0.83	1.00	0.70	0.10
Sandbar	0.76	0.82	0.70	0.08
Emergent marsh	0.70	0.88	0.52	0.14
Warm water slough	0.42	0.45	0.33	0.06
Recreational pond	0.21	0.21	0.21	
Overall	**0.78**	**1.00**	**0.21**	**0.18**

Table 46. Index values for frog breeding habitat.

Habitat Type	Mean	Max	Min	SD
Emergent marsh	0.57	0.78	0.41	0.13
Recharge pond / moist soil unit	0.65	0.65	0.65	
Gravel pits	0.62	0.62	0.62	
Warm water slough	0.57	0.59	0.51	0.04
Riparian wetland (woody)	0.54	0.65	0.39	0.12
Stock pond	0.51	0.53	0.44	0.04
Recreational pond	0.50	0.50	0.50	
Playa	0.48	0.53	0.47	0.03
Riparian wetland (herbaceous)	0.48	0.53	0.44	0.05
Overall	**0.54**	**0.78**	**0.39**	**0.09**

Table 47. Index values for frog wintering habitat.

Habitat Type	Mean	Max	Min	SD
Gravel pits	0.41	0.41	0.41	
Warm water slough	0.38	0.53	0.25	0.15
River / stream channel	0.29	0.48	0.19	0.13
Overall	**0.32**	**0.53**	**0.19**	**0.13**

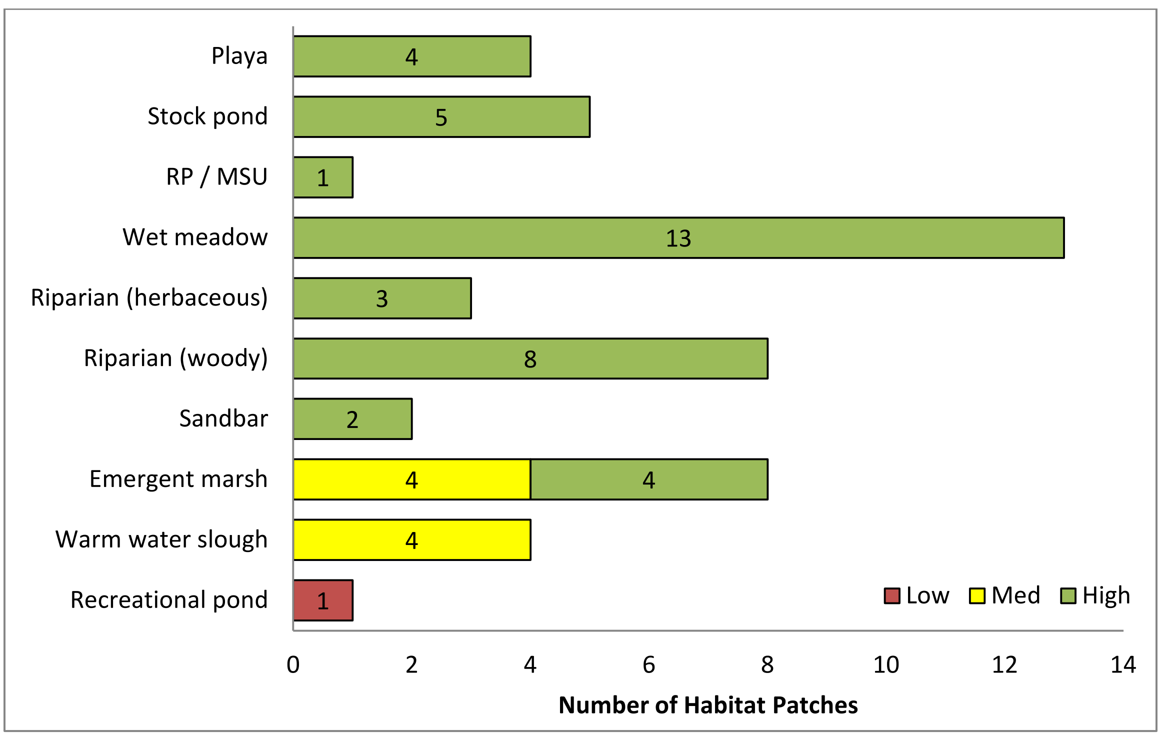


Figure 38. Index rank (High, Med, Low) for frog feeding habitat.

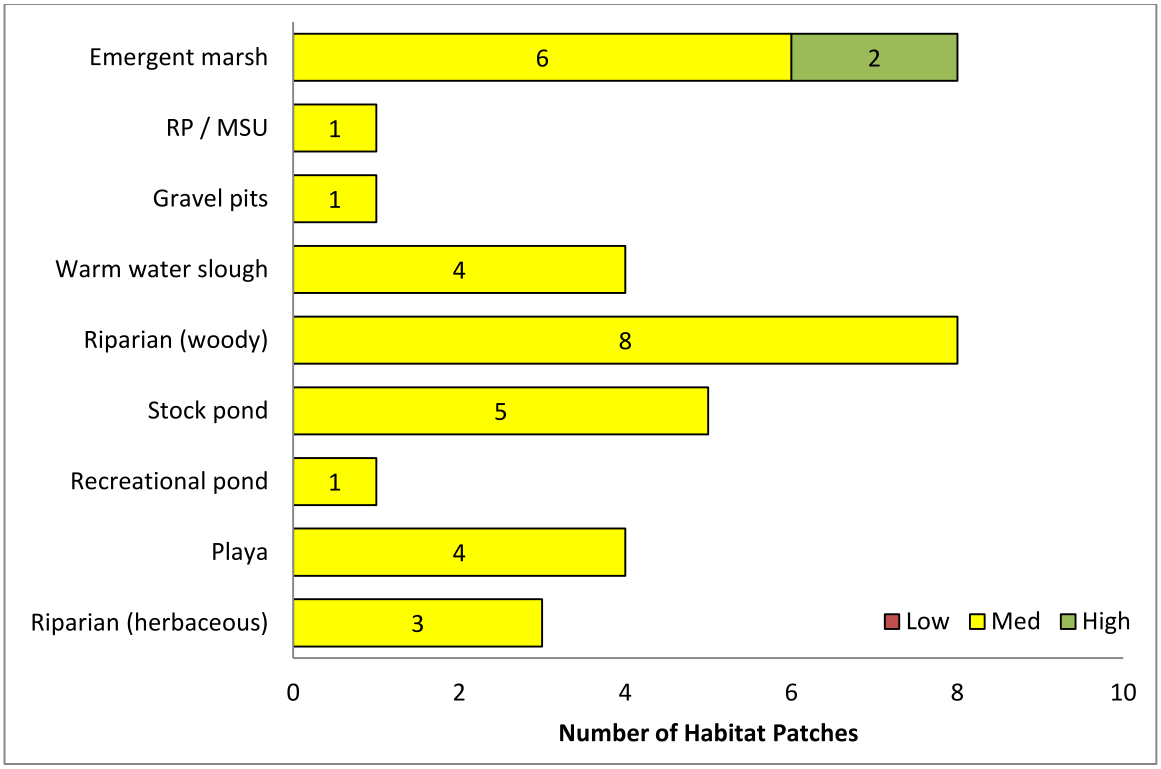


Figure 39. Index rank (High, Med, Low) for frog breeding habitat.

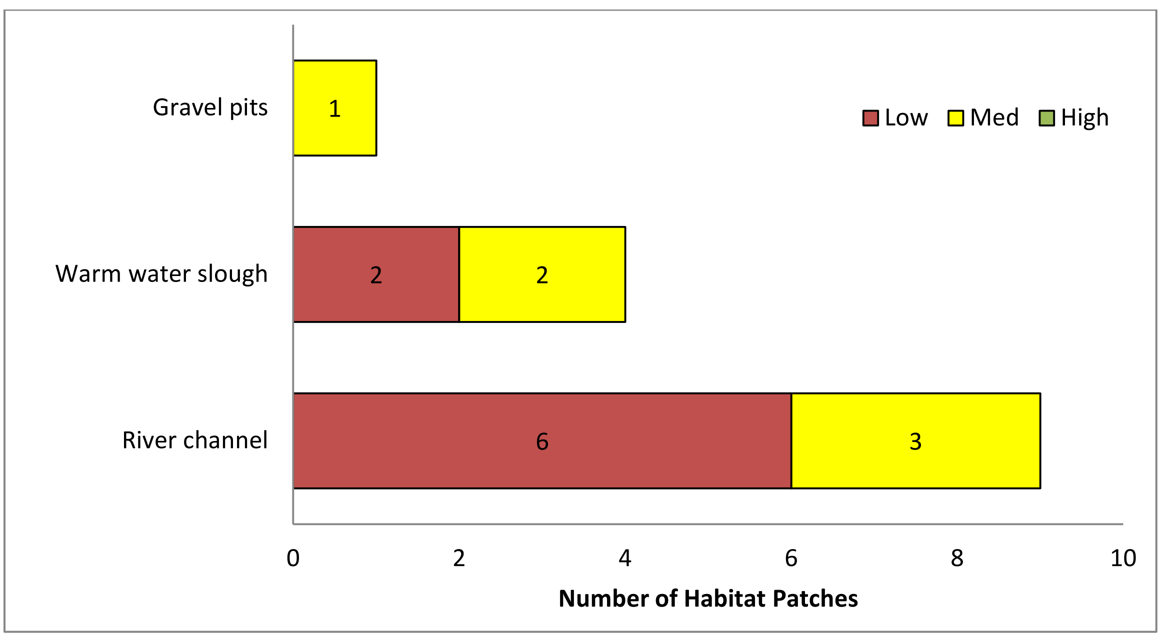


Figure 40. Index rank (High, Med, Low) for frog wintering habitat.

6.3.8 Red-Sided Garter Snake

Red-sided garter snakes can be found in a variety of habitats. All moist habitats were evaluated, except river and stream channels, bringing the number of sites with snake habitat to 47 of 60 sites (72%). High value snakes habitat was found in the moist soil unit, in several emergent marshes, one warm water slough, and two woody riparian stands (Table 47 and Figure 41).

Table 48. Index values for snake habitat.

Habitat Type	Mean	Max	Min	SD
Recharge pond/Moist soil unit	0.75	0.75	0.75	
Emergent marsh	0.65	1.00	0.24	0.27
Gravel pits	0.64	0.64	0.64	
Recreational pond	0.52	0.52	0.52	
Warm water slough	0.50	0.72	0.24	0.20
Wet meadow	0.48	0.48	0.48	0.00
Riparian wetland (woody)	0.46	0.75	0.24	0.23
Stock pond	0.43	0.48	0.36	0.07
Riparian wetland (herbaceous)	0.40	0.48	0.24	0.14
Sandbar	0.38	0.52	0.24	0.20
Playa	0.27	0.36	0.24	0.06
Overall	**0.48**	**1.00**	**0.24**	**0.18**

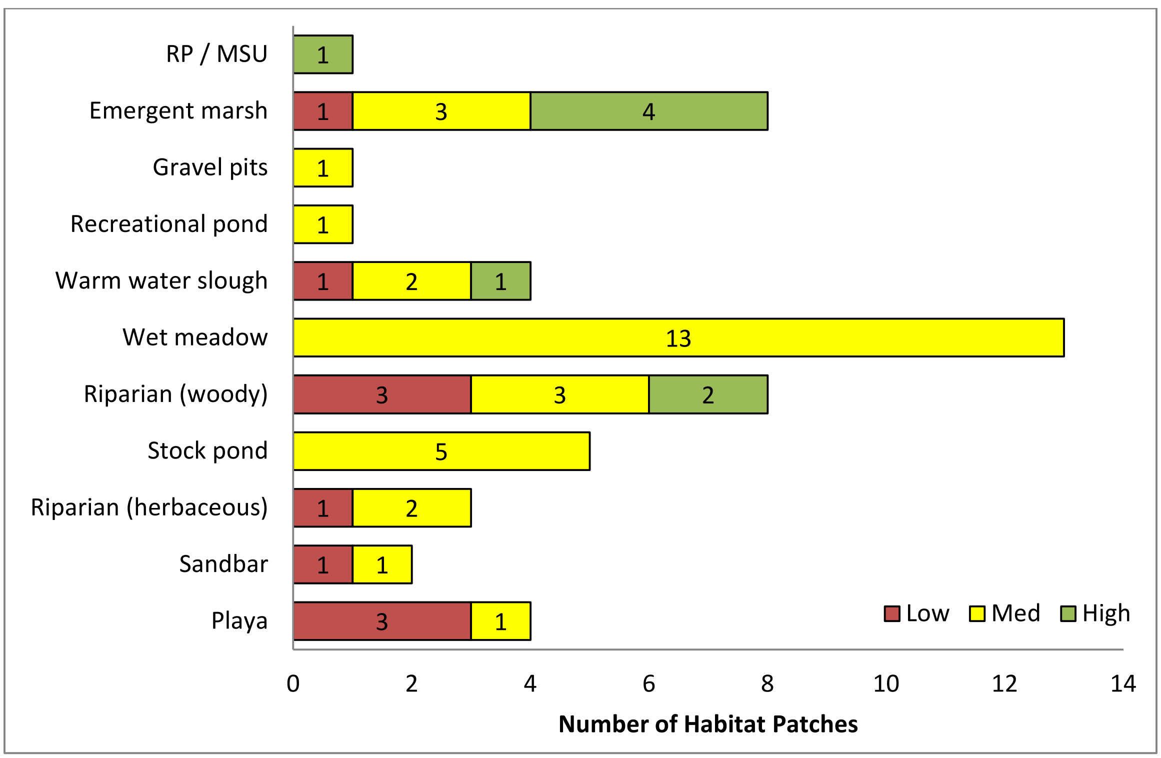


Figure 41. Index rank (High, Med, Low) for snake habitat.

6.3.9 Fish Guild

The fish guild included two rare plains species: the northern redbelly dace and the brassy minnow. Both species were combined in one index that evaluated river / stream channels and warm water sloughs. These two habitats were found in 12 of 60 sites (20%). Only one floodplain site included both a portion a channel and a slough. All other sites had either one or the other. Generally, fish habitat scored higher in warm water sloughs than in river / stream channels (Table 48 and Figure 42). Many of the plains riparian systems were intermittent or ephemeral channels and were often dry at the time of sampling. Deep water sections of the rivers themselves were not targeted in this survey, so the low habitat value scores must be viewed in that context.

Table 49. Index values for fish habitat.

Habitat Type	Mean	Max	Min	SD
River / stream channel	0.30	0.83	0.08	0.28
Warm water slough	0.56	0.83	0.33	0.21
Overall	**0.38**	**0.83**	**0.08**	**0.28**

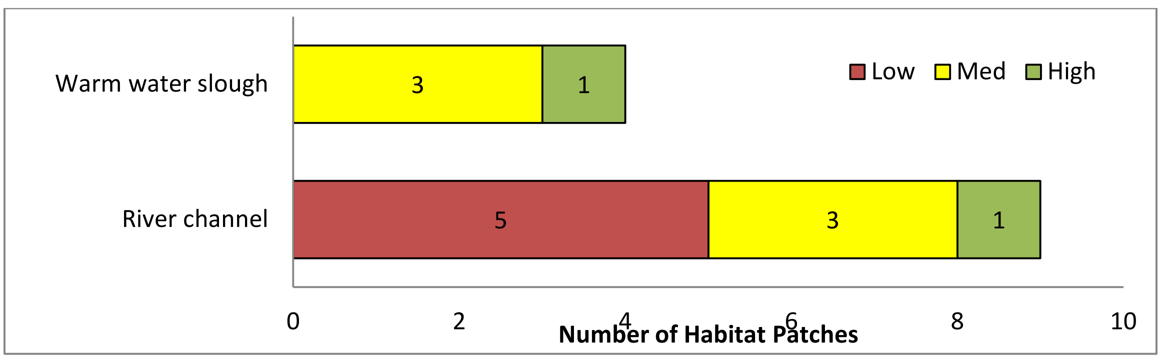


Figure 42. Index rank (High, Med, Low) for fish habitat.

6.3.10 River Otter

Like the fish index, river otter habitat was only evaluated in river / stream channels and warm water sloughs, which were found in 12 of 60 sites (20%). Otter habitat was moderate in both habitats (Table 49 and Figure 43).

Table 50. Index values for river otter habitat.

Habitat Type	Mean	Max	Min	SD
River / stream channel	0.40	0.47	0.36	0.04
Warm water slough	0.41	0.47	0.36	0.06
Overall	**0.40**	**0.47**	**0.36**	**0.05**

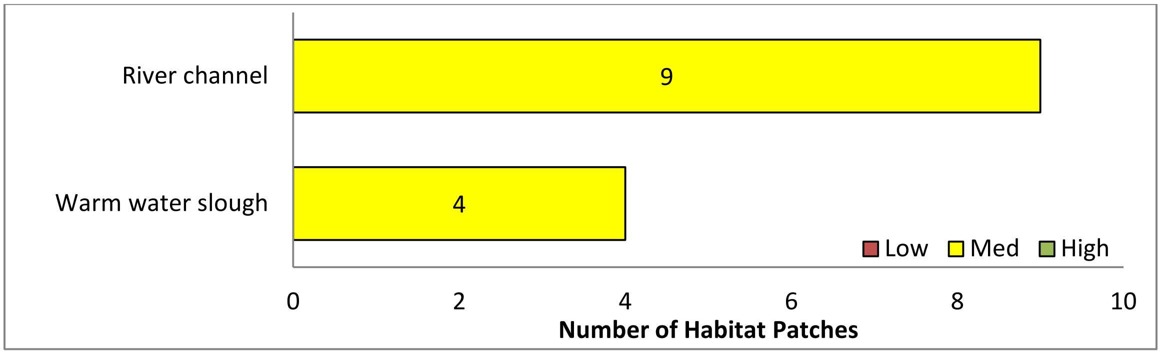


Figure 43. Index rank (High, Med, Low) for river otter habitat.

6.3.11 Summary of Random Sites by Habitat

In summary, there was a range of habitat values observed in the basin, which varied both by species group and by habitat (Table 50). Habitat for curlews appears to be in the best shape across the basin, with a mean value of 0.82 out of 1.00, though it is not as common. Sandhill feeding and frog feeding habitat also appears to be generally good in the basin. However, both those species groups rely on other habitat characteristics during their life cycle, and those other habitat indices did not score as well. For frogs in particular, the Frog Wintering index had the lowest mean scores, indicating that this may be the limiting factor or frog populations.

Table 51. Summary of habitat value by index.

Habitat Type	% of sites	Mean	Max	Min	SD
Curlew	28%	0.82	1.00	0.43	0.16
Sandhill Feeding	37%	0.79	1.00	0.33	0.23
Frogs Feeding	70%	0.78	1.00	0.21	0.18
Plover	3%	0.64	0.67	0.60	0.05
Owl	42%	0.62	0.93	0.21	0.20
Ducks Diurnal	78%	0.56	1.00	0.30	0.13
Frogs Breeding	48%	0.54	0.78	0.39	0.09
Sandhill Roosting	20%	0.52	0.96	0.33	0.19
Ducks Nocturnal	52%	0.52	0.76	0.35	0.08
Bittern	47%	0.50	0.79	0.29	0.13
Snake	72%	0.48	1.00	0.24	0.18
Otter	20%	0.40	0.47	0.36	0.05
Fish	20%	0.38	0.83	0.08	0.28
Frogs Wintering	22%	0.32	0.53	0.19	0.13

6.3.12 Priority Wildlife Habitats

Of the priority habitats visited, warm water sloughs, which are more natural environments, provided higher habitat value than did recharge ponds and moist soil units (Figures 44 and 45). Warm water slough provided high quality diurnal habitat for ducks, breeding and feeding habitat for frogs, and good general habitat for bitterns. The quality of nocturnal duck habitat and frog wintering habitat was lower, however. Habitat for both fish and otters was also relatively low. Habitat provided by soil units was best for frogs and sandhill feeding, but of lower quality for ducks. This may pose a concern for wildlife managers, as ducks are the main target for moist soil units.

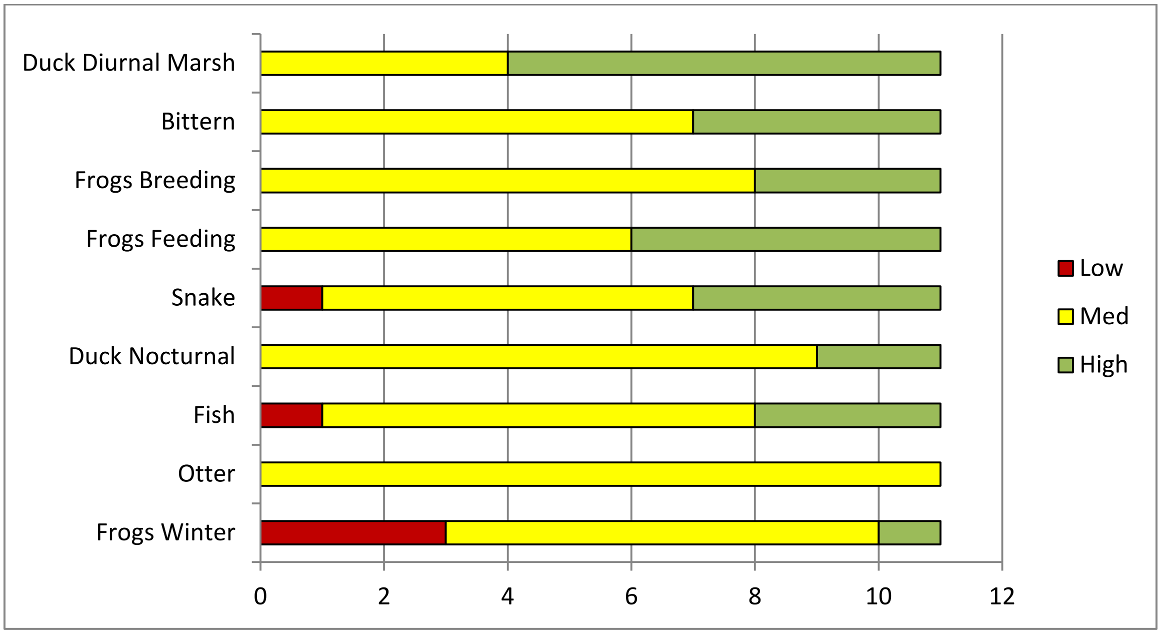


Figure 44. Index rank (High, Med, Low) for warm water sloughs.

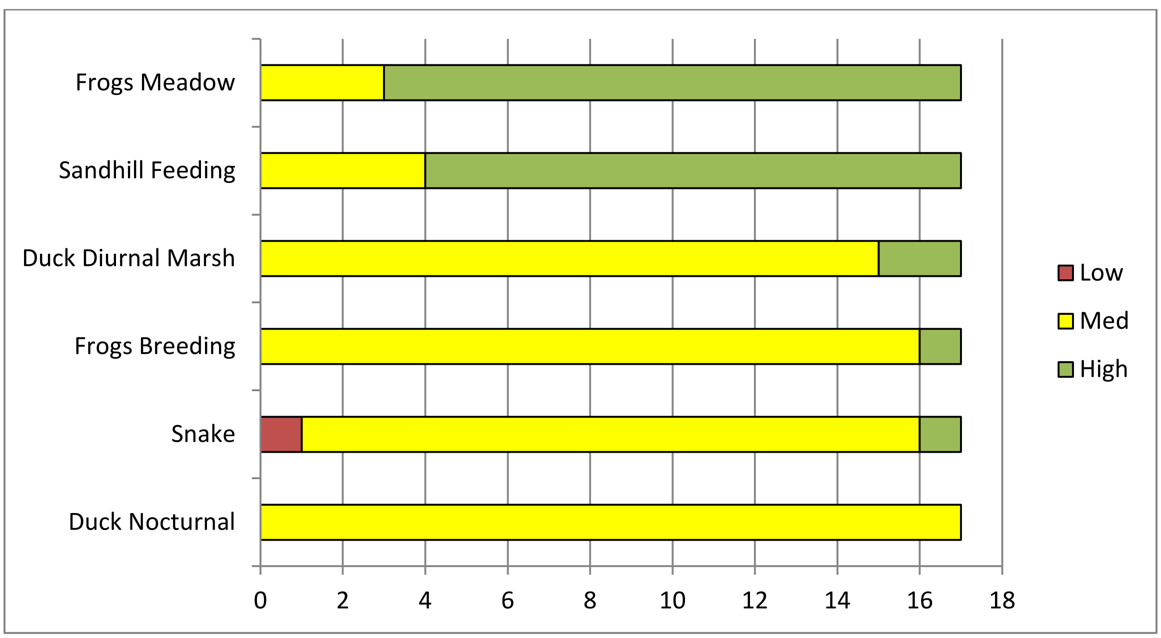


Figure 45. Index rank (High, Med, Low) for recharge ponds and moist soil units.

7.0 DISCUSSION

The overarching goal of this project was to build a foundation of scientifically grounded information on the quantity and quality of wetlands across the Lower South Platte River basin. The information obtained through four targeted objectives represents a significant advancement in our understanding of the wetland and riparian resources in the basin. The project also serves as a model for conducting future studies of plains wetlands and poses important questions for further investigation.

Converting original NWI maps from the 1970s into digital data allowed for the first estimate of wetland acres across the basin: 158,468 acres of wetlands and 95,193 acres of lakes and rivers were mapped by NWI in the 1970s. More than half these acres were concentrated along the South Platte floodplain, with an additional 15% spread across the Front Range. The mapping showed a clear dominance of herbaceous wetlands across the basin, though forested wetlands made up a notable 27% of mapped acres. Mapped wetlands and aquatic resources in the basin were overwhelmingly (83%) located on private lands.

Through a systematic accuracy assessment, however, the raw NWI acres proved to be unreliable for estimating the extent and distribution of wetlands within today's landscape. Overall accuracy of the map was less than 50%, which would be considered unacceptable for any mapping effort. Without conducting an in-depth analysis of aerial imagery from the 1970s, it is impossible to know exactly how much of the inaccuracy is related to change on the landscape since the original mapping was created and how much represents change in mapping methodology. A previous in-depth analysis comparing original NWI mapping to new, up-to-date mapping along the northern Front Range revealed that the change attributed to mapping methodology was two to three times greater than the change attributed to landscape (Lemly et al. 2013). It is reasonable to assume that mapping methods are similarly responsible for the majority of inaccuracies in the Lower South Platte. The greatest sources of inaccuracy in this study area were overmapped forested wetlands, many of which would be mapped as non-wetland riparian areas today, and overmapped herbaceous wetlands, many of which are now too dry to be considered wetlands. It is likely that most of the cottonwood galleries along the South Platte floodplain depicted in the forested wetland polygons were dry in the 1970s, as they are today, though they may be even less connected to the river channel than they were originally. However, further research would be needed to understand whether the overmapping of herbaceous wetlands represents true overmapping, even in the 1970s, or if basinwide trends towards a drier climate and increased hydrologic alterations have led to widespread drying of herbaceous wetlands.

Important conclusions can be drawn from the assessment of wetland condition as well. The Level 1 landscape analysis indicated that the majority of mapped wetlands experience high or severe stress (80% between the two stress classes). Field data also indicate high stress on wetlands and riparian areas in the basin. Based on the coarse classification of wetland/riparian source, 87% of sampled wetlands were considered natural, but altered or augmented and only 2% were considered relatively unaltered. Compared to mountainous areas of Colorado, this represents a very high degree of alteration to natural wetlands. However, few sites in the Lower South Platte (12%) were classified as non-natural features derived entirely from human action (intentional or unintentional). This is a significantly lower number than found in a focused study of wetlands in the urban Front Range corridor (74%: Lemly et al. 2013), indicating that, though stressed, the Lower South Platte wetland and riparian resources are still more natural than those found in Colorado's more highly developed regions.

Sites sampled in the basin included a wide range of wetland and riparian types, from those closely tied to rivers and streams, to those driven entirely by precipitation events. Many sites surveyed were either entirely dry, non-wetland riparian areas or were boarder line wetlands that contained relict hydric soils or remnant wetland plants. This does indicate that wetlands in the basin may be drying. Of all wetland and riparian types surveyed, warm water sloughs most consistently contained water and represent the majority of true wetlands within the basin. This underscores the importance of this wetland type, already considered a priority for land managers.

Ecological Integrity Assessment (EIA) scores calculated for all random and reference condition sites confirm that the basin's wetland and riparian resources are stressed. Among reference sites, which were hand-picked to represent the best available condition, only four were rated in excellent (A) condition. The majority (62%) were rated as good (B) condition, while another 24% were ranked C. The lack of very high condition reference sites complicates the use of their site-level data to help refine and develop metrics for the plains. The purpose of reference sites is to help set the bar against which to measure the condition of randomly selected sites. When reference sites are in less than excellent condition, it is more difficult to know where along the bar those sites truly sit.

While condition assessment methods used in this project were developed and used successfully in several previous studies, the Lower South Platte River basin was the first study area on Colorado's plains. Several new wetland and riparian types were encountered in the study, including Western Great Plains Floodplain, Western Great Plains Riparian, and Western Great Plains Closed Depression (playas). For these three systems, one standard metric of biotic integrity (Mean C) did not appear to show the same strong response to disturbance. For this analysis, Mean C was removed from the metric scoring and a higher weight was given to other biotic measures, including percent non-native, percent noxious, and presence of aggressive natives. There is considerable need for further study of these wetlands types to refine the condition assessment methods. In addition, the hydrology metrics proved difficult to evaluate for plains systems, as the impact of many cumulative upstream stressors are difficult to quantify.

EIA scores for random sites, calculated with the above-mentioned modifications, showed that just over half (57%) of randomly selected sites were rated in C condition, while nearly a third were rated in B condition. An additional 12% were rated D, indicating significant deviation from reference. Among the component scores, sites rated highest for landscape context and lowest for biotic integrity. The generally rural landscape of the Lower South Platte River basin contained less modification than other, more developed regions of the state. However, the vegetation in South Platte wetlands and riparian areas is highly disturbed and contains considerable cover of non-native species. Wetlands in the basin are impacted by a range of stressors. The most frequently noted included unpaved and paved roads, agricultural crops, light to moderate grazing, and human recreation. Agricultural irrigation related stressors frequently impacted site hydrology within and surrounding the AA. Compaction and soil disturbance were common physiochemical stressors from human use or livestock.

Wildlife habitat research conducted through this project compiled a rich collection of information about priority wetland dependent species in the basin. A thorough report on this research is included here as Appendix A. From this research, new metrics were developed to assess the quality of wildlife habitat. Across all randomly sampled sites, there was a range of habitat values observed in the basin. Duck habitat, which is a major focus of wetland management in the basin, was rated as moderate overall by the indices. Duck habitat was highest in the two sandbars encountered and in warm water sloughs. Habitat for curlews appears to be in the best shape across the basin, though it is not common. Sandhill feeding and frog feeding habitat also appears to be generally good in the basin. However, both those species groups rely on other habitat characteristics during their life cycle, and those other habitat indices did not score as well. For frogs in particular, wintering habitat showed low scores, indicating that this may be the limiting factor or frog populations. This report included results on the initial evaluation of habitat quality, as this newly developed method is still under development. Additional work on the habitat indices will likely reveal other important trends.

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APPENDIX A: RESEARCH ON WILDLIFE HABITAT NEEDS

Habitat Quality for Wetland-Dependent Priority Wildlife Species in the Lower South Platte River Basin, Colorado: Species Assessments and Monitoring Protocols

December 15, 2013

Habitat Quality for Wetland-Dependent Priority Wildlife Species in the Lower South Platte River Basin, Colorado: Species Assessments and Monitoring Protocols

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EXECUTIVE SUMMARY

The Lower South Platte River Basin (LSPRB), located within the northeast quadrant of Colorado, supports 18/34 (53%) Colorado Parks and Wildlife (CPW) wetland-dependent priority wildlife species/subspecies within 18 wetland habitats:

Wetland-dependent priority wildlife species

Gadwall *Anas strepera*
American wigeon *Anas americana*
Mallard *Anas platyrhynchos*
Blue-winged teal *Anas discors*
Cinnamon teal *Anas cyanoptera*
Northern pintail *Anas acuta*
American green-winged teal *Anas crecca*
American bittern *Botaurus lentiginosus*
Greater sandhill crane *Grus canadensis tabida*
Piping plover *Charadrius melodus*
Long-billed curlew *Numenius americanus*
Short-eared owl *Asio flammeus*
Northern leopard frog *Rana pipiens*
Plains leopard frog *Rana blairi*
Northern redbelly dace *Phoxinus eos*
Brassy minnow *Hybognathus hankinsoni*
Red-sided garter snake *Thamnophis sirtalis*
River otter *Lontra canadensis*

Wetland habitats

Natural wetland habitat types
Beaver pond
Emergent marsh
Playa
Riparian wetland – herbaceous plants
Riparian wetland – shrub-scrub
Sandbar
Stream channel
Warm water slough
Wet meadow

Human created/influenced wetlands
Irrigation-influenced wet meadow
Irrigation ditch
Gravel pits
Moist soil unit
Recharge pond
Recharge pond/Moist soil unit
Reservoir
Sewage lagoon
Stock pond
Urban runoff ponds

The wetlands cover approximately 102,612 hectares (253,559 acres) or 3% of LSPRB's land. CPW and other partners have identified the LSPRB as a high priority conservation area, as evidenced from millions of dollars invested in over one hundred wetland improvement projects since 1997.

In partnership among the Colorado Natural Heritage Program (CNHP), CPW, and the South Platte Wetland Focus Area Committee (SP-WFAC), this LSPRB project is third in a series of Wetland Profile and Condition Assessment projects in Colorado, funded through the Environmental Protection Agency (EPA), with the San Luis Valley first and North Park second. Each project has become more comprehensive, based on knowledge gained from the previous projects. The North Park project included identification of key habitat variables important for dabbling ducks along with some suggestions on methods to measure the variables.

The LSPRB project extends what was accomplished in the North Park project by including all 18 wetland-dependent priority species occurring within the LSPRB and working with CNHP to incorporate the identified habitat variables into existing protocols used in the field to assess wetland condition.

The ultimate purpose of this project is to provide a set of methods and tools that can be used in wetland assessments that will directly link wildlife habitat requirements with quality of the wetlands, which will assist with prioritization of effective on-the-ground conservation actions. This project has relied heavily on the expertise provided by the SP-WFAC, especially the Steering Committee, formed with SP-WFAC partners. The products resulting from the project will also assist SP-WFAC and its partners with information that can guide prioritization based on existing and potential values of wetlands to priority species within LSPRB. This report, *Habitat Quality for Wetland-Dependent Priority Wildlife Species in the Lower South Platte River Basin, Colorado: Species Assessments and Monitoring Protocols*, is the companion document to the *Lower South Platte River Basin Wetland Profile and Condition Assessment*, written by CNHP staff.

We conducted a crosswalk between and among (1) 18 wetland habitats for the priority wildlife species, (2) 10 ecological systems, and 111 National Wetlands Inventory (NWI) codes. The products include the results of these crosswalks as well as a glossary of wetland habitat terms and a field key to habitat types. For each of the priority species, with several species placed into guilds (ducks, frogs, and fish), a species (or guild) profile is provided with brief population distribution summaries, seasonal occurrence in wetland habitats within the LSPRB, and key habitat variables that are most important.

Not including food resources, 21 key habitat variables were identified as either high or medium importance to the 18 priority species under consideration. Landscape context is of high importance to all 18 priority species and is, therefore, the most important variable, followed by size of habitat, water depth, dominant vegetation type, and percent of emergent cover.

Most of these variables were incorporated into the existing sampling framework used by CNHP for their wetland assessments. The data will enhance CPW's ability to determine the quantity and quality of wetland habitat available for each priority species and, in concert with some additional GIS work, will further provide information on locations of important conservation areas, which can guide management decisions and allocations of funding resources.

ACKNOWLEDGEMENTS

We thank all the members of the South Platte Wetland Focus Area Committee who provided their expertise, information, and comments, especially the Steering Committee: Colin Lee (Mountain Bird Observatory, RMBO, and Natural Resources Conservation Service, NRCS), Noe Marymor (RMBO, and NRCS), Matt Reddy (Ducks Unlimited, DU), and Greg Stoebner (U. S. Fish and Wildlife Service, USFWS).

Robert Andrews (International Educator, currently Liberia, Africa) provided feedback regarding the distribution and occurrence of wetland-dependent priority birds that have a spotty or questionable distribution in the Lower South Platte River Basin. The following experts provided reviews as described in the methods section, under Review Processes:

- American bittern: Pete Walker (Colorado Parks and Wildlife, CPW) and Colin Lee (NRCS)
- Frog guild and red-sided garter snake: Tina Jackson (CPW)
- Fish guild: Boyd Wright (CPW) with thanks also to Jim White and Paul Foutz (CPW) for initial feedback on distribution and for recommending Boyd Wright
- Dabbling duck guild: Brian Sullivan (CPW)
- Long-billed curlew: Colin Lee with thanks also to Seth Gallagher (RMBO)
- Short-eared owl and greater sandhill crane: Rick Schnaderbeck (USFWS)
- Piping plover: James Fraser (Department of Fish and Wildlife Conservation, Virginia Tech)
- River otter: Eric Odell and Scott Wait (CPW)

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LIST OF ACRONYMS AND ABBREVIATIONS

BBS	Breeding Bird Survey
BCR	Bird Conservation Region
CBC	Christmas Bird Count
cm	Centimeter
CNHP	Colorado Natural Heritage Program
COBBA	Colorado Breeding Bird Atlas
COPIF	Colorado Partners in Flight
CPW	Colorado Parks and Wildlife
DU	Ducks Unlimited
EPA	Environmental Protection Agency
ha	Hectare
ICF	International Crane Foundation
IUCN	International Union for Conservation of Nature
km	Kilometer
LSPRB	Lower South Platte River Basin
m	Meter
NGO	Non-government Organization
NWI	National Wetland Inventory
NRCS	Natural Resources Conservation Service
PLJV	Playa Lakes Joint Venture
RMBO	Rocky Mountain Bird Observatory
SP-WFAC	South Platte Wetland Focus Area Committee
USDA	U. S. Department of Agriculture
USFWS	U. S. Fish and Wildlife Service
WFAC	Wetland Focus Area Committee

1.0 INTRODUCTION

The South Platte River Basin, located within the northeast quadrant of Colorado, supports 70% of Colorado's human population. It sits within the Central Flyway (Figure 1) and Bird Conservation Region (BCR) 18. The Lower South Platte River Basin (LSPRB), the study site for this project (Figure 1), does not include the high-elevation western portion of the more comprehensive South Platte River Basin. The National Wetland Inventory (NWI) identifies 102,612 hectares (253,559 acres) of wetlands within the LSPRB, representing 111 NWI codes and 3% of the LSPRB surface area.

Humans have altered the natural hydrology (Propst and Carlson 1986, Young et al. 1986) and greatly modified the landscape of the LSPRB (Baron et al. 1998, 2000), particularly over the last century. Nevertheless, in addition to the existing wetlands, with over four thousand hectares (or over one million acres) of irrigated agricultural lands (Colorado Geological Survey 2012) interspersed with grasslands and sand sage (PLJV 2006, 2008), the LSPRB remains important to a wide diversity of wildlife species. Because of the high importance of the LSPRB to wetland-dependent wildlife as well as other wildlife species, Colorado Parks and Wildlife (CPW) identified the LSPRB as a high priority emphasis area for wetland conservation in Colorado (CPW 2011). For example, CPW and other partners have invested millions of dollars on over a hundred wetland improvement projects in the LSPRB since inception of the Colorado Wetland Wildlife Program in 1997 (Lemly 2010).

In their Wetland Wildlife Conservation Program Strategic Plan, CPW identified 34 wetland-dependent priority species/subspecies: 8 species of ducks and 26 species/subspecies (12 birds, 4 mammals, 2 reptiles, 3 amphibians, and 5 fishes) that are either at risk or declining in populations (CPW 2011, Table 1). While the CPW Wetland Wildlife Conservation Program targets these 34 species/subspecies in their funding prioritizations, many other wetland-dependent and wetland-facultative wildlife species will benefit from conservation efforts directed at improving populations of the priority species.

In order to facilitate habitat improvements for these species, it is critical to identify the key habitat variables that define high quality habitat and contribute to stabilizing or increasing populations through recruitment and/or survival. Many habitat variables overlap among species regarding their importance to recruitment and/or survival; in other words, enhancement of a single variable may benefit several priority species. On the other hand, a single target condition will not benefit all priority species, and some of the priority species identified for this project (see methods and results for selected species) need non-overlapping conditions, which may be detrimental to other priority species. For example, habitat conditions that favor American bitterns (*Botaurus lentiginosus,* e.g., ponds fringed with extensive cattails and other tall and robust wetland plants) often do not favor dabbling ducks. Therefore, in order to accommodate appropriate conditions for all priority species on the landscape, a diversity of conditions must be provided.

Key habitat variables that are important to wetland-dependent wildlife include both those within the wetland, itself, and conditions on a landscape scale – up to many miles beyond the wetland boundaries. Within wetland boundaries, variables identified as either important or critical to many wetland-dependent wildlife species often include, but are not limited to, dominant vegetation type (Kaiser et al. 1979, Kantrud, 1986, Gammonley 1996, Dechant et al. 2003b, Earnst and Holmes 2012), relative amount of vegetation (Wiggins 2004, Gregory 2011, Krapu et al. 2011), vegetation height (Young et al. 1988, Herkert et al. 1999, Dechant et al. 2003b, Gregory 2011), how vegetation is dispersed within the wetland (interspersion; Murkin et al. 1982, Euliss and Harris 1987, Rehm and Baldassarre 2007), water depth (Gilbert et al. 1994, Austin and Miller 1995, Leschack et al. 1997, Johnson and Rohwer 2000), water quality (Bestgen 1989, Nichols 2006, Stasiak 2006), food availability (Dechant et al. 1998, Ballard et al. 2004, Nelms et al. 2007, Crowley et al. 2012), and size of wetland (Brown and Dinsmore 1986, Paquette and Ankney 1996, Fleskes et al. 2007). Some wetland-dependent wildlife species require additional conditions (Gaines and Ryan 1988, Gilbert et al. 1994, Stasiak 2006, Germaine and Hays 2009, Depue and Ben-David 2010). The landscape context often significantly contributes to the overall quality of wetlands and can determine, to some degree, the extent of occupancy by wildlife. Landscape variables often identified include, but are not limited to, the distance of and abundance of other wetlands (Tacha et al. 1992, Niemuth and Solberg 2003, Arnold et al. 2007) and distance and abundance of other habitat types, such as grasslands, certain crops, and grazing (Wiggins et al. 2006, Saalfeld et al. 2010). All of these habitat variables can be measured at one or more levels (1-2-3, EPA 2011), depending on available resources, and most can be measured within the existing framework adopted by the Colorado Natural Heritage Program (CNHP, EPA 2011).

While measurements of key habitat variables can be useful for determining overall habitat quality and aid in conservation efforts, certain assumptions should be evaluated: (1) what appears as high quality habitat, measured in terms of all the important key habitat variables, can sometimes be "ecological traps." For example, even if all other key habitat variables suggest high quality, if a frog brood-rearing pond is so infested with predatory fish or bullfrogs that they consume all or most of the next generation of frogs, it will not contribute to the frog population. (2) Wildlife species cannot always assess ecological traps, and their abundances do not necessarily correlate with quality. In a well-cited example, Johnson and Temple (1986) found in a tall-grass prairie that individual abundance and nest success were inversely related; if they had identified the habitat with highest abundance as being the highest quality, this would have led to counterproductive management practices.

In partnership between CNHP and CPW, this LSPRB project is third in a series of Wetland Profile and Condition Assessment projects in Colorado, funded through EPA, with the San Luis Valley first and North Park second. Each project has become more comprehensive, based on knowledge gained from the previous projects. The North Park project included identification of key habitat variables important for dabbling ducks along with some suggestions on methods to measure the variables. The LSPRB project extends what was accomplished in the North Park project by including all relevant CPW priority species, working with CNHP to incorporate the identified habitat variables into existing protocols, and developing standards to rank the quality of wetlands for the priority wildlife species. The ultimate purpose of this project is to provide a set of methods and tools that can be used in wetland assessments that will directly link wildlife habitat requirements with quality of the wetlands, which will assist with prioritization of effective on-the-ground conservation actions.

In Colorado, Wetland Focus Area Committees (WFAC) enhance CPW's conservation efforts through local expertise and knowledge about wetland needs, potential projects, local resources, and outreach to landowners. The importance of local expertise is exemplified by local partners selecting and evaluating potential sites for recharge ponds within LSPRB (Shrier et al. 2008). Many of Colorado's 11 WFACs were formed in 1997 in response to the formation of the Colorado Division of Wildlife Wetlands Program, now called the Wetland Wildlife Conservation Program. The South Platte Wetland Focus Area Committee's (SP-WFAC) primary mission is "*to conserve wetlands that sustain the natural integrity of the South Platte ecosystem*" (SP-WFAC 2002). As is typical of the Focus Area Committees throughout the state, SP-WFAC consists of a wide diversity of interested partners, representing private landowners, land managers, Federal, state, and local agencies, non-profit organizations, non-governmental agencies, and special interest groups. This project has relied heavily on the expertise provided by the SP-WFAC, especially the Steering Committee, formed with SP-WFAC partners (see acknowledgements and methods for more details). The products resulting from this project will also assist SP-WFAC and its partners with information that can guide prioritization based on existing and potential values of wetlands to priority species within LSPRB.

This project contributes to several goals in the Strategic Plan for the Wetland Wildlife Conservation Program. Specifically, identification of best management practices and monitoring protocols for key habitat variables contributes to both Biological Planning Strategies and Conservation Design Strategies in the plan (CPW 2011). This information directly links wetland assessments with habitat quality for wildlife, and it can be used to better inform sampling selection for wetland assessments, which will assist with prioritization of effective on-the-ground conservation actions. Decisions based on biological knowledge can lead to the most meaningful landscape conservation, which will benefit not only priority species, but also functional communities and connectivity for movement and gene flow across the landscape.

The major goals of the LSPRB Wetland Profile and Condition Assessment project include "(1) create a digital map of wetlands in the Lower South Platte River Basin and determine its accuracy; (2) Conduct a thorough and systematic review of habitat requirements of wildlife species on the CDOW's [CPW] Wetlands Program target list; (3) Identify a set of reference condition wetlands in the basin to refine existing Level 2 and develop Level 3 assessment methods appropriate for use in Colorado's High Plains Ecoregion; and (4) Conduct a statistically valid, field-based survey of wetland condition in the basin" (From the proposal: Lemly 2010). This report focuses on the second goal, with the following tasks:

"1. From the list of CDOW [CPW] Wetlands Program priority wildlife species (*n*=34; see previous attachment), identify those that occur in the Lower South Platte Basin by studying available range/distribution maps.
2. For each species, identify important wetland types used by the species, and describe in general wetland categories familiar to wildlife biologists (e.g., floodplain marshes, reservoirs, warm water sloughs, playas, etc.).

3. For each wetland type, describe period of seasonal use by the species (e.g., spring and fall during migration).
4. For each wetland type, develop a crosswalk with the NWI classification system.
5. For each wetland type and season of use, describe the biotic and abiotic factors known to influence use by the wildlife species (e.g., dominant vegetation, interspersion of open water and vegetation, residual cover, proximity to other wetlands, etc.).
6. For each factor, qualify or quantify if possible the wildlife value. E.g., for dominant vegetation, grasses=high, willows mixed with grasses=medium, willow=low for duck nesting).
7. For each factor, develop field measurement protocols.
8. For each factor, describe management practices used to influence the factor and potentially benefit wildlife use."

Although not the specific goal of this scope of work, the information acquired from this project may be transferable to other wetland basins within and outside of Colorado.

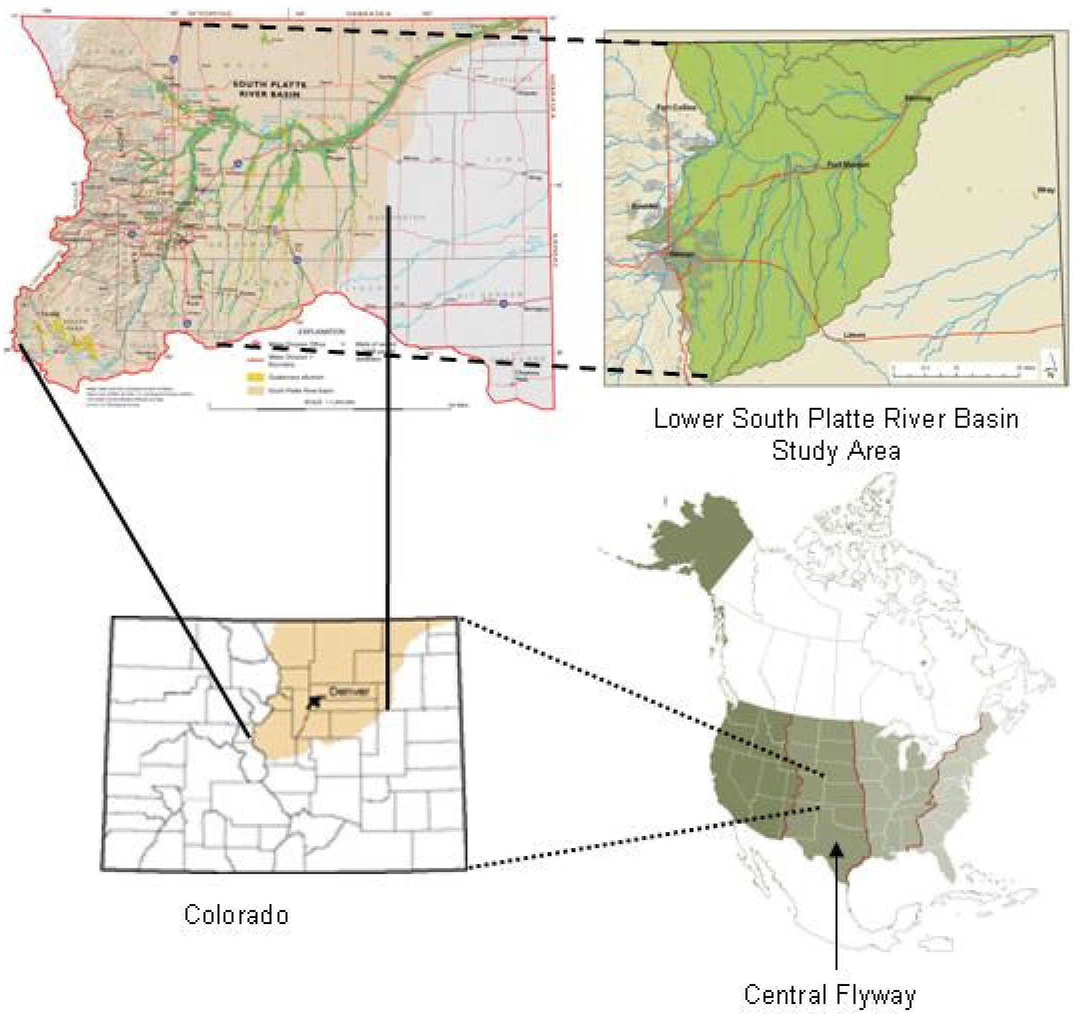


Figure 1. Location of the Lower South Platte River Basin in relation to the entire South Platte River Basin, Colorado, and the Central Flyway. Maps from Colorado Geological Survey (2012) and USFWS 2012.

Table 1. Wetland-dependent wildlife priority species for the Wetland Wildlife Conservation Program (CPW 2011) state-wide and species included in the Lower South Platte River Basin (LSPRB) Wetland Profile and Condition Assessment.

CPW Wetland-dependent Priority Species	Included in LSPRB Assessment	Population Status	Listing Status
Waterfowl species (8 species)			
Gadwall *Anas strepera*	√		
American wigeon *Anas americana*	√		
Mallard *Anas platyrhynchos*	√		
Blue-winged teal *Anas discors*	√		
Cinnamon teal *Anas cyanoptera*	√		
Northern pintail *Anas acuta*	√		
American green-winged teal *Anas crecca*	√		
Lesser scaup *Aythya affinis*			
At-risk species/subspecies (26 species/subspecies, all Tier 1)			
Amphibians			
Boreal toad *Bufo boreas boreas* (S. Rocky Mtn. Population)		Low	SE
Northern leopard frog *Rana pipiens*	√	Low	SC
Plains leopard frog *Rana blairi*	√	Medium	SC
Birds			
American bittern *Botaurus lentiginosus*	√	Unknown	
Bald eagle *Haliaeetus leucocephalus*		Low	ST
Greater sandhill crane *Grus canadensis tabida*	√	Medium	SC
Piping plover *Charadrius melodus*	√	Low	FT, ST
Western snowy plover *Charadrius alexandrinus nivosus*		Low	SC
Long-billed curlew *Numenius americanus*	√	Low	SC
Least tern *Sternula antillarum*		Low	FE, SE
W. yellow-billed cuckoo *Coccyzus americanus occidentalis*		Low	FPT, SC
Short-eared owl *Asio flammeus*	√	Low	
Lewis's woodpecker *Melanerpes lewis*		Medium	
Red-naped sapsucker *Sphyrapicus nuchalis*		Medium	
Southwestern willow flycatcher *Empidonax traillii extimus*		Low	FE, SE
Fish			
Northern redbelly dace *Phoxinus eos*	√	Low	SE
Southern redbelly dace *Phoxinus erythrogaster*		Low	SE
Brassy minnow *Hybognathus hankinsoni*	√	Low	ST
Arkansas darter *Etheostoma cragini*		Medium	ST
Plains orangethroat darter *Etheostoma spectabile*		Low	SC
Mammals			
Preble's jumping mouse *Zapus hudsonius preblei*		Low	FT, ST
New Mexico jumping mouse *Zapus hudsonius luteus*		Low	FPE
River otter *Lontra canadensis*	√	Low	ST
Dwarf shrew *Sorex nanus*		Unknown	
Reptiles			
Yellow mud turtle *Kinosternon flavescens*		Low	SC
Red-sided (common) garter snake *Thamnophis sirtalis*	√	Medium	SC

Listing Status: SC=State Species of Concern, ST= State Threatened, SE= State Endangered, FT= Federally Threatened, FE= Federally Endangered, FPT=Federally Proposed Threatened, FPE=Federally Proposed Endangered.

2.0 METHODS

2.1 Selection of Species

CPW identified 34 wetland-dependent priority wildlife species/subspecies for the Wetland Wildlife Conservation Program (CPW 2011). The list of priority species for the entire state includes eight species of ducks that contribute to nearly 90% of the state's duck harvest and 26 species/subspecies that are declining or at risk (Table 1, CPW 2011). Of these 34 species, 15 do not occur at all or occur very rarely in the LSPRB (details in Appendix I). We removed three species that do occur in the LSPRB: lesser scaup (*Aythya affinis*), bald eagle (*Haliaeetus leucocephalus*), and Preble's jumping mouse (*Zapus hudsonius preblei*) for reasons identified in Appendix I.

Removing the above 18 species resulted in a tentative list of 16 species. The SP-WFAC, in a meeting on February 1, 2012, suggested that we reconsider two of the species removed from the initial list because (1) river otter (*Lontra canadensis*) populations appear to be increasing in the LSPRB, and (2) piping plovers (*Charadrius melodus*) might increase in the LSPRB with management of sandbar habitat. Therefore, river otters and piping plovers were added back to the list. The final list consists of 18 species, from here on, referred to collectively as priority species (see Table 1).

2.2 Literature Review

For each of the 18 priority species, I conducted a thorough literature review, including published scientific literature, credible on-line resources, and databases. I gleaned out information regarding their distribution, population status, seasonal occurrence in each wetland habitat type, relative value of each wetland habitat type, key habitat quality variables, food preferences, foraging methods, and any additional information that could be useful in determining habitat quality. I also conducted a literature review on protocols used to measure key habitat quality variables.

2.3 Review Processes

Experts reviewed this work in two phases: (1) review of initial information, and (2) review of the species assessments (Section 3.2, Priority Species). For all species except one, local experts familiar with the LSPRB were used. For piping plovers, a national expert, who works with populations throughout their range, served as a reviewer. Reviewers are listed in the Acknowledgements section.

The first round of reviews consisted of evaluating three tables, confirming or correcting any information and filling in gaps. The three tables included (1) identification of key habitat variables and descriptions of conditions that make these variables high, medium, or low quality, (2) seasonal occurrence in each relevant wetland habitat type and the relative importance (high, medium, or low) of these wetland habitat types, and (3) numerical rankings for key habitat variables (highest to lowest importance). In addition to the tables, the reviewers were provided with more detailed information and citations from the literature used to create the tables. All comments and/or additions of the reviewers were incorporated into these tables, which were subsequently used in the species assessments (Section 3.2, Priority Species).

The second round of reviews consisted of reviewers evaluating the species assessments and incorporating comments and suggestions (Section 3.2, Priority Species).

2.4 Focus Area Committee and Steering Committee

We met with the SP-WFAC, chaired by Noe Marymor, to obtain feedback on the *Lower South Platte River Basin Wetland Profile and Condition Assessment* project, including this section, *Habitat Quality for Wetland-Dependent Priority Wildlife Species in the Lower South Platte River Basin, Colorado: Species Assessments and Monitoring Protocols*. We met with the SP-WFAC on February 1, 2012, in Brush, Colorado, to introduce the committee to the project and to obtain immediate feedback regarding the priority wetland-dependent wildlife species that should be included (see Section 2.1, Selection of Species). We also met on June 27, 2012, in Brush, Colorado, to update the committee on the progress of the project. At this meeting, we suggested forming a Steering Committee, consisting of members who have the ability and knowledge to provide more intensive feedback on a more frequent basis (see Acknowledgements section for members of this committee). We met with the Steering Committee on November 1, 2012, in Greeley, Colorado, to discuss and refine some of the wetland habitat types.

2.5 Wetland Crosswalk with CNHP

For the overall project, we use three classification schemes to describe wetland ecosystems: (1) the National Wetland Inventory (2), the Ecological Systems classification, adopted by CNHP for this project, and (3) wetland systems that describe wildlife habitats. To facilitate communication, particularly between CNHP and CPW, we conducted a crosswalk among these classification systems, resulting in several products: (1) a glossary of wetland habitat types, (2) a field key to wetland habitat types, and (3) results of the crosswalk among the three classification schemes, which consists of a table listing all ecological systems and NWI categories that describe each wetland habitat.

2.6 Selection of Metric Protocols

After determining the key habitat quality variables (see Section 2.2., Literature Review), I conducted another literature review to identify existing methods of measuring the most important key habitat quality variables for all 18 priority species. In most cases, important habitat variables overlapped considerably among species. I prepared a document listing the habitat variables and all applicable levels (EPA 1-2-3 levels) and methods of measuring them in the field. I compared these with variables with the existing protocol that CNHP has used in the field.

Prior to the field season of 2012, I met with CNHP staff (Joanna Lemly and Laurie Gilligan) and CPW staff (Brian Sullivan) to discuss and refine the field protocol and how to incorporate measurements of key habitat quality variables that were not already in the CNHP protocol. We then tested the protocol in the field, evaluating whether the protocol would result in collection of all data required to determine habitat quality for the priority wildlife species. The field testing resulted in further discussions and adjustments to the protocol.

3.0 RESULTS

3.1 Wetland Types

We identified 18 wetland habitats in the LSPRB: 9 natural and 9 human-created habitats (Table 2). Definitions of relevant wetland habitats and a field key to wetland habitats within the LSPRB are provided in Appendices II and III, respectively. These 18 habitats correspond with ten ecological systems. The importance to wildlife of each wetland habitat depends on the species, condition and habitat variables (e.g., size of wetland, water levels, dominant vegetation, pH), as well as the overall landscape context and time of year (Table 3).

Table 2. Crosswalk between wildlife habitat types and ecological systems in the Lower South Platte River Basin.

Habitat	Description	Ecological System(s)	NWI Codes
Natural wetland habitat types			
Beaver pond	Impoundment created by beaver dam, usually made of mud and woody plant material.	• Open Freshwater Depression Wetland[1] • Riparian Woodland and Shrubland[2] • Floodplain Woodland and Shrubland[2] [1]If dominated by emergent marsh or aquatic vegetation [2]If dominated by overstory vegetation	PABGb, PEMFb
Emergent marsh	A shallow water wetland that is frequently or continuously inundated and supports herbaceous plants adapted to saturated conditions; can be isolated or along reservoirs and other water bodies.	• Open Freshwater Depression Wetland	PABF, PABG, PEMF, PEMFd, PUBF, PUBG
Playa	An isolated depressional wetland with distinctive wet and dry seasons, fed by precipitation and runoff.	• Closed Depression Wetland • Saline Depression Wetland • Inter-Mountain Basins Playa	PEMAf, PEMJ, Pf, PUSA, PUSAh, PUSAx, PUSC, PUSCh, PUSCx, PUSJ, PUSKA, PUSKC
Riparian wetland (herbaceous)	Wetland adjacent to stream; flooded intermittently, seasonally, or permanently; fed by water from the stream either above or below ground; dominated by herbaceous phreatophytic plants.	• Floodplain Wet Meadow	PEMA, PEMAd, PEMB, PEMC, PEMCd

Table 2, continued.

Habitat Type	Description	Ecological System(s)	
Natural wetland habitat types			
Riparian wetland (scrub-shrub/forested)	Wetland adjacent to stream; flooded intermittently, seasonally, or permanently; fed by water from the stream either above or below ground; dominated by woody phreatophytic shrubs.	• Riparian Woodland and Shrubland* • Floodplain Woodland and Shrubland* • Rocky Mountain Riparian Woodland and Shrubland[1] * Lumped into Riparian and Floodplain Woodland and Shrublands	PSSA, PSSAd, PSSAh, PSSAx, PSSB, PSSC, PSSCd, PSSCh, PSSJ, PSSKA, PSSKC
Wet meadow	Grassy areas within the floodplain saturated at or near the surface for part of the year.	• Floodplain Wet Meadow • Isolated Wet Meadow	PEMA, PEMAd, PEMB, PEMC, PEMCd
Warm water slough	Slowly moving shallow water adjacent to river; source originates from ground water; in winter water temperature warmer than in river and under normal conditions does not freeze during winter.	• Open Freshwater Depression Wetland • Riparian Woodland and Shrubland • Floodplain Woodland and Shrubland	
Sandbar	Accumulation of sand and/or gravel along a river channel; often maintained by scouring action.	• Riparian Woodland and Shrubland • Floodplain Woodland and Shrubland	R2USA. R2USC, R3USA, R3USC, R4USA, R4USC. R4USCx
Stream channel	Area of river confined by banks and a streambed.		

Table 2, continued.

Habitat Type	Description	Ecological System(s)	
Impoundments and other human created wetlands			
Irrigation-influenced wet meadow	Meadows receiving surface or subsurface irrigation waters	• Irrigated Hay Wet Meadow	PEMK, PEMKC, PEMKF
Irrigation ditch	Excavated canal that supplies water to dry land.	• Open Freshwater Depression Wetland[*] • Riparian Woodland and Shrubland[*] [*] If vegetated	R4SBCx
Gravel pit	Steep-sided excavation, usually in association with gravel mining operations; may or may not have sloped wetlands on fringe.	• Open Freshwater Depression Wetland[*] [*]Only the vegetated edges considered wetlands	
Moist-soil unit	Managed wetland with dike and water control structure; manipulated to flood intermittently or seasonally to maximize production of moist-soil annual and/or perennial herbaceous plants; sometimes planted with crops that provide seeds, vegetation, and/or roots that benefit wetland-dependent species.	• Open Freshwater Depression Wetland • Wet Meadow	PABFh, PABFx, PABGh, PABGx, PEMAh, PEMAx, PEMCh, PEMCx, PEMFh, PEMFx, PUBFh, PUBFx, PUBGh, PUBGx, PUBK, PUBKF, PUBKG
Recharge pond	Diked shallow water impoundment on ephemeral drainage designed to retime S. Platte River flows into Nebraska according to legal mandates.		
Reservoir	Impoundment used to store and regulate water for agricultural or municipal use; usually > 2 ha.		
Sewage lagoon	Impoundment fully contained by dikes and receiving domestic/industrial/agricultural effluent; usually near urban areas or feedlots; rectangular or square in shape		
Stock pond	Diked pond on ephemeral drainage in pasture or prairie; used for watering livestock; usually created by humans and < 2 ha.		
Urban runoff pond	Ponds that capture effluent from urban storm runoff		

Table 3. Relative importance of each wetland habitat to CPW wetland-dependent priority species occurring in the Lower South Platte River Basin. Ranges of value depend on the condition of the wetland, especially water levels, dominant vegetation, and proximity and connectivity with other wetlands on the landscape.

Wetland habitat type	**Dabbling Duck Guild**	**American Bittern**	**Greater Sandhill Crane**	**Piping Plover**	**Long-billed Curlew**	**Short-eared Owl**	**Frog Guild**	**Garter Snake**	**Fish Guild**	**River Otter**
Natural wetland habitat types										
Beaver pond	M-H	L-H					H	H	H	H
Emergent marsh	H	H	M-H			H	H	H		
Playa	L-H		M-H		L-H	M	M	L-H		
Riparian wetland –herbaceous plants	H	L					H	H		
Riparian wetland –shrub-scrub	L						M	M-H		
Sandbar	M			H			L	L		
Stream channel	L						M-H		H	H
Warm water slough	H	L					H	H	H	H
Wet meadow	H	L	M-H		H	M	H	H		
Impoundments and other human created wetlands										
Irrigation-influenced wet meadow	M-H	L	M-H		H	M	H	H		
Irrigation ditch	L						L-M	L-M	H	
Gravel pits	L-M	L					L-H	L-H		
Moist soil unit	H		M-H				L-M	L-M		
Recharge pond/Moist soil unit	M-H		M-H				M	M-H		
Reservoir*	L-H		L-H				L-H	L	Size?	
Sewage lagoon	M						L-H	L-H		
Stock pond	L-H						L-H	L-H		
Urban runoff ponds	L-M						L-H	L-H		

L= low, M = medium, H = high; empty cells indicate that these wetland habitat types are not used on a regular basis by the species. "Size?" indicates that presence is usually size-dependent.
*Mostly unvegetated shores.

3.2 Priority Species

Species profiles for the CPW wetland-dependent priority species are provided below with brief population summaries, seasonal occurrence in wetland habitats within the LSPRB, and key habitat variables that are most important.

3.2.1 Dabbling Ducks

The dabbling duck guild includes gadwall (*Anas strepera*), American wigeon (*Anas americana*), mallard (*Anas platyrhynchos*), blue-winged teal (*Anas discors*), cinnamon teal (*Anas cyanoptera*), northern pintail (*Anas acuta*), and green-winged teal (*Anas crecca*). The CPW Wetland Wildlife Conservation Program does not consider the LSPRB as an important breeding area for dabbling ducks; therefore, summer months are not considered in this report. However, dabbling ducks depend on high quality habitat within the LSPRB during winter as well as spring and fall migration. The quality of habitat during these stressful months directly affects body condition, which influences reproductive success and recruits to the population (Miller 1986; Ballard et al. 2004, 2006; Moon et al. 2007; Yerkes et al. 2008). Therefore, the condition of wetlands in the LSPRB has a direct effect on populations wintering and migrating through the region. Although the dabbling ducks are grouped together as a guild, each species has different habitat needs; thus, the habitat will influence the presence of particular species within the guild.

Range, population status, conservation status. The dabbling ducks in this guild are widely distributed (Figure 2), and all, except cinnamon teal, have a distribution beyond the Americas. The population status differs among species. The only species with a consistent wide-spread population increase is the gadwall (Table 4, Sauer et al. 2012).

American wigeon. According to the Breeding Bird Survey (BBS), American wigeons have experienced wide-spread and significant population declines (Sauer et al. 2012). From 1966–2011, American wigeon populations declined significantly throughout the BBS survey-wide area and within the BBS Central Region where the LSPRB is located (Table 4). However, the negative trend became less severe in these survey areas from 2001–2011, and Mowbray (1999) pointed out that during 1997, the population exceeded the long-term average of 3 million individuals. Data from the Audubon Society's Christmas Bird Count (CBC) indicates a decreasing trend of wintering American wigeons throughout the United States and an increasing trend in Colorado, emphasizing the possible importance of available wintering habitat in Colorado for American wigeons (Figure 3).

Northern pintail. Northern pintails had been declining in the BBS Central Region and survey-wide (Sauer et al. 2011), but new analysis suggests this decline is no longer significant (Sauer et al. 2012). However, Sauer et al. (2012) report northern pintails to still be in decline in the Eastern and Western BBS regions. CBC data show negative trends in both Colorado and throughout the United States during the winter (Figure 3). Concerns have been expressed about continual declines of northern pintail populations (Ballard et al. 2006, Haukos et al. 2006, Fleskes et al. 2007, Lee et al. 2007), especially concerns that northern pintail populations remain well below both the long-term average and the goal in the North American Waterfowl

Management Plan of 5.6 million individuals (Miller and Duncan 1999, Richkus et al. 2005, Moon et al. 2007, Pearse et al. 2011).

All ducks in this guild are federally protected game birds in the United States, Canada, and Mexico. CPW designated these ducks as priority species because they provide valuable hunting and viewing opportunities.

Wetland habitat types. Dabbling ducks occupy all 18 wetland habitats within the LSPRB during spring and fall (Table 5). During winter, most wetland habitats within the LSPRB become frozen, and the majority of ducks congregate in wetland habitats with deeper, unfrozen water, such as open parts of river channels, warm water sloughs, reservoirs, and deep gravel pits, or on land immediately adjacent to open water, such as sandbars. The most important wetland habitats for dabbling ducks include beaver ponds, emergent marshes, riparian wetlands dominated by an herbaceous plant community, warm water sloughs, wet meadows, and moist soil units (Table 5).

Key habitat quality variables. Measurable habitat quality variables for dabbling ducks include dominant vegetation (both type and structure), emergent cover, submergent vegetation, aquatic invertebrates, the relationship to other habitats within the landscape (landscape context), size of habitat patch, stream order, and water depth (Table 6). Not all habitat quality variables are relevant for each wetland habitat type, and the metric values or categories of the habitat quality variables differ among the species of dabbling ducks.

Dominant vegetation. Vegetation provides both food and cover. Ducks consume vegetation directly (e.g., seeds, vegetative parts, and roots), and they consume aquatic invertebrates, many of which depend on aquatic vegetation as a substrate. Vegetation also provides cover, which is especially important at night for protection from predators and for providing a suitable micro-climate. If, however, vegetation is too dense and/or too rigid to move through easily and rapidly, it can impede access to open water. Vegetation that provides a combination of nutritious food, cover, and ease of access to open water is of the highest quality to dabbling ducks.

In general, grasses, sedges, rushes, submergent plants, and plants with high seed production are preferred over other herbaceous plants with little to no food value for ducks, and these other herbaceous plants are preferred over willows and other woody or stiff vegetation. While some variation exists among the seven species of dabbling ducks in their preference for foods (Table 7), preferences overlap and, therefore, some generalizations can be made for the dabbling duck guild (Table 8). However, no single vegetation type fulfills all needs of a single species, much less the entire dabbling duck guild.

Emergent cover. The preferred percent of emergent cover differs considerably depending on wetland habitat type and time of day. It also differs between the breeding season and the seasons considered in this report. In general, in the fall and spring, dabbling ducks prefer wetlands with more open water during the day; for nocturnal roosting, they prefer more densely vegetated wetlands or large expanses of open water (e.g., reservoirs or gravel pits). Therefore, the quality of this key habitat variable is closely linked with the landscape context. The closer preferred diurnal wetlands are to high-quality nocturnal roosts, the more valuable they are to dabbling ducks. In other words, landscapes with interspersion of relatively open wetlands and more density vegetated wetlands and/or larger reservoirs are the most valuable to dabbling ducks during these seasons.

Invertebrate food requirements. Most dabbling ducks consume far more invertebrates during the breeding season compared with other times of year (Austin and Miller 1995, Gammonley 1996, Leschack et al. 1997, Mowbray 1999, Drilling et al. 2002, Rohwer et al. 2002). Ingestion of invertebrates outside the breeding season for some dabbling ducks is thought to be incidental (Leschack et al. 1997, Mowbray 1999, Drilling et al. 2002). For blue-winged teal during the spring, snails, aquatic insects, and crustaceans may be important; during the fall, ingestion of invertebrates may be more incidental (Rohwer et al. 2002). In addition to vegetable material and seeds, cinnamon teal consume midges (Chironomidae), gastropods, and water fleas (Cladocera) during spring and gastropods during the fall (Thorn and Zwank 1993, Gammonley 1996). The diet of northern pintails during the winter consists primarily of seeds, but during fall, the amount of invertebrates they consume varies considerably (Austin and Miller 1995); thus, ingestion of invertebrates could be considered opportunistic rather than incidental. Green-winged teal eat mostly vegetable matter and seeds, but a small part (< 10%) of their winter diet may consist of mollusks (Johnson 1995).

Landscape context. Dabbling ducks not only move from diurnal wetlands to nocturnal wetlands, but they also move a fair amount during the day in search of a variety of foods and safe loafing areas. Numerous investigators have found wetland adjacencies to other landscape variables important to dabbling ducks. The most important landscape context variables include proximity to agricultural fields containing food resources (Drilling et al. 2002), proximity of appropriate feeding and nocturnal roosting habitat, and juxtaposition and amount of other flooded habitat (Naugle et al. 2001, Moon and Haukos 2006, Fleskes et al. 2007). In a study on the roles of various landscape variables on habitat suitability and conservation efforts, Naugle et al. (2001) concluded that small (< 0.5 ha) wetlands exert a significant effect on suitability of larger wetlands within a landscape. Specifically, they concluded that for northern pintails, the number of suitable wetlands > 0.5 ha decreased by 21% when wetlands < 0.5 ha were removed from the landscape, suggesting the conservation and functional importance of small wetlands for connectivity.

To some degree, ducks disperse seeds and larval forms of their own food resources, both aquatic invertebrates (Charalambidou and Santamaría 2005) and plants (Mueller and van der Valk 2002, Charalambidou and Santamaría 2005, Wongsriphuek et al. 2008). The potential distance of dispersal from the source is typically only 20–30 km (Mueller and van der Valk 2002) but may be much less, emphasizing the importance of proximity to other wetlands on the landscape.

Size of habitat. The precise size requirements for wetlands during migration and winter do not appear well understood, other than larger wetlands may attract more ducks (Stafford et al. 2007). In general, larger wetlands have the capacity to result in a greater diversity of plants and other food resources and, therefore, maximize species richness and abundance. Larger wetlands also often have a greater diversity of water depths and may, thus, accommodate the requirements of all the dabbling ducks as well as other waterfowl. The role of smaller wetlands, however, is essential in a landscape context.

Stream order. Increasing stream order generally results in higher quality habitat for dabbling ducks simply because under most normal circumstances, the water has more access to flood plains with increasing stream order. The wetlands most affected by stream order include riparian wetlands, some beaver ponds, sandbars, as well as the river channel, itself.

Submergent Vegetation. An abundance of submergent vegetation is important for dabbling ducks (Baldwin and Loworn 1994, Johnson 1995, Gammonley 1996, Leschack et al. 1997, Mowbray 1999, Drilling 2002), not only as a source of plant material, but as a substrate for other organisms consumed by ducks (Rohwer et al. 2002). There seems to be a paucity of information regarding the desired range of percent submergents in the water column; however, Gammonley (1996) reported a positive correlation between winter distribution of cinnamon teal and standing crop of submergents; similarly, Hargeby et al. (1994) found that duck abundance increased with submergents.

Water depth. Dabbling ducks prefer water depths less than 30 cm (Euliss and Harris 1987, Thorn and Zwank 1993, Austin and Miller 1995, Leschack et al. 1997, Rohwer et al. 2002, Heitmeyer 2006), and even shallower waters (< 20 cm) are often preferable (Mowbray 1999, Johnson and Rohwer 2000), especially for mallard and teal species. Gadwall feed in deeper water than any of the other species of dabbling ducks, from the surface up to depths of 30 cm (Leschack et al. 1997). In some cases, depending on the topography of the wetland and surrounding area, increases in water level may increase the available surface area of shallow water and improve conditions for staging dabbling ducks (Boertmann and Riget 2006). Wetlands with varying water depths will provide for the largest number of species and individuals.

Ranking of habitat quality variables. Most habitat quality variables for ducks can be considered of high importance (Table 9). The size of the wetland may be less important than the other variables, although the size of the wetland may restrict the number of dabbling duck species because small wetlands are not as likely as larger wetlands to provide as much diversity of other variables, such as water depth and plant community.

Table 4. Adjusted population trends (2.5% CI, 97.5%CI) for dabbling ducks from the Breeding Bird Survey (Sauer et al. 2012) in Colorado, the United States, and survey-wide.

Species / Region	Trends 1966–2011	Trends 2001–2011
Gadwall		
Colorado [b]	-0.3 (-3.0, 2.3)	-0.2 (-6.4, 5.4)
BBS Central [a]*	3.4 (2.4, 4.6)	4.9 (1.6, 8.7)
United States [a] *	2.9 (1.7, 4.0)	2.4 (-1.1, 5.6)
Survey-wide [a] *	3.1 (2.1, 4.0)	4.7 (1.9, 7.9)
American wigeon		
Colorado [c]	5.0 (-0.7, 10.4)	5.0 (-3.4, 12.3)
BBS Central [a]**	-2.7 (-4.0, -1.2)	0.1 (-3.0, 4.7)
United States [b]	-0.8 (-2.5, 0.6)	0.5 (-3.5, 4.8)
Survey-wide [a]**	-2.8 (-4.6, -1.6)	0.3 (-2.1, 3.6)
Mallard		
Colorado [a]	-1.1 (-2.3, 0.2)	-1.3 (-4.1, 1.4)
BBS Central [a]	0.6 (-0.2, 1.4)	1.2 (-0.8, 3.4)
United States [a]*	1.8 (1.1, 2.4)	1.4 (-1.1, 3.7)
Survey-wide [a]	0.2 (-0.5, 0.9)	1.1 (-0.5, 2.7)
Blue-winged teal		
Colorado [b]	-0.8 (-4.4, 3.0)	-4.1 (-14.3, 4.9)
BBS Central [a]	1.2 (0.0, 2.3)	5.1 (1.3, 9.3)
United States [c]	0.4 (-19.5, 2.0)	2.5 (-2.2, 7.6)
Survey-wide [c]	0.1 (-18.1, 1.4)	4.3 (0.9, 8.1)
Cinnamon teal		
Colorado [b]	-1.0 (-4.5, 2.6)	-3.6 (-12.9, 3.7)
BBS Central [c]	2.6 (-3.2, 7.1)	9.1 (1.1, 28.2)
United States [c]	-2.8 (-20.9, -0.8)	0.4 (-2.9, 7.2)
Survey-wide [c]	-2.5 (-20.7, -0.6)	0.9 (-2.3, 7.3)
Northern pintail		
Colorado [b]	-3.3 (-7.0, 0.4)	-2.6 (-11.7, 7.8)
BBS Central [a]	-0.9 (-3.5, 1.2)	10.6 (4.8, 17.0)
United States [b]	-0.7 (-4.0, 1.3)	4.3 (-2.1, 11.1)
Survey-wide [a]	-1.3 (-4.2, -0.6)	9.8 (4.4, 15.8)
Green-winged teal		
Colorado [b]	-1.8 (-4.6, 1.2)	-1.6 (-7.3, 4.3)
BBS Central [b]	-0.4 (-3.2, 1.4)	2.1 (-2.5, 8.4)
United States [b]	-1.4 (-4.7, 0.2)	-1.8 (-7.8, 3.9)
Survey-wide [b]	-0.3 (-2.6, 1.0)	1.9 (-1.8, 6.1)

* Significantly increasing trend, $P < 0.05$

** Significantly decreasing trend, $P < 0.05$

[a] Indicates the data for this region have moderately precise results over time.

[b] Indicates the data for this region have some deficiencies with imprecise results over time.

[c] Indicates the data for this region has important deficiencies with very imprecise results over time.

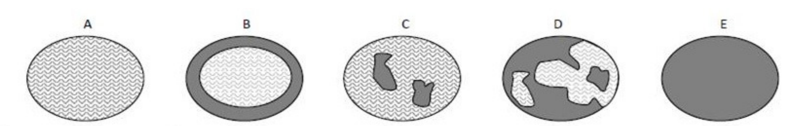
Table 5. Occurrence and seasonal importance to dabbling ducks of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland habitat type	Spring (Ice Thaw-mid May)	Fall (Sept.-Ice Formation)	Winter	Relative Range of Importance
Natural wetland habitat types				
Beaver pond	√	√		Medium-high
Emergent marsh	√	√		High
Playa	√	√		Low-high
Riparian wetland (shrub-scrub)	√	√		Low
Riparian wetland (herbaceous)	√	√		High
Sandbar	√	√	√	Medium
Stream channel	√	√	√	Low
Warm water slough	√	√	√	High
Wet meadow	√	√		High
Impoundments and other human created wetlands				
Irrigation-influenced wet meadow	√			Medium
Irrigation ditch	√	√		Low
Gravel pits	√	√	√	Low-medium
Moist soil unit	√	√		High
Recharge pond/Moist soil unit	√	√		Medium-high
Reservoir	√	√	√	Low to high
Sewage lagoon	√	√		Medium
Stock pond	√	√		Low-high
Urban runoff ponds	√	√		Low-medium

Table 6. Quality (high, medium and low) of key habitat quality variables for dabbling ducks in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	Value		
	High	**Medium**	**Low**
Dominant vegetation			
General type	Grasses, sedges, rushes submergents, and other seed-producing plants	Herbaceous plants that provide little to no food resources for ducks	Willows and other woody shrubs
Structure	Soft and easy to move through	Courser, more rigid, and dense	Woody or stiff and dense
% emergent (soft) cover			
Reservoirs/gravel pits	> 5%	1–5%	0%
Diurnal	21–50%	5–20%	< 5% or > 50%
Nocturnal	61–80%	21–60%	10-20%
Interspersion pattern (does not include open water areas that are not wetlands)[a]			
Diurnal	C or D	B	A or E
Nocturnal	C or D		A, B, or E
Invertebrates			
(Not considered during summer months)	Gastropods, other mollusks, midges		None
Landscape context			
Distance to roosts (Known locations)	< 8 km	8–16 km	> 16 km
% water within 8 km	> 2% other wetlands on landscape	1-2% other wetlands on landscape	< 1% other wetlands on landscape
Distance to agricultural fields, especially corn	< 8 km	8–16 km	> 16 km
Size of habitat			
Wet meadows	> 8 ha	2–8 ha	< 2 ha
Reservoirs/gravel pits	> 8 ha	4–8 ha	< 4 ha
Others	> .8 ha	.2–.8 ha	< .2 ha
Stream order			
	5th or 6th order	3rd or 4th order	1st or 2nd order
% Submergent vegetation			
	31-60%	11-30%	0-10%
Water depth (cm)			
	10-30 cm	31–60 cm	> 60 cm

[a] Interspersion pattern refers to the following diagram:



A: Open Water	Habitat feature is essentially not vegetated and covered exclusively by open water
B: Fringe	Habitat feature has vegetation around the perimeter of the wetland with central open water
C: Partially interspersed	Habitat feature contains a few vegetation patches in the central portion
D: Complex	Habitat feature contains vegetation interspersed in many patches
E: Closed	Habitat feature has few or no areas of open water

Table 7. Food preferences for dabbling ducks.

Species	Foods	References
Gadwall	Submergents, seeds, aquatic invertebrates; milfoil particularly important	Sousa 1985, Leschack et al. 1997
American wigeon	Herbivorous: submergents, leafy aquatic and upland vegetation and seeds	Turnbull and Baldassarre 1987, Mowbray 1999, Guillemain et al. 2002
Mallard	Mostly vegetarian, seeds, aquatic plants, arrowhead tubers, crops (e.g., corn)	Hughes and Young 1982, Turnbull and Baldassarre 1987, Johnson and Rohwer 2000, Drilling et al.2002
Blue-winged teal	Seeds, aquatic invertebrates, aquatic plants, duckweed, algae, grains; milfoil particularly important	Rollo and Bolen 1969, Bellrose 1980, Rohwer et al. 2002
Cinnamon teal	Seeds, aquatic invertebrates, aquatic plants; in spring invertebrates particularly important	Thorn and Zwank 1993, Gammonley 1995, 1996
Northern pintail	Aquatic vegetation (e.g., sago pondweed), aquatic invertebrates, crops (e.g., corn)	Euliss and Harris 1987, Austin and Miller 1995, Pearse et al. 2011
Green-winged teal	Seeds, invertebrates, plant material	Hughes and Young 1982, Euliss and Harris 1987, Johnson 1995, Anderson et al. 2000

Table 8. Food value to dabbling ducks of plants existing within the Lower South Platte River Basin.

Common Name	Scientific Name	Reference
High value		
Nodding beggarticks	*Bidens cernua*	LaGrange et al. 1999, Nelms et al. 2007
Threelobe beggarticks**	*Bidens comosa*	LaGrange et al. 1999, Nelms et al. 2007
Devil's beggarticks	*Bidens frondosa*	LaGrange et al. 1999, Nelms et al. 2007
Sedges	*Carex* spp.	Hughes and Young 1982, Johnson 1995
Redroot flatsedge*	*Cyperus erythrorhizos*	LaGrange et al. 1999
Chufa or Yellow nutsedge*	*Cyperus esculentes*	LaGrange et al. 1999, Taylor and Smith 2005, Nelms et al. 2007
Flatsedge spp.	*Cyperus spp.*	Rollo and Bolen 1969, Austin and Miller 1995, Johnson 1995
Crabgrass	*Digitaria* spp.	Nelms et al. 2007
Barnyardgrass	*Echinochloa crus-galli*	Rollo and Bolen 1969, Euliss and Harris 1987, Austin and Miller 1995, Johnson 1995, LaGrange et al. 1999, Anderson et al. 2000, Drilling et al. 2002, Rohwer et al. 2002, Nelms et al. 2007, Pearse et al. 2011
Rough barnyardgrass	*Echinochloa muricata*	LaGrange et al. 1999, Nelms et al. 2007
Blunt spikerush*	*Eleocharis obtusa*	Nelms et al. 2007

Common Name	Scientific Name	Reference
High value		
Spikerush spp.	*Eleocharis* spp.	Sousa 1985, Johnson 1995, Gammonley 1996, Mowbray 1999, Leschack et al. 1997, Anderson et al. 2000, Drilling et al. 2002
Teal lovegrass**	*Eragrostis hypnoides*	Nelms et al. 2007
Rice cutgrass	*Leersia oryzoides*	LaGrange et al. 1999, Drilling et al. 2002, Nelms et al. 2007
Duckweed	*Lemna* spp.	Mowbray 1999
Sprangletop	*Leptochloa* spp.	Euliss and Harris 1987, Johnson 1995, Nelms et al. 2007
Shortspike water milfoil	*Myriophyllum exalbescens*	Mowbray 1999
Water milfoil spp.	*Myriophyllum* spp.	Leschack et al. 1997
Panic grass	*Panicum* spp.	Johnson 1995, Mowbray 1999, Nelms et al. 2007
Pink (Pennsylvania) smartweed	*Polygonum bicorne*	Rollo and Bolen 1969, LaGrange et al. 1999, Anderson et al. 2000, Nelms et al. 2007
Curly-top knotweed (willow-weed)	*Polygonum lapathifolium*	LaGrange et al. 1999, Drilling et al. 2002
Spotted lady's thumb	*Polygonum persicaria*	LaGrange et al. 1999
Annual smartweeds	*Polygonum* spp.	Austin and Miller 1995, Johnson 1995, Gammonley 1996, Leschack et al. 1997, Anderson et al. 2000, Nelms et al. 2007
Longleaf pondweed**	*Potamogeton nodosus*	LaGrange et al. 1999
Pondweeds	*Potamogeton* spp.	Rollo and Bolen 1969, Sousa 1985, Johnson 1995, Leschack et al. 1997
Arumleaf arrowhead	*Sagittaria cuneata*	LaGrange et al. 1999, Nelms et al. 2007
Broadleaf arrowhead	*Sagittaria latifolia*	LaGrange et al. 1999, Nelms et al. 2007
Long-barb arrowhead ???	*Sagittaria longiloba*	LaGrange et al. 1999
Chairmaker's bulrush	*Schoenoplectus americanus*	Nelms et al. 2007
Bulrush spp.	*Schoenoplectus* spp.	Rollo and Bolen 1969, Austin and Miller 1995, Johnson 1995, Gammonley 1996
Sorghum (milo)	*Sorghum bicolor*	LaGrange et al. 1999
Common wheat**	*Triticum aestivum*	LaGrange et al. 1999, Drilling et al. 2002
Horned pondweed**	*Zannichelia palustris*	Austin and Miller 1995, Gammonley 1996
Corn	*Zea maize*	LaGrange et al. 1999, Drilling et al. 2002, Rohwer et al. 2002, Nelms et al. 2007, Pearse et al. 2011
Medium value		
American water plantain ???	*Alisma subcordatum*	LaGrange et al. 1999, Nelms et al. 2007
Red-root amaranth	*Amaranthus retroflexus*	LaGrange et al. 1999
Amaranthus spp.	*Amaranthus spp.*	Euliss and Harris 1987, LaGrange et al. 1999, Nelms et al. 2007, Pearse et al. 2011
Disk waterhyssop*	*Bacopa rotundifolia*	LaGrange et al. 1999
Shortbeak sedge	*Carex brevior*	LaGrange et al. 1999
Woolly sedge	*Carex pellita*	LaGrange et al. 1999

Common Name	Scientific Name	Reference
Medium value		
Awlfruit sedge**	*Carex stipata*	LaGrange et al. 1999
Lambsquarter**	*Chenopodium album*	LaGrange et al. 1999
Narrowleaf goosefoot	*Chenopodium leptophyllum*	LaGrange et al. 1999
Desert goosefoot	*Chenopodium pratericola*	LaGrange et al. 1999
Tapertip flatsedge**	*Cyperus acuminatus*	LaGrange et al. 1999
Great Plains flatsedge*	*Cyperus lupulinus*	LaGrange et al. 1999
Bearded flatsedge	*Cyperus squarrosus*	LaGrange et al. 1999
Needle spikerush	*Eleocharis acicularis*	LaGrange et al. 1999
Flatstem spikerush	*Eleocharis compressa*	LaGrange et al. 1999
Blunt spikerush*	*Eleocharis obtusa*	LaGrange et al. 1999
Green ash**	*Fraxinus pennsylvanica*	LaGrange et al. 1999
Common sunflower	*Helianthus annuus*	LaGrange et al. 1999, Pearse et al. 2011
Blue mudplantain*	*Heteranthera limosa*	LaGrange et al. 1999
Common duckweed	*Lemna minor*	LaGrange et al. 1999
Duckweed spp.	*Lemna spp.*	LaGrange et al. 1999
Bearded sprangletop	*Leptochloa fascicularis*	LaGrange et al. 1999
Alfalfa	*Medicago sativa*	LaGrange et al. 1999
Fall panicgrass*	*Panicum dichotomiflorum*	LaGrange et al. 1999
Water smartweed	*Polygonum amphibium*	LaGrange et al. 1999
Variable pondweed**	*Potamogeton gramineus*	LaGrange et al. 1999
Pondweeds	*Potamogeton spp.*	LaGrange et al. 1999
Pale dock**	*Rumex altissimus*	LaGrange et al. 1999
Curly dock	*Rumex crispus*	LaGrange et al. 1999
Dock	*Rumex spp.*	Euliss and Harris 1987, LaGrange et al. 1999, Anderson et al. 2000, Nelms et al. 2007
Common threesquare	*Schoenoplectus pungens*	LaGrange et al. 1999
Yellow foxtail*	*Setaria pumila*	LaGrange et al. 1999
Green bristlegrass	*Setaria viridis*	LaGrange et al. 1999
Broadfruit bur-reed**	*Sparganium eurycarpum*	LaGrange et al. 1999, Nelms et al. 2007
Common bladderwort*	*Utricularia vulgaris*	LaGrange et al. 1999

*Occurs in one or two counties within LSPRB (NRCS 2012).
**Occurs in two to four counties within LSPRB (NRCS 2012).
Unless otherwise indicated, occurs in five or more counties within LSPRB (NRCS 2012).

Table 9. Importance, ranking, and EPA monitoring level of key habitat quality variables for dabbling ducks in the Lower South Platte River Basin, Colorado.

	Importance				EPA Level		
Habitat Variable	**Rank**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Dominant vegetation	1	√				√	√
% emergent cover	2	√			√	√	√
Landscape context*	3	√			√		
Water depth	4	√					√
% submergents	5	√			√	√	√
Interspersion pattern	6	√			√	√	√
Size of habitat	7		√		√	√	
Invertebrates	8		√				√

*Identification of high-quality diurnal wetlands and wetlands appropriate for nocturnal roosting depends on both dominant vegetation (Levels 2 and 3 assessments) and percent of emergent vegetation (Levels 2 and/or 3 assessments).

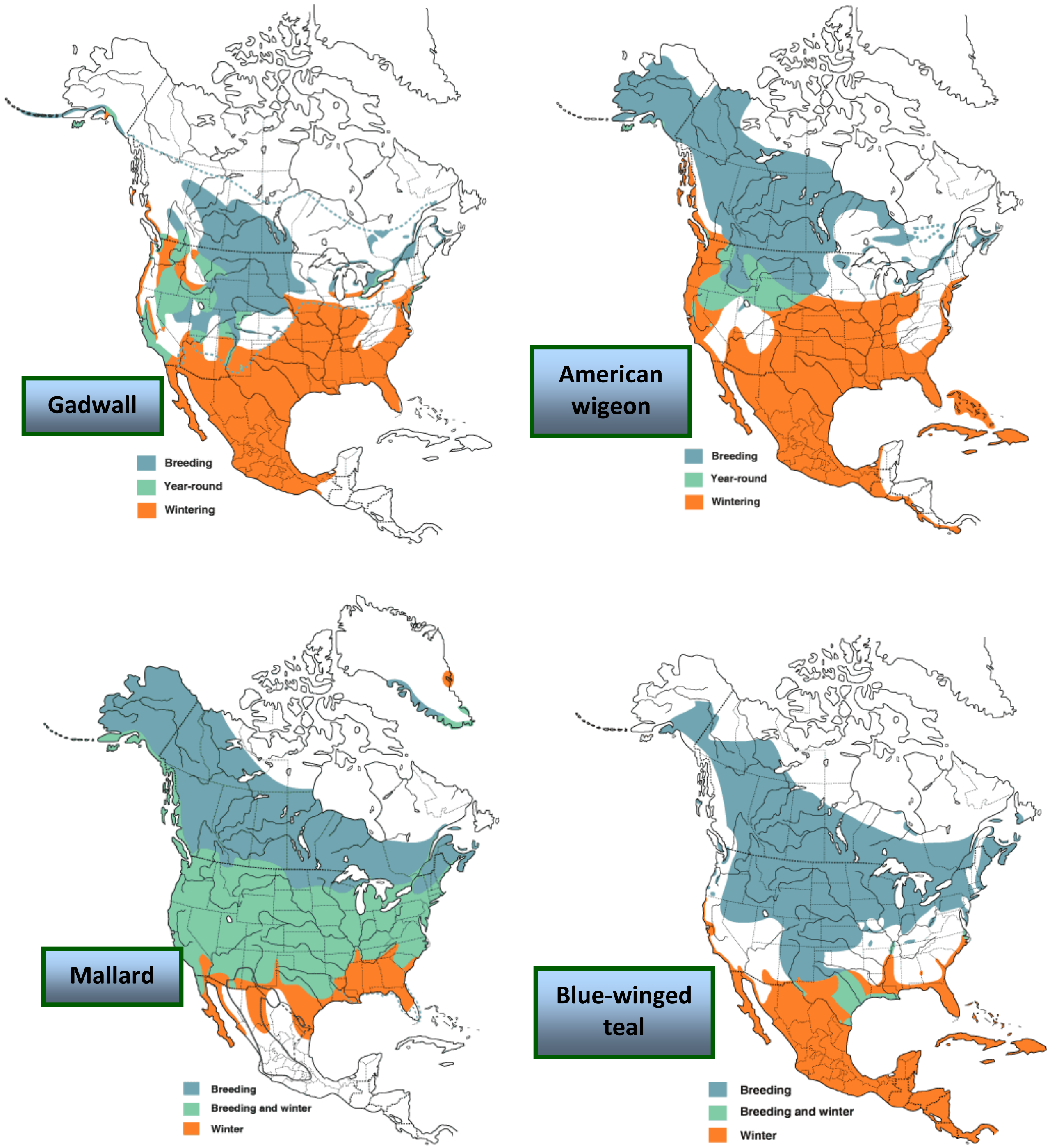


Figure 2. Distribution of dabbling ducks:
Distribution of gadwall (Leschack et al. 1997), American wigeon (Mowbray 1999), mallard (Drilling et al. 2002), and blue-winged teal (Rohwer et al. 2002).

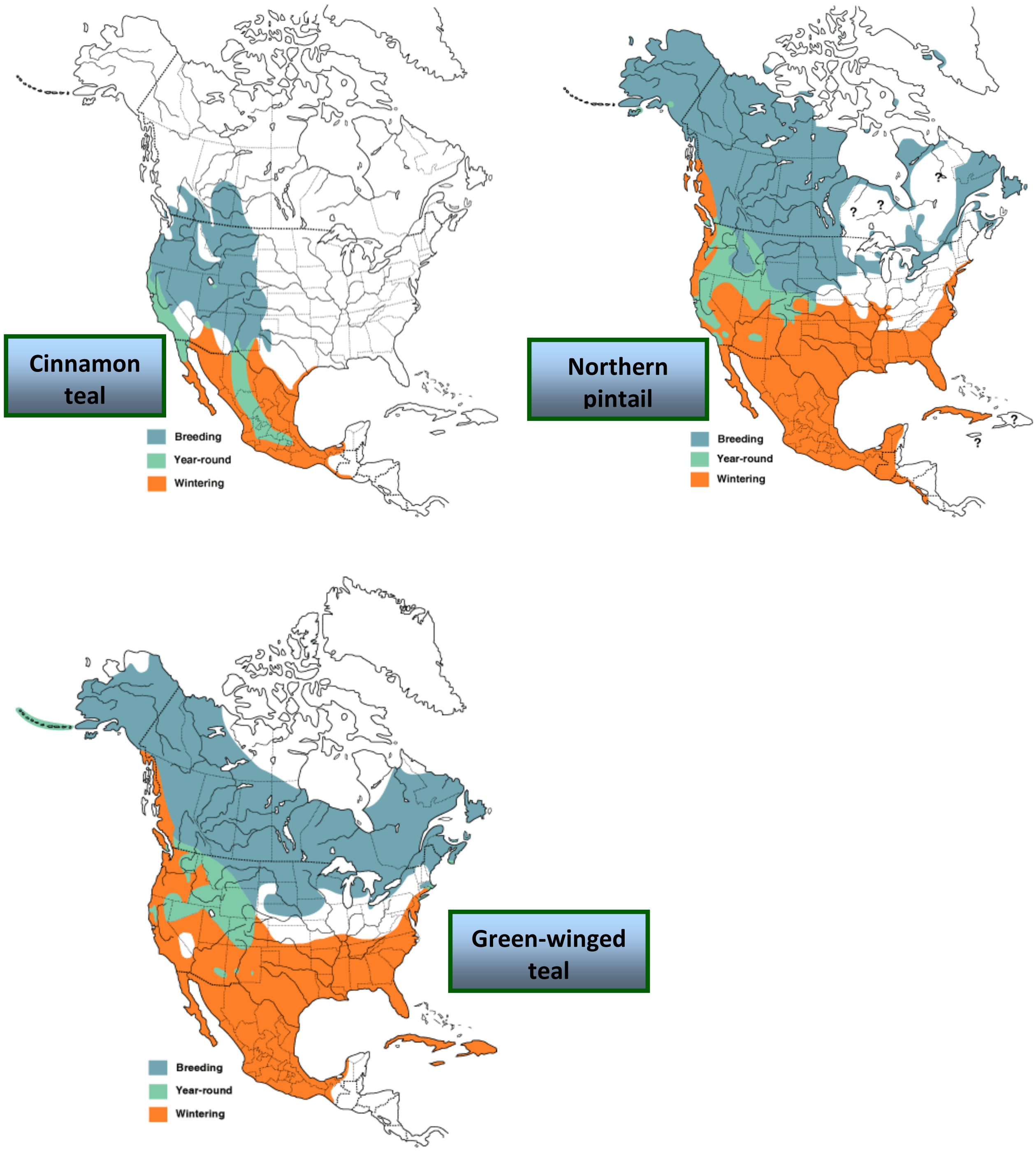


Figure 2, continued. Distribution of cinnamon teal (Gammonley 1996), northern pintail (Austin and Miller 1995), and green-winged teal (Johnson 1995).

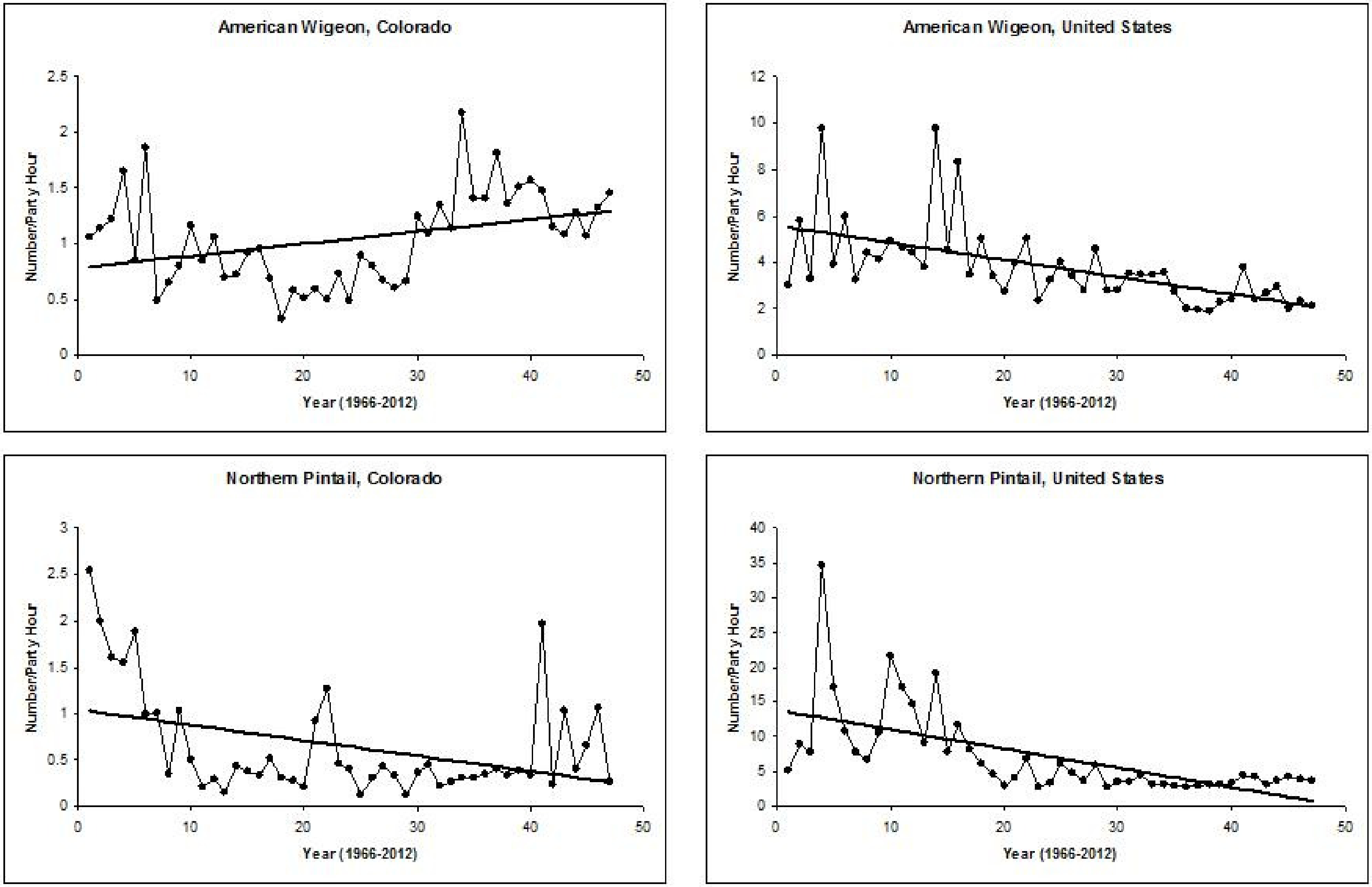


Figure 3. Wintering population trends of American wigeons and northern pintails in Colorado and throughout the United States from 1966 through 2012. Figures generated from the Audubon Society Christmas Bird Count (http://netapp.audubon.org/cbcobservation/)

3.2.2 American Bittern

Range, population status, conservation status. American bitterns (*Botaurus lentiginosus*) breed from the mid United States through northern Canada (Figures 4 and 5A). They have declined throughout much of their breeding range since 1966, but the population trend throughout the United States recently changed from a significant decline (Sauer et al. 2011) to a non-significant decline (Table 10, Sauer et al. 2012). Lor and Malecki (2006) and Nadeau et al. (2008), however, pointed out that American bitterns are easily missed in national and local surveys because they are difficult to see and are not consistently vocal enough to be aurally detected. Nevertheless, they are probably not common in the LSPRB (Figures 4 and 5A). Only two blocks within the LSPRB in the first Colorado Breeding Bird Atlas (COBBA) had possible breeding records (Yaeger 1998). The BBS map indicates a decline in the LSPRB (Figure 5B), but the second COBBA shows a small increase in the number of blocks with detections (probable breeding codes) compared with the first atlas (COBBAII 2013, accessed 12-6-2013). They were historically described as fairly common on the eastern plains of Colorado (Sclater 1912 cited in Wiggins 2006).

American bitterns were listed by the USFWS in 1982 and 1987 as a Nongame Species of Management Concern, and they were on the Audubon Society's Blue List from 1976–1986 (Lowther et al. 2009). They are variously listed by states as endangered (Connecticut, Illinois, Indiana, Massachusetts, Missouri, New Jersey, and Ohio), imperiled (Pennsylvania), at risk (Montana), species of special concern (Michigan, New York, and Wisconsin), and species of greatest conservation need (Minnesota). BirdLife International (2013) also lists the population as decreasing, but because of its extensive range, it is considered in the category of least concern on the International Union for Conservation of Nature (IUCN) Red List.

Wetland habitat types. American bitterns probably occupy only one wetland habitat in the LSPRB on a regular basis: emergent marshes. However, they could potentially be found in six additional habitats, depending on conditions (Table 11).

Key habitat quality variables. Important habitat variables for American bitterns include dominant vegetation, emergent cover, interspersion, the relationship to other habitats within the landscape (landscape context), residual cover depth, and size of habitat patch (Table 12).

Dominant vegetation. American bitterns prefer tall, dense emergent vegetation, regardless of wetland habitat type (Dechant et al. 2003b). For example, mean preferred height is 1.3 m (Brininger 1996 and Hanowski and Niemi 1988, cited in Dechant et al. 2003b), and Hanowski and Niemi (1988, cited in Dechant et al. 2003b) reported a mean vegetation density of 114 grass stems/m^2.

Percent emergent cover. Naugle (1997) found a positive relationship between occupied sites and percent of emergent cover. Similarly, Rehm and Baldassarre (2007) found a positive relationship between amount of emergent cover edge and relative abundance of American bitterns.

Interspersion. Bitterns use a variety of cover:water interspersion ratios and patterns, but prefer complex patterns (Lowther et l. 2009). Gibbs et al. (1991 cited in Lowther et al. 2009) described bitterns as requiring a high degree of cover:water. Some investigators have found that bitterns are most common in wetlands with open water and fringe vegetation (Weber 1978, Weber et al. 1982, cited in Dechant et al. 2003b). Bitterns often feed at the interface between open water and vegetation edge on the wetland interior; therefore, more extensive and complicated interspersion patterns will provide the most interior edge (Rehm and Baldassarre 2007).

Landscape context. Some authors have suggested a very high importance of an undisturbed buffer surrounding the wetland. An undisturbed and uncontaminated buffer provides protection from predators as well as increased foraging success because many of their prey items are sensitive to contamination (Table 13, Wiggins 2006). Wiggins (2006) suggested a buffer > 200 m free from disturbance (including livestock grazing, mowing, and burning) would benefit American bitterns. They tend to occupy wetlands that are surrounded by idle grasslands (Dechant et al. 2003b) and not isolated from other wetlands on the landscape. Niemuth and Solberg (2003) found that the distribution and density of American bitterns was correlated with the number of wetlands on the landscape.

Residual cover. Residual cover appears important enough to have evolutionarily influenced the cryptic plumage of the American bittern, making them difficult to distinguish from dried cattails and other dried emergent vegetation (Ortega 1988, Lowther et al. 2009). Manci and Rusch (1988) found American bitterns only in areas with dry cattails.

Size of habitat. American bitterns will sometimes use smaller marshes, but they prefer habitat patches > 10 ha (Brown and Dinsmore 1986) or larger (> 20 ha, Craig 2008). Yet, other occupied sites in Minnesota averaged 36.7 ha (Hanowski and Niemi 1986).

Water depth. Water depth of occupied sites vary from 3–91 cm (reviewed by Dechant et al. 2003b), but American bitterns appear to require at least some open water.

Ranking of habitat quality variables. All habitat quality variables identified for American bitterns can be considered of high importance (Table 14).

Table 10. Adjusted population trends (2.5% CI, 97.5%CI) for American bitterns from the Breeding Bird Survey (Sauer et al. 2012) in the United States, and survey-wide.

Species	**Trends**	
Region	**1966–2011**	**2001–2011**
BBS Central*	0.0 (-1.5, 1.5)	1.7 (-2.4, 6.1)
United States*	-1.2 (-4.0, 0.0)	-0.8 (-4.5, 2.9)
Survey-wide*	-0.6 (-2.6, 0.4)	2.2 (-0.3, 4.6)

* Indicates the data for this region have some deficiencies with imprecise results over time.

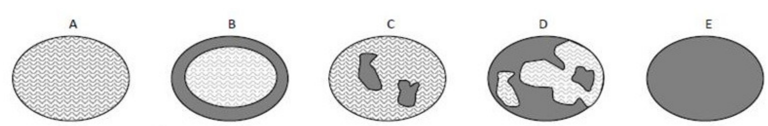
Table11. Occurrence and seasonal importance to American bitterns of wetland habitat types in the Lower South Platte River Basin, Colorado.

Habitat Type	Spring Ice Thaw-mid May	Summer	Fall Sept.-Ice Formation	Winter	Relative Range of Importance
Natural wetland habitat types					
Beaver pond	Possibly	Possibly	Possibly	Absent	Low-high
Emergent marsh	√	√	√	Absent	High
Riparian wetland (herbaceous)	Possibly	Possibly	Possibly	Absent	Low
Warm water slough	Possibly	Possibly	Possibly	Absent	Low
Wet meadow	Possibly	Possibly	Possibly	Absent	Low
Impoundments and other human created wetlands					
Gravel pits	Possibly	Possibly	Possibly	Absent	Low

Table 12. Quality (high, medium and low) of key habitat quality variables for American bitterns in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	Value: High	Medium	Low
Dominant vegetation			
	Cattails/Bulrush/Sedges/ Reed grasses/Bur-reeds	Other tall/medium emergents	Short (e.g., sedges) or no emergents
Dominant vegetation height			
	Tall (1-2 m)	Medium (0.5-< 1 m)	Short (< 0.5 m)
% emergent cover			
	61–80%	31–60% or 81-100%	15–30%
Interspersion [a]			
	B, C, or D		A or E
Landscape context			
	> 200 m buffer from disturbance		
% Residual cover			
	41–60%	21–40% or 61-100%	10–20%
Residual cover depth			
	> 10-20 cm		
Size of habitat			
	>10 ha	5–10 ha	1-5 ha
Water depth (cm)			
	5–20 cm	> 21–100 cm	< 5 cm or >100 m

[a] Interspersion pattern refers to the following diagram:



A: Open Water	Habitat feature is essentially not vegetated and covered exclusively by open water
B: Fringe	Habitat feature has vegetation around the perimeter of the wetland with central open water
C: Partially interspersed	Habitat feature contains a few vegetation patches in the central portion
D: Complex	Habitat feature contains vegetation interspersed in many patches
E: Closed	Habitat feature has few or no areas of open water

Table 13. Food preferences for American bitterns.

Foods	References
Insects	References in Lowther et al. 2009
Amphibians, especially frogs and salamanders	Bailey 1925, References in Lowther et al. 2009
Fish	References in Lowther et al. 2009
Crayfish	References in Lowther et al. 2009
Small mammals, e.g., meadow voles	References in Lowther et al. 2009
Snakes	Ingram 1941
Crabs	References in Lowther et al. 2009
Spiders	References in Lowther et al. 2009
Various other invertebrates	References in Lowther et al. 2009

Table 14. Importance, ranking, and EPA monitoring level of key habitat quality variables for American bitterns in the Lower South Platte River Basin, Colorado.

	Importance				EPA Level		
Habitat Variable	**Rank**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Size of habitat	1	√			√		
Residual cover	2	√					√
% emergent cover	3	√					√
Dominant vegetation	4	√				√	√
Vegetation height	5	√					√
Landscape context*	6	√			√		
Interspersion	7	√				√	√
Water depth	8	√					√

Figure 4. Distribution of American bitterns Lowther et al. (2009).

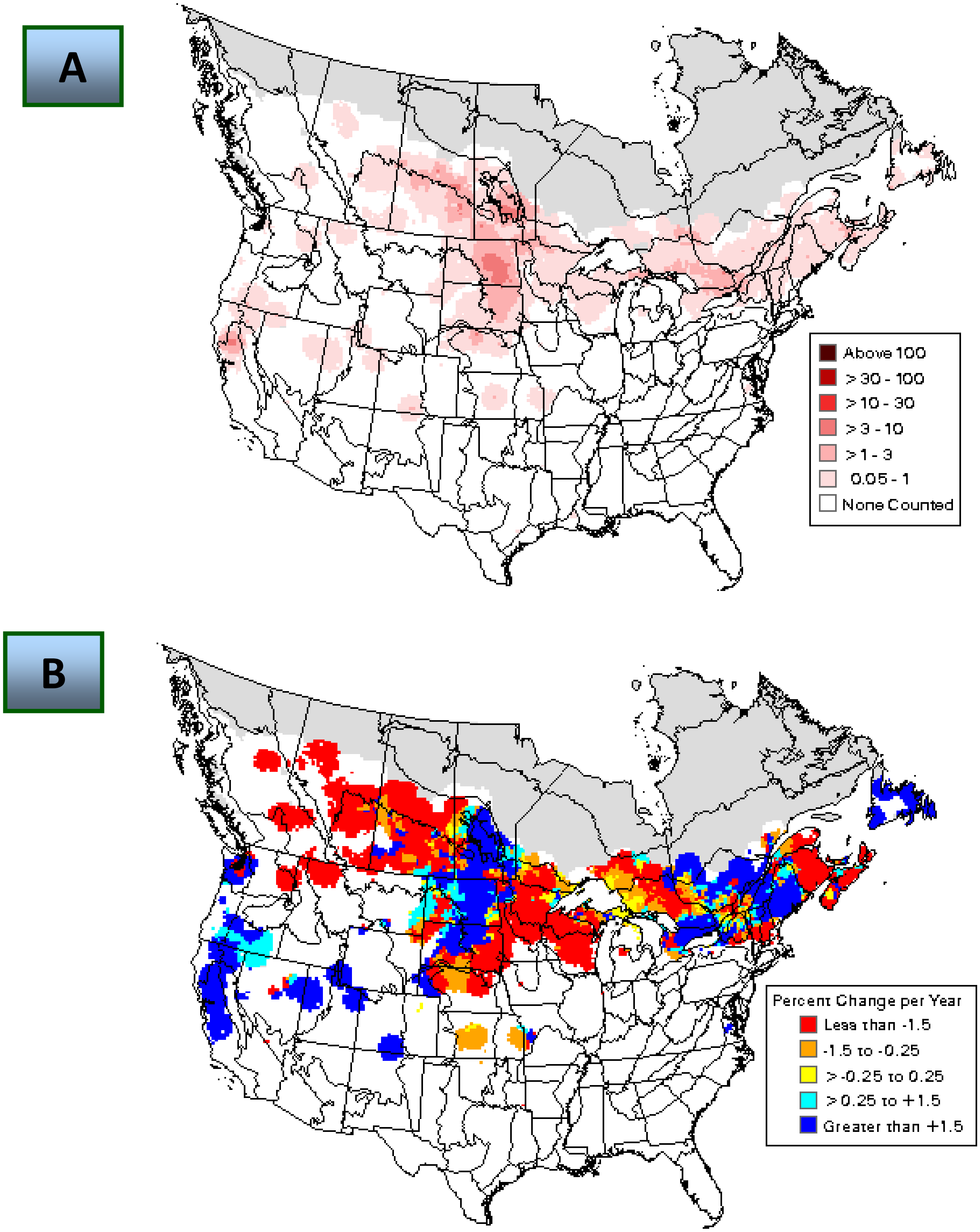


Figure 5. (A) Abundance map, and (B) population trend for American bittern Breeding Bird Survey (Sauer et al. 2011). Abundance map is based on data from 2006-2011; population trend map is based on data from 1966-2011.

3.2.31 Greater Sandhill Crane

Range, population status, conservation status. Six subspecies of sandhill cranes (*Grus canadensis*) are often recognized (but see Tacha et al. 1985, 1992).[1] The subspecies on the CPW priority list (State Species of Concern), the greater sandhill crane (*G. c.s tabida*), winters primarily in Rio Grande County, New Mexico, with spring and fall stopovers in the San Luis Valley of Colorado. Although two other subspecies (*G. c. pulla* and *G. c. nesiotes*) are listed as endangered under the Endangered Species Act (ESA), sandhill crane populations appear to be stable or increasing in most areas (Tacha et al. 1992, Sauer et al. 2012, Table 15).

Greater sandhill cranes breed in a variety of northern regions, including northwestern Colorado (Drewien and Bizeau 1974). Although they do not breed within the LSPRB (Andrews and Righter 1992, Barrett 1998b), the SP-WFAC suggested that at least some sandhill cranes use the LSPRB as a migratory stopover, and Krapu et al. (2011) clearly show the LSPRB falls within the autumnal migratory path of the Western Alaska–Siberia population (Figure 6). Tacha et al. (1992) identified four populations of the greater sandhill crane: Eastern, Rocky Mountain, Colorado River Valley, and Central Valley. None of these populations breed in the western Alaska and Siberia regions (Tacha et al. 1992, Krapu et al. 2011). Therefore, most sandhill cranes that use the LSPRB are likely from the mid-continental population, subspecies *G. c. canadensis* and may not represent the target priority species.

Wetland habitat types. Sandhill cranes probably occupy up to seven wetland habitats in the LSPRB during spring and fall migration (Table 16). Depending on the conditions, especially water depth and landscape context, all these wetland habitats could potentially provide migrating cranes with suitable resting and feeding opportunities.

Key habitat quality variables. Measurable habitat quality variables for sandhill cranes include dominant vegetation, percent emergent cover, landscape context, size of habitat, and water depth (Table 17). Nesting and wintering habitat is not considered.

Dominant vegetation. During migration, dominant vegetation is applicable only to feeding sites, which are most likely to be croplands with waste grains, particularly corn stubble, alfalfa, wheat, sorghum, barley, and oats (Krapu et al. 1984, Armbruster 1987, Iverson et al. 1987, Laubhan and Gammonley 2001). Interestingly, however, Sparling and Krapu (1994) found that cornfields were under-utilized according to availability compared with daily foraging in native grasslands and planted hay lands. Taylor and Smith (2005) reported sandhill cranes in moist-soil units in New Mexico used underground food resources, especially chufa tubers (*Cyperus esculentu*).

Percent emergent cover. During nocturnal roosting, sandhill cranes seek shallow-water wetlands with an open view and little to no emergent vegetation (Krapu et al. 2011).

[1] The Sandhill Crane Foundation (ICF, 2012) recognizes six subspecies: lesser sandhill crane (*Grus canadensis canadensis*), Greater sandhill crane (*G. c. tabida*), Canadian sandhill crane (*G. c. rowani*), Florida sandhill crane (*G. c. pratensis*), Mississippi sandhill crane (*G. c. pulla*) and Cuban sandhill crane (*G. c. nesiotes*).

Landscape context. Many investigators have reported on juxtaposition of feeding sites and nocturnal roosting sites (Krapu et al. 1984, Iverson et al. 1987, Tacha et al. 1992, Sparling and Krapu 1994, Krapu et al. 2011). Among other research needs, Kruse et al. (2011) suggested that we need to better understand the agricultural landscape as it relates to high quality habitat for sandhill cranes because of potential changes in crop types, particularly corn. Cropland is a critical component influencing migration patterns; prior to agriculture, sandhill cranes probably had to be more flexible and opportunistic in their migration patters (Krapu et al. 2011). Lovvorn and Kirkpatrick (1981) found that in the eastern population, greater sandhill cranes roosted closer to human disturbance if their open-water roosts were surrounded by trees.

Size of habitat. Folk and Tacha (1990) reported that 90% of sandhill cranes roosting in Nebraska used habitat widths of greater than 23 m, and only 10% used widths between 12–22 m, but Krapu et al. (1984) found a preference between 50 and 150 m from shore.

Water depth. Sandhill cranes are found in water depths of less than 20 cm (Lovvorn and Kirkpatrick 1981, Folk and Tacha 1990, Tacha et al. 1992).

Ranking of habitat quality variables. Numerous investigators have suggested that water depth of nocturnal roosts and landscape context are two of the most important habitat quality variables explaining the use of areas by sandhill cranes (Krapu et al. 1984, Iverson et al. 1987, Tacha et al. 1992, see Table 18).

Table 15. Adjusted population trends (2.5% CI, 97.5%CI) for greater sandhill crane from the Breeding Bird Survey (Sauer et al. 2012) in Colorado, the United States, and survey-wide.

Species	**Trends**	
Region	**1966–2011**	**2001–2011**
Colorado [c]	15.5 (7.8, 25.3)	14.5 (2.5, 24.8)
BBS Central [b] *	9.0 (5.9, 12.1)	10.2 (4.9, 15.1)
United States [a] *	5.3 (4.4, 6.2)	7.8 (6.3, 9.5)
Survey-wide [a] *	5.3 (3.5, 6.3)	8.3 (6.2, 10.6)

* Significantly increasing trend, P > 0.05
[a] Indicates the data for this region have moderately precise results over time.
[b] Indicates the data for this region have some deficiencies with imprecise results over time.
[c] Indicates the data for this region has important deficiencies with very imprecise results over time.

Table 16. Potential occurrence and seasonal importance to Greater Sandhill Crane of wetland habitats in the Lower South Platte River Basin, Colorado.

Habitat Type	Spring Ice Thaw–mid May	Summer	Fall Sept.–Ice Formation	Winter	Relative Range of Importance
Natural wetland habitat types					
Emergent marsh	√	Absent	√	Absent	Med-High
Playa	√	Absent	√	Absent	Med-High
Wet meadow	√	Absent	√	Absent	Med-High
Impoundments and other human created wetlands					
Irrigation-influenced wet meadow	√	Absent	√	Absent	Med-High
Moist soil unit	√	Absent	√	Absent	Med-High
Recharge pond/Moist soil unit	√	Absent	√	Absent	Med-High
Reservoir	√	Absent	√	Absent	Low-High

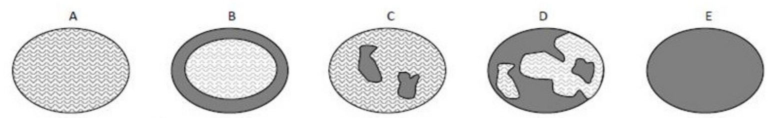
Table 17. Quality (high, medium and low) of key habitat quality variables for greater sandhill crane in the Lower South Platte River Basin, Colorado. Roosting habitats include emergent marshes, playas, and reservoirs; feeding habitats may include emergent marshes, playas, wet meadows, and recharge ponds/moist soil units.

Habitat Quality Variable	Value		
	High	**Medium**	**Low**
Dominant vegetation			
Roosting	NA	NA	NA
Feeding	Grasses, sedges, crops (particularly corn stubble)		Dense woody vegetation
Dominant vegetation height			
Feeding	<0.5 m	.05-1 m	1-2 m
% emergent cover			
Roosting	0–20%	21–40%	> 40%
Interspersion pattern [a]			
Roosting	A	B or C	D or E
Landscape context			
Roosting and feeding	≥ 1 wetland within 4 km of the roost site; relatively free from human disturbance		
% water within 8 km	> 2% other wetlands on landscape	1-2% other wetlands on landscape	< 1% other wetlands on landscape
Size of habitat			
Roosting	50–150 m from shore OR >1 ha	26–50 m from shore OR 1 ha	15-25 m from shore OR < 1 ha

Table 17, continued.

Habitat Quality Variable	Value		
	High	Medium	Low
Water depth (cm)			
Roosting	5–20 cm	20–40 cm	> 40 cm or dry
Feeding	Usually dry or shallow hummocks		

[a] Interspersion pattern refers to the following diagram (next page):



A: Open Water	Habitat feature is essentially not vegetated and covered exclusively by open water
B: Fringe	Habitat feature has vegetation around the perimeter of the wetland with central open water
C: Partially interspersed	Habitat feature contains a few vegetation patches in the central portion
D: Complex	Habitat feature contains vegetation interspersed in many patches
E: Closed	Habitat feature has few or no areas of open water

Table 18. Importance, ranking, and EPA monitoring level of key habitat quality variables for greater sandhill crane in the Lower South Platte River Basin, Colorado.

	Importance				EPA Level		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Water depth	1	√					√
Landscape context	2	√				√	
% emergent cover	3	√					√
Size of habitat	4	√				√	
Interspersion	5			√		√	√
Dominant vegetation	6			√		√	√

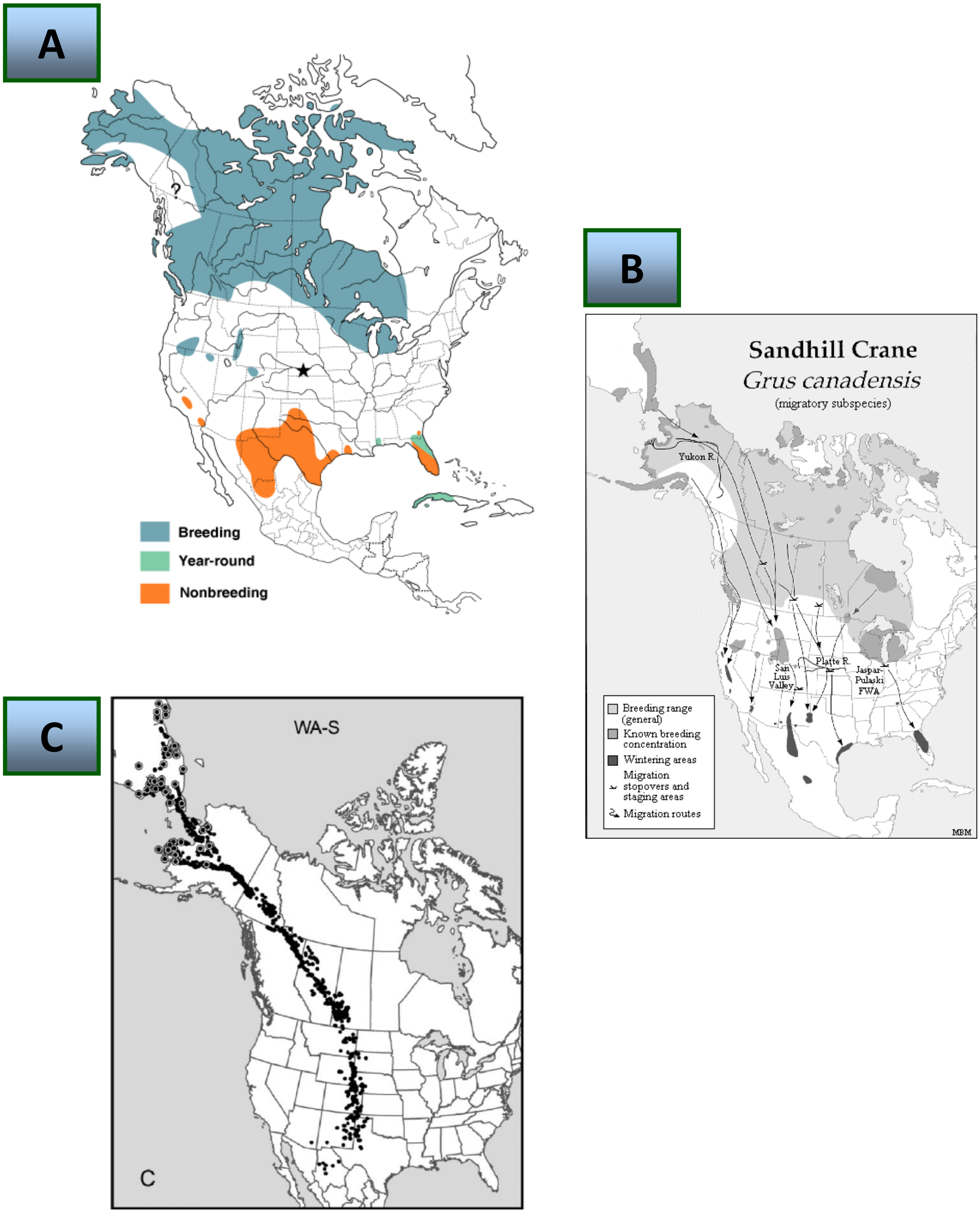


Figure 6. Distribution of Sandhill Cranes
(A) Tacha et al. (1992), (B): ICF (2012), (C) Western Alaska–Siberia population, Krapu et al. (2011).

3.2.4 Piping Plover

Range, population status, conservation status. The interior population of piping plovers (*Charadrius melodus*) is on the federal and State of Colorado threatened list (Elliott-Smith and Haig 2004, Brown et al. 2011, CPW 2012). In Colorado, they occur in the far eastern part of the state, mostly along the edges of reservoirs (Haig and Plissner 1993, Elliott-Smith and Haig 2004, Brown et al. 2011, Figure 7). They very rarely occur in the LSPRB, only as spring and fall migrants (Andrews and Righter 1992, Andrews, pers. comm. in Appendix 1), and they have not appeared within the LSPRB in the Colorado Breeding Bird Atlas (Nelson 1998c, COBBAII 2013).

Wetland habitats. The only wetland habitat in the LSPRB piping plovers would use is unvegetated or sparsely-vegetated sandbars.

Key habitat quality variables. The key habitat quality variables for piping plovers include dominant vegetation, landscape context, percent open sand or gravel area, proximity to objects, size of habitat, and percent of vegetation cover (Table 19).

Dominant vegetation. Piping plovers prefer sparse clumps of grasses or sedges (Gaines and Ryan 1988, Powell and Cutbert 1992).

Landscape context. Gaines and Ryan (1988) reported lower nest success in grazed areas and areas with motorized traffic compared to sites without these disturbances. Piping plovers nest on the ground, and the daily nest survival in some studies is extremely low (see Table 7 in Brown et al. 2011); therefore any anthropogenic landscape changes that result in increased abundance of predators will likely lower the success of piping plover nests.

Open sand or gravel area on sandbar. Piping plovers prefer open sandbars, either newly created or relatively free of vegetation, which normally occurs through scouring action of flood events (Sidle et al. 1992, Sidle and Kirsch 1993, Busby et al. 1997, Poff et al. 1997, Le Fer et al. 2008). Gaines and Ryan (1988) reported more abundant and evenly distributed gravel at sites occupied by piping plovers compared with unoccupied sites.

Proximity to large object, e.g., rocks, logs. Some authors have reported that nests are placed more often near larger objects (e.g., rocks, stones, logs) than would be expected by chance (Elliott-Smith and Haig 2004), but this has not been well defined.

Size of habitat. Gaines and Ryan (1988) found mean beach widths of occupied sites 27–39 m compared with mean beach widths 12–16 m of unoccupied sites. Similarly, Powell and Cuthbert (1992) found mean beach widths of 23–24 m for occupied sites. J. Fraser (pers. comm.) suggests that the larger habitat patches are better.

Vegetation cover. Piping plovers select for a very sparse amount of vegetation (e.g., 4% cover, Gaines and Ryan 1988).

Ranking of habitat quality variables. The importance of habitat variables is summarized in Table 20.

Table 19. Quality (high, medium and low) of key habitat quality variables for piping plovers in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	Value		
	High	**Medium**	**Low**
Dominant vegetation			
	Sparse grasses clumps preferred	Denser grasses	Woody vegetation
Landscape context			
	Along river with natural flow regimes and ungrazed		Sites away from river (less successful)
% open sand or gravel area			
	Near 100% open		Less than open
Proximity to large object, e.g., rocks, logs			
	Close	More distant	Far
Size of habitat			
	> 20 m wide (the larger the better)	15–20 m wide	10-15 m wide
% vegetation			
	0–5%	6–10%	11-20%

Table 20. Importance, ranking, and EPA monitoring level of key habitat quality variables for piping plovers in the Lower South Platte River Basin, Colorado.

	Importance				EPA Level		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
% open sand or gravel area on sandbar	1	√			√		
Size of habitat	2	√			√		
% vegetation cover	3	√					√
Landscape context	4	√			√		
Dominant vegetation	5	√				√	√
Proximity to large object, e.g., rocks, logs	6	?	?			√	√

Figure 7. Distribution of piping plovers
Elliot-Smith and Haig 2004

3.2.5 Long-billed Curlew

Range, population status, conservation status. Long-billed curlews (*Numenius americanus*) breed in the western United States, including eastern Colorado, and southwestern Canada (Figure 8). They do not breed abundantly in the LSPRB (Andrews and Righter 1992, Nelson 1998b, COBBAII 2013, Figure 9a) and do not occur in Colorado during winter months (Dugger and Dugger 2002). Although declines have occurred elsewhere (Figure 9b), Colorado is the only region covered by BBS that has experienced significant declines (Sauer et al. 2012, Table 21). However, along the east coast, where they were once common during migration, they are now rarely observed (Dugger and Dugger 2002). The long-billed curlew is listed as a Colorado Species of Concern (CPW 2012). They are also listed as a USFWS Bird of Conservation Concern (Fellows and Jones 2009). Jones et al. (2008) suggested that long-billed curlews are underestimated in BBS surveys.

Wetland habitats. Long-billed curlews may be found within the LSPRB in playas as well as natural and irrigation-influenced wet meadows (Table 22).

Key habitat quality variables. Key habitat variables include dominant vegetation, landscape context, proximity to water and to large objects, size of habitat, percent vegetative cover, vegetation height, and water depth (Table 23).

Dominant vegetation. Long-billed curlews prefer short grasses and generally avoid areas with trees, dense shrubs, and tall grasses (McCallum et al. 1977, Pampush and Anthony 1993, Dugger and Dugger 2002). However, a wide variety of plant species are used by long-billed curlews, and it appears that plant structure is more important than species (Dugger and Dugger 2002). They will even nest in cheatgrass fields (Allen 1980, Pampush and Anthony 1993, Earnst and Holmes 2012). Saunders (2001) found in Alberta, Canada, that when abundantly available, curlews preferred native grasslands over human-influenced pastures.

Landscape context. Mueller (2000) suggested that habitat heterogeneity is important with juxtaposition of "short-growth grasslands, agricultural fields, meadows, prairies, grazed mixed-grass, and scrub communities." Similarly, Saalfeld et al. (2010) found that curlews were positively associated with wetlands and hay or pasture meadows and negatively associated with shrub/scrub and forested habitats on a landscape scale. In Colorado, foraging may take place in nearby agricultural fields (King 1978 cited in Dugger and Dugger 2002), but curlews do not generally use agricultural fields for nesting (Dark-Smiley and Keinath 2004, Dechant et al. 2003a). In southeastern Colorado, King (1978 cited in Dark-Smiley and Keinath 2004) reported 55% of foraging observations occurred in grasslands and 40% in croplands. Livestock grazing promotes the short grass conditions favored by long-billed curlews, but cattle pose a significant trampling effect on nests, and sheep pose an even greater risk (Sugden 1933, Timken 1969, Clarke 2006); therefore, manipulations of timing, density and distribution of cattle may increase nest success (Clarke 2006, Mueller 2000).

Proximity to water. Although long-billed curlews are rarely observed using water (COPIF 2012), proximity to standing water (< 400 m) appears to be a feature that curlews select for nest sites (McCallum et al. 1977, Clarke 2006), and Saalfeld et al. (2010) found a positive association with wetlands. However, the actual nest sites are dry. Preference for water depth, also, does not seem to be well understood, and Davis and Smith (1998) reported out of 30 species studied during migration in the Playa Lakes Region, long-billed curlews were the only species using water with depths not differing from availability. Fellows and Jones (2009) pointed out that the role water plays probably varies geographically and with local conditions; also, the heavy grazing near water sources provides the short grass conditions that curlews prefer.

Proximity to large objects, e.g., rocks, logs, branches, dirt mounds, cattle manure, discarded trash from humans . Some authors have reported that nests are placed more often near larger objects than would be expected by chance (Allen 1980, Dugger and Dugger 2002).

Size of habitat. In northern California, Colwell et al. (2002) found a relationship during the non-breeding season between home range and diet although both varied; they found an average home range of 3 ha during the breeding season and suggested that home range size is habitat specific. Allen (1980) reported the smallest defended territories in areas where the habitat and topography were most varied with a range in size of 6–20 ha. In South Dakota, Clarke (2006) reported much larger home range sizes of 15–489 ha (mean of 187 ha) across the breeding season. In California, Mathis (2000) found much smaller summer home range sizes: 1.3–7.5 ha. Mueller (2000) and Pampush and Anthony (1993) suggested 14–49 ha and 4.4–20 ha, respectively, depending on habitat and topographic diversity.

Percent vegetation cover. King (1978,cited in COPIF 2012) reported a range of 50–95% vegetation cover in Colorado. The average grass cover was 44% and bare ground 33% at brooding sites in Gregory's (2011) study in South Dakota.

Vegetation height. Long-billed curlews use short grass habitat for foraging and breeding activities, e.g. < 10–20 cm (Allen 1980), 10–27 cm (Clarke 2006), 7.5–23 cm (Mueller 2000), 4–15 cm (Saalfeld et al. 2010), <10–30 cm (COPIF 2012). In Colorado, King (1978 cited in COPIF 2012) reported a mean of 11 cm. Gregory (2011) found a negative relationship between vegetation height and nest success.

Diet. Long-billed curlews probe or peck for invertebrates, including mollusks, worms, crustaceans (Stenzel et al. 1976, Colwell et al. 2002), and spiders (Abbott 1944). Insects, such as grasshoppers (COPIF 2012), may be especially important in some areas (Dugger and Dugger 2002). They also consume some vertebrate species, including fish (Colwell et al. 2002), amphibians (Mueller 2000), and bird eggs/nestlings (references in Sedgwick 2006).

Ranking of habitat quality variables. The importance of habitat variables for long-billed curlews is summarized in Table 24.

Table 21. Adjusted population trends (2.5% CI, 97.5%CI) for long-billed curlews from the Breeding Bird Survey (Sauer et al. 2012) in Colorado, the United States, and survey-wide.

Species **Region**	**Trends** **1966-2011**	 **2001-2011**
Colorado [b] **	-4.1 (-6.8, -0.8)	-3.0 (-7.6, 6.1)
BBS Central [c]	-0.7 (-2.4, 0.4)	0.4 (-1.6, 2.8)
United States [c]	0.3 (-2.0, 1.2)	1.5 (-0.3, 3.5)
Survey-wide [c]	0.1 (-1.8, 0.9)	1.2 (-0.3, 2.8)

** Significantly decreasing trend, $P < 0.05$. Data for all regions have moderately precise results over time.
[a] Indicates the data for this region have moderately precise results over time.
[b] Indicates the data for this region have some deficiencies with imprecise results over time.
[c] Indicates the data for this region has important deficiencies with very imprecise results over time.

Table 22. Occurrence and seasonal importance to long-billed curlews of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland Habitat	**Spring Ice Thaw-mid May**	**Summer**	**Fall Sept.-Ice Formation**	**Winter**	**Relative Range of Importance**
Natural wetland types					
Playa	√	?	√	Absent	Low-High
Wet meadow	√	√	√	Absent	High
Impoundments and other human created wetlands					
Irrigation-influenced wet meadow	√	√	√	Absent	High

Table 23. Quality (high, medium and low) of key habitat quality variables for long-billed curlews in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	**Value**		
	High	**Medium**	**Low**
Dominant vegetation			
Playas	Sparse, short, soft		Dense, tall, woody
Wet meadows	Open, short grasses		Trees/high grass
Dominant vegetation height			
	Short (< 50 cm)	Medium (50–100 cm)	Tall (1-5 m)
% emergent cover			
Playas	0-33%	34-50%	50-70%
Landscape context			
	Wet meadows near agricultural field and wetlands; within 400 m of water		
% water within 8 km	> 2% other wetlands on landscape	1-2% other wetlands on landscape	< 1% other wetlands on landscape
Proximity to large objects (near nest)			
	Close	More distant	Far
Size of habitat			
	> 20 ha	5–20 ha	3-5 ha
Water depth (cm)			
Playas	0–16 cm[a]	17-18 cm	> 19 cm
Wet meadows	Dry	Hummocks?	Deep

[a]Used in proportion to availability.

Table 24. Importance, ranking, and EPA monitoring level of key habitat quality variables for long-billed curlews in the Lower South Platte River Basin, Colorado.

	Importance in playas				**EPA Level**		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Landscape context	1	√			√		
% emergent cover	2	√				√	√
Water depth	3	√					√
Size of habitat	4		√		√		
Dominant vegetation	5			√			√
	Importance in wet meadows				**EPA Level**		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Vegetation height	1	√				√	√
Landscape context	2	√			√		
Water depth	3	√					√
Size of habitat	4		√		√		
Dominant vegetation	5			√			√

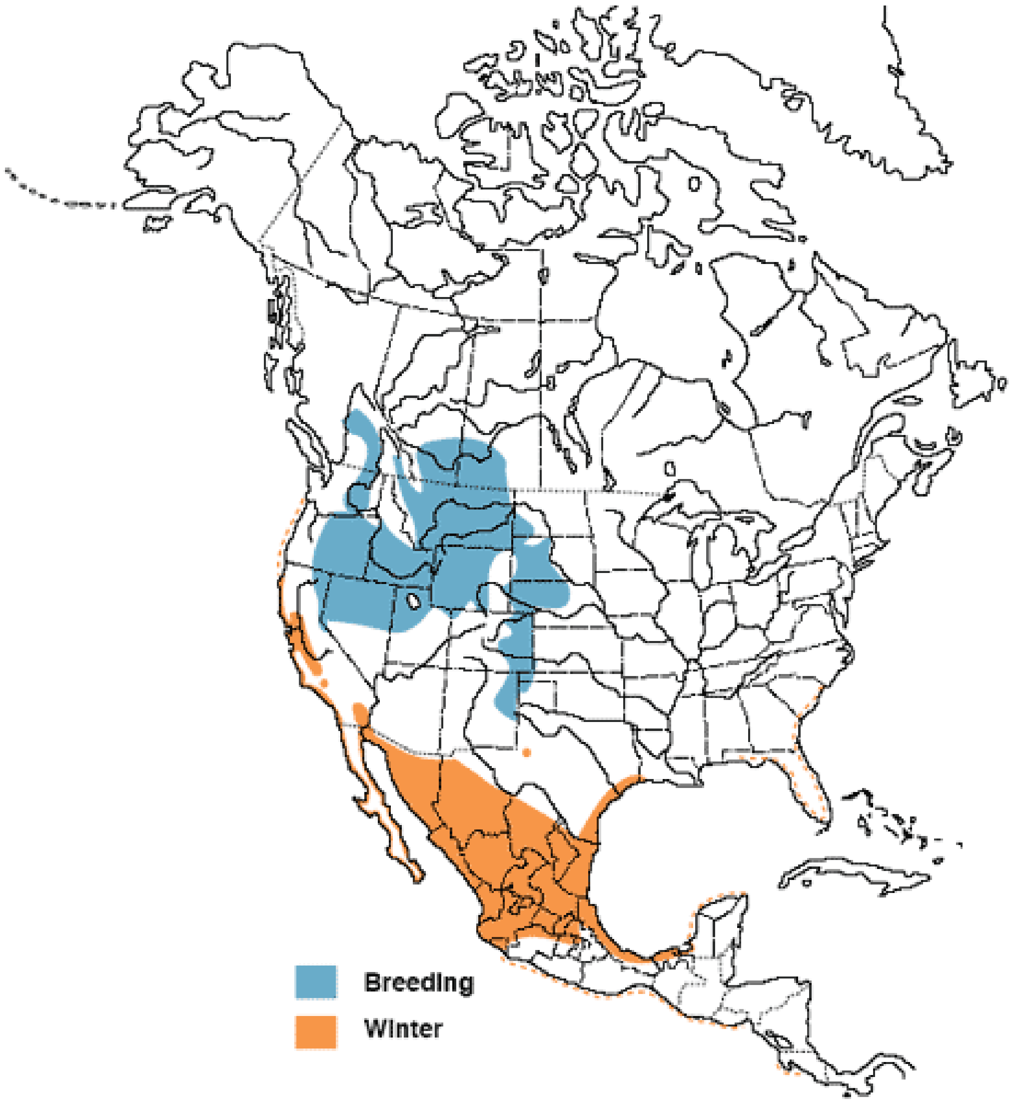


Figure 8. Distribution of long-billed curlews Dugger and Dugger 2002.

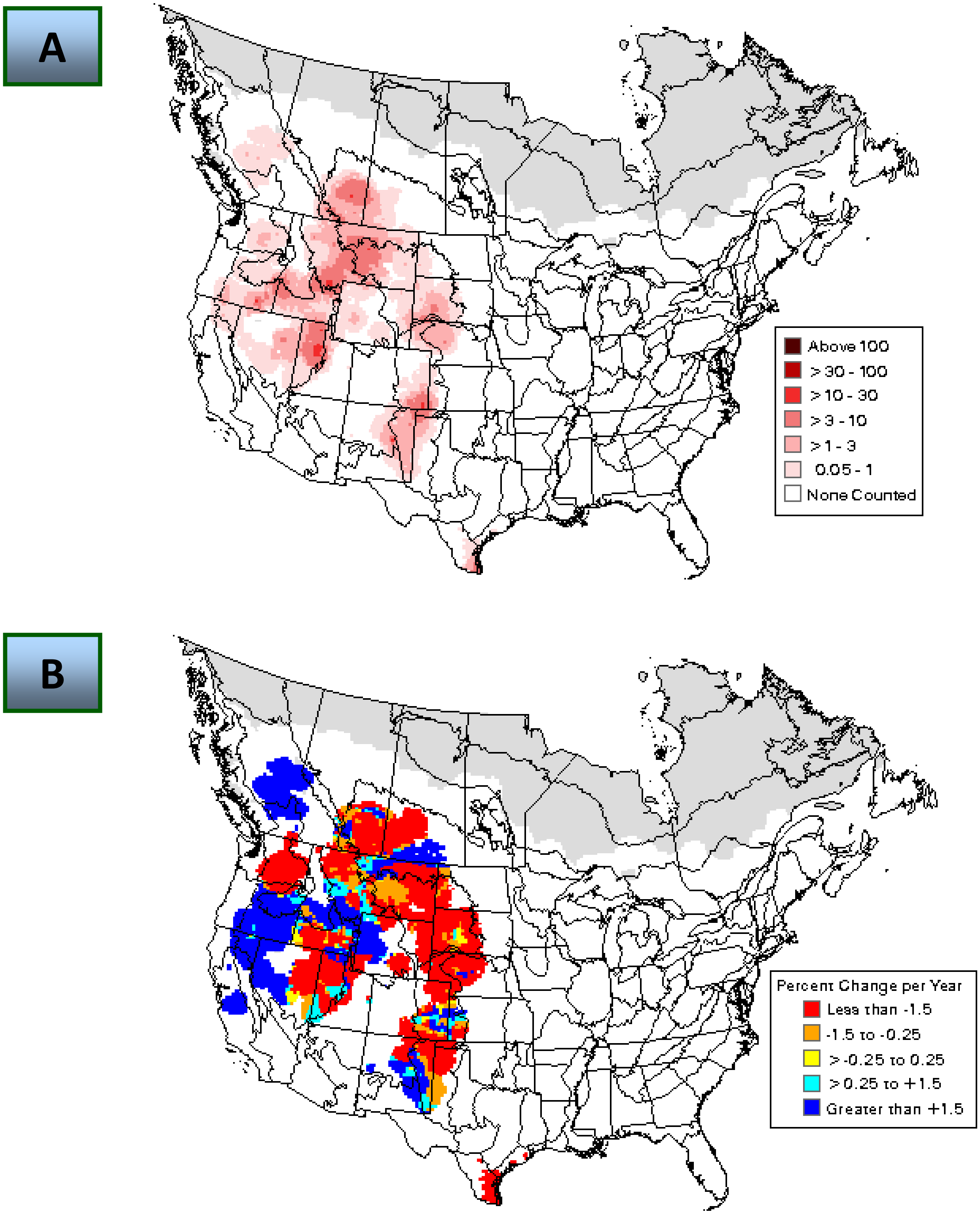


Figure 9. (A) Abundance map, and (B) population trend map for long-billed curlew Breeding Bird Survey (Sauer et al. 2012). Abundance map based on data from 2006-2011; population trend map based on data from 1966-2011.

3.2.6 Short-eared Owl

Range, population status, conservation status. Short-eared owls (*Asio flammeus*) exist throughout much of the world, including numerous islands (Wiggins et al. 2006, IUCN 2013). Although their populations are declining in many of these areas, including the United States (Table 25, Sauer et al. 2012), IUCN lists them as a species of least concern. The short-eared owl is a year-round resident in much of the LSPRB and occurs throughout the LSPRB outside the breeding season (Figure 10). Although the BBS results suggest they breed only in the northern portion of the LSPRB (Figure 11), Andrews and Righter (1992) and Boyle (1998) identified breeding records extending farther south; however, the second Colorado Breeding Bird Atlas (COBBAII 2013) shows no confirmed breeding records in the LSPRB between 2007 and 2012. BBS trends reflected this potential decline in Colorado, with a positive population trend from 1966–2010 switching to a negative trend between 1999 and 2010 (Sauer et al. 2011). With the addition of 2011 data, this trend reversed to an increase (Table 25, Sauer et al. 2012); Wiggins et al. (2006) pointed out that the BBS surveys do not adequately sample short-eared owls because their populations are prone to wide fluctuations. Nevertheless, declines have occurred throughout much of their range (Wiggins 2004, IUCN 2012).

Wetland habitats. Within the LSPRB, short-eared owls use emergent marshes, playas, and wet meadows (Table 26). Extensive grasslands may be the most important habitat, especially during the breeding season; therefore, the wetland habitats closest to large tracts of grasslands will be of highest value to short-eared owls. While many authors mention marshes as one habitat that short-eared owls occupy, very few details have been published regarding their use of marshes and other wetland habitats.

Key habitat quality variables. The key habitat variables that determine quality for short-eared owls include dominant vegetation, landscape context, residual cover, size of habitat, % vegetation cover, vegetation height, and water depth (Table 27).

Dominant vegetation. For nesting, short-eared owls rarely use wet sites (references in Wiggins et al. 2006). Short-eared owls are most often found in grasslands and areas with sparse woody vegetation (Vukovich and Ritchison 2008).

Landscape context. Short-eared owls are strongly associated with a mosaic of grasslands with relatively shorter grasses (30–60 cm) and marshes. In some areas, they commonly use agricultural fields with stubble (Goelitz 1918, Clark 1975 cited in Wiggins 2004, Dechant et al. 2001, Wiggins et al. 2006), especially during winter. Close proximity of other habitats to large grasslands with grasses < 60 cm seems to be essential (Wiggins 2004). At least in some studies, short-eared owls prefer ungrazed grasslands to grazed areas (Skinner et al. 1984 cited in Dechant et al. 2001, Wiggins 2004).

Residual cover. Duebbert and Lokemoen (1977, cited in Dechant et al. 2001) found short-eared owls nesting in residual cover 2–8 years old.

Size of habitat. Dechant et al. (2001) indicated that short-eared owls require more than 100 ha; Wiggins (2004) also suggested large grasslands are required. However, short-eared owls can also be found in much smaller parcels, suggesting that the amount of grassland in the general area may be more important than size of individual grassland tracts (Herkert et al. 1999).

% Vegetation cover. Most reports suggest that short-eared owls prefer dense grasslands, but "dense" has not been well defined (references in Dechant et al. 2001, Wiggins 2004).

Vegetation height. Holt and Leasure (1993) and Duebbert and Lokemoen (1977, both cited in Dechant et al. 2003) reported that the majority of nests were in vegetation less than 50 cm and 30–60 cm, respectively. Herkert et al. (1999), also found short-eared owl nests in vegetation less than 50 cm. Vukovich and Ritchison (2008) reported a mean of 24 cm in foraging areas; similarly, Young et al. (1988) reported grass height of 30–35 cm in grasslands used for foraging.

Water depth. Very little is published about short-eared owl water depth preference other than nest sites are dry.

Diet. The diet of short-eared owls consists almost entirely of small mammals, especially voles (*Microtus* spp., Fisher 1960, Baker and Brooks 1981, Holt 1993, Dechant et al. 2001) and in some areas mice (*Peromyscus* spp., Hendrickson and Swan 1938, Maser et al. 1970) and shrews (*Cryptotis* spp. Hogan et al. 1996). To a far lesser degree, they eat birds (Munro 1918, Errington 1937, Hughes 1982, Wiggins et al. 2006). Some investigators have found that populations of short-eared owls fluctuate with voles (Village 1987, Korpimäki 1994) or mice (Snyder and Hope 1938). Food robbing by (Bildstein and Ashby 1975) and from (Berger 1958, Korpimäki 1984) short-eared owls is common.

Ranking of habitat quality variables. The ranked importance of habitat variables for short-eared owls is summarized in Table 28.

Table 25. Adjusted population trends (2.5% CI, 97.5%CI) for short-eared owl from the Breeding Bird Survey (Sauer et al. 2012) in Colorado, the United States, and survey-wide.

Species	**Trends**	
Region	**1966–2011**	**2001–2011**
Colorado [c]	3.5 (-3.6, 14.5)	0.3 (-22.2, 23.1)
BBS Central [b]	0.3 (-3.6, 3.5)	14.4 (4.9, 26.4)
United States [b]	0.0 (-3.5, 2.7)	7.1 (-0.6, 18.7)
Survey-wide [b]	-0.7 (-4.9,-1.7)	9.9 (3.2, 19.1)

[a] Indicates the data for this region have moderately precise results over time.
[b] Indicates the data for this region have some deficiencies with imprecise results over time.
[c] Indicates the data for this region has important deficiencies with very imprecise results over time.

Table 26. Seasonal importance to short-eared owl of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland Habitat	Spring Ice Thaw–mid May	Summer	Fall Sept.–Ice Formation	Winter	Relative Range of Importance
Natural wetland types					
Emergent marsh	√	√	√	√	High
Playa	√	√	√		Medium
Wet meadow	√	√	√	√	Medium
Impoundments and other human created wetlands					
Irrigation-influenced wet meadow	√	√	√	√	Medium

Table 27. Quality (high, medium and low) of key habitat quality variables for short-eared owl in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	Value		
	High	**Medium**	**Low**
Dominant vegetation			
	Grasses	Fields with woody vegetation	Trees (but will occasionally roost in trees)
Landscape context			
	Juxtaposition of large grasslands and wetlands; ungrazed		
% grass on the landscape within an 8-km buffer	35-70%		< 35%
% Residual cover			
For nesting	41-60%	21-40%	10-20%
Size of habitat			
	> 100 ha	50–100 ha	25-50 ha
Vegetation height			
	30–60 cm		> 60 cm
Vegetation cover			
	Close to 100%		
Water depth (cm)			
	0 cm	1-2 cm	3-20 cm

Table 28. Importance, ranking, and EPA monitoring level of key habitat quality variables for short-eared owl in the Lower South Platte River Basin, Colorado.

	Importance				EPA Level		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Vegetation height	1	√					√
Landscape context*	2	√			√		
% vegetation cover	3	√					√
Residual cover depth	4	√					√
Size of habitat	5	√			√		
Dominant vegetation	6		√			√	√
Water depth	7		√				√

Figure 10. Distribution of short-eared owls Wiggins et al. 2006.

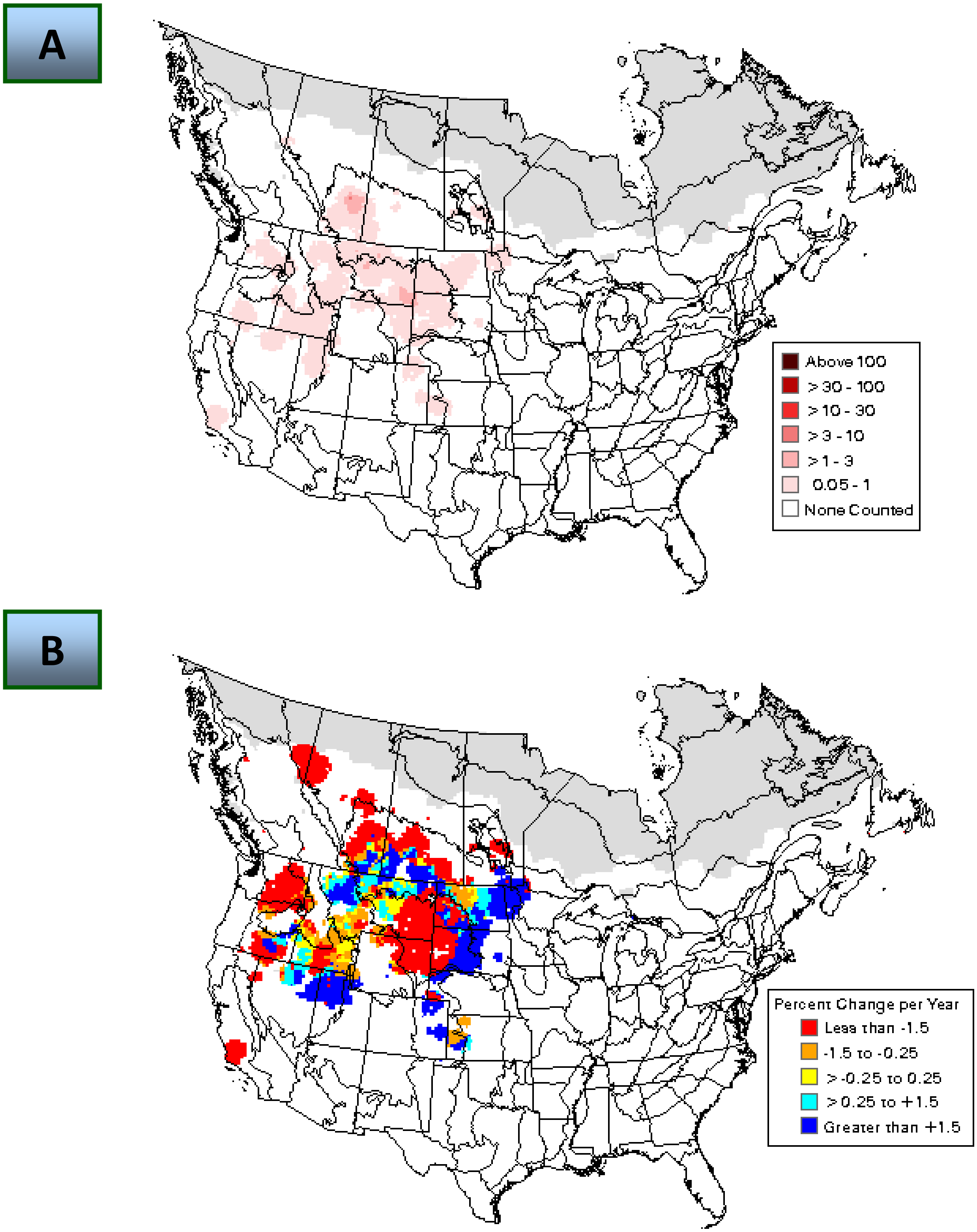


Figure 11. (A) Abundance map, and (B) population trend map for short-eared owl Breeding Bird Survey (Sauer et al. 2012). Abundance map based on data from 2006-2011; population trend map based on data from 1966-2011.

3.2.7 Frog Guild

Lynch (1978) noted that in Nebraska, northern leopard frogs (*Rana pipiens*, also *Lithobates*) occur mainly in areas with sandy soils, whereas plains leopard frogs (*Rana blairi*, also *Lithobates*) occur more frequently in loess soil areas. In general, however, their habitat needs are similar enough to combine the two species into a frog guild. Where appropriate, differences in their needs are identified.

Range, population status, conservation status.

Leopard frogs range from the northern United States and Canada as well as the more northern parts of the southwest United States (Figure 12a). They occur throughout the LSPRB (Figure 12b, NDIS 2012). Their populations are decreasing, and a petition to have them listed as threatened under the ESA (Nichols 2006) was found unwarranted by USFWS on 5 October 2011 (Federal Register 2011). IUCN (2013) lists them as a species of least concern because they are abundant, widespread, and consist of thousands of populations. Nevertheless, population declines appear to have occurred throughout their range (Clarkson and Rorabaugh 1989, Lannoo et al. 1994, Leonard et al. 1999, Kendall 2002, Germaine and Hays 2009), and they are listed in all western states and Canada as sensitive, threatened, or endangered (Germaine and Hays 2009). Both frog species are lists as Colorado species of concern. At nine sites in Larimer County where northern leopard frogs formerly bred, Corn and Fogleman (1984) found failure to breed and subsequent extinction of all these populations. In addition to habitat loss, numerous other environmental factors have been identified as agents of extermination, including (but perhaps not limited to) predation by introduced species, toxins, acid rain, parasites, pathogens, and global climate change (Clarkson and Rorabaugh 1989, Werner 2003, King et al. 2008). In regions that have been buffered from habitat loss and other disturbances (e.g., national parks), amphibians, in general, have not declined as dramatically as they have in more disturbed areas (Hossack et al. 2005).

Plains leopard frogs have a much smaller distribution than northern leopard frogs, occurring through the Great Plains (Brown and Morris 1990, Figure 13a) into southeastern Arizona (Frost and Bagnara 1977), and they are likely to occur in the eastern counties of the LSPRB (Figure 13b, NDIS 2012). Their populations are considered widespread, abundant, and secure (USDA 2003). As such, plains leopard frogs are considered a species of least concern (IUCN 2013). However, as Smith and Keinath (2005) pointed out, very little is known about population trends of plains leopard frogs, precluding meaningful information on threats to the species. Smith and Keinath (2005) assume, though, that the threats to plains leopard frogs are similar to those of northern leopard frogs.

Wetland habitats. Due to their complicated life history traits, especially their developmental patterns, frogs occupy many habitats during different seasons and stages of development, but they are closely associated with wet environments. In general, leopard frogs occupy three categories of habitat: (1) over-wintering habitat with deep water that does not freeze solid, (2) foraging habitat for adults, which may consist of uplands, riparian areas, and wet meadows, and (3) breeding habitat suitable for egg development and tadpole survival. Within the LSPRB, northern and plains leopard frogs likely inhabit most of the wetland habitats, depending on condition of the wetland and landscape context (Table 29).

Key habitat quality variables. The key habitat variables that determine quality for frogs include absence of predatory fish and bullfrogs (*Rana* [*Lithobates*] *catesbeiana*), dominant vegetation, percent emergent cover, landscape context, exposure to sunlight, size of habitat, vegetation height, water depth, and water quality (Table 30). Not all key habitat variables are applicable to all three main categories of habitat (breeding, foraging, wintering).

Absence of predatory fish and bullfrogs. Leopard frogs are usually found in ponds devoid of predatory fish and bullfrogs (Leonard et al. 1999, McAllister et al. 1999, Germaine and Hays 2009), but it is not necessarily clear whether frogs select for ponds devoid of these predators or whether the frogs/tadpoles are absent because they have been depredated. Regardless of cause and effect, the association has clear implications for management as these predators can cause local extinctions (Germaine and Hays 2009).

Dominant vegetation at breeding wetlands. Vegetation is a critical component of breeding ponds because egg masses are usually attached to emergent vegetation, such as cattails (Smith 2003, Smith and Keinath 2004), sedges and rushes (Dole 1965, Corn and Livo 1989), reed canary grass (Gilbert et al. 1994), or attached to submergent vegetation (Hine et al. 1981 cited in McAllister 1999). Very occasionally, egg masses are attached to woody vegetation, such as willow, or not attached to any vegetation (Corn and Livo 1989). Vegetation surrounding breeding ponds is important for subadult dispersal and may include grasses, sedges, rushes, and spike rushes (Corn and Fogleman 1984).

Dominant vegetation in adult foraging wetlands. Wetlands for foraging adults may consist of a variety of dominant vegetation types, including (but probably not limited to) grasses, sedges, alfalfa (McAllister et al. 1999, Germaine and Hays 2009).

Landscape context. Proximity to the three main habitat categories (breeding, over-wintering, and adult foraging habitats) appears to be one of the most important features that can predict leopard frog occupancy. While distances can be longer (e.g., 5 km, Dole 1971), 1–2 km between habitats is often noted (references in McAllister et al. 1999 and Nichols 2006, Germaine and Hays 2009). Hine (1981 cited in McAllister et al. 1999) found breeding habitat of leopard frogs by surveying all temporary ponds within 1.6 km of permanent deep-water habitat where frogs could potentially over-winter. Mushet et al. (2012) similarly suggested that deep-water over-wintering habitat in the landscape partially defined suitable habitat for frogs, and conservation programs (e.g., Conservation Reserve Program, Wetlands Reserve Program, Partners for Wildlife Program) that preserve important grassland features are important at the landscape level.

At the one-square km scale in Washington, Germaine and Hays (2009) defined sites occupied by leopard frogs as having deeper ponds with more herbaceous vegetation and fewer ponds occupied by bullfrogs and/or carp (*Cyprinus carpio*). In New York, where acid rain is relatively common, Gibbs et al. (2005) reported the most important landscape-scale variables defining occupancy as less acidic soil, lower elevations, intermediate amount of pasture land, less swamp but more marsh, and more open water. Grazing on the landscape may or may not have a negative effect, depending on the management. Knutson et al. (2004) reported a negative effect of grazing on multiple species of amphibians, including northern leopard frog; they attributed the negative effect to loss of emergent vegetation, loss of shrub and tree community surrounding ponds, and poor water quality, especially turbidity, low oxygen, and elevated nitrogen levels.

Percent vegetation cover. Very little exists in the literature regarding adequate amount of emergent cover, but Hine et al. (1981 cited in McAllister et al. 1999) suggested that leopard frogs may prefer a 67% fringe of emergent vegetation around breeding/tadpole ponds, and Germaine and Hays (2009) suggested 30–90%. Others have used more qualitative terms, such as extensive (Smith and Keinath 2004) or luxuriant (Dole 1965). Hine et al. (1981 cited in McAllister et al. 1999) suggested that submergent vegetation of about 50% would provide attachment of eggs, adequate cover for escape, and food sources for tadpoles. In adult foraging habitats, areas lacking vegetation are avoided as are heavily grazed and mowed areas (Merrell 1977, Mazerolle and Desrochers 2005, both cited in Nichols 2006). Hine et al. (1981 cited in McAllister et al. 1999) suggested that frogs prefer a gradual slope to the deepest part of breeding ponds, allowing for more emergent vegetation.

Size of habitat. The size of habitat patches that are sometimes used by leopard frogs can be as small as 0.001 ha (Dole 1965) or 0.03 ha (Corn and Fogleman 1984). Dole (1965) found that both quality and size of the habitat influenced home range size, with frogs in smaller, less suitable habitat (albeit with standing water) having smaller home ranges.

Sunlight. In general, leopard frog eggs are laid in ponds with high sunlight exposure, where the sun warms the water (Hine et al. 1981 cited in McAllister et al. 1999), or areas of a pond that are well exposed to sunlight (Gilbert et al. 1994). Exposure to sunlight also promotes algal growth, which is a major food resource for tadpoles. However, embryos of plains leopard frogs exposed to higher levels of UV-B radiation resulted in sublethal effects (Smith et al. 2000) or lethal effects (Tietge et al. 2001) at the tadpole stage.

Vegetation height in adult foraging wetlands. Adult leopard frogs seem to tolerate a range of vegetation heights in foraging areas but may avoid areas greater than 1 m (McAllister et al. 1999). Others have suggested various ranges, including 15–30 cm (Merril 1977 cited in McAllister et al. 1999).

Water depth at breeding wetlands. Water depth in breeding ponds where egg masses are laid varies greatly: less than 65 cm (Gilbert et al. 1994), less than 1.5 m (Hine et al. 1981 cited in McAllister et al. 1999), 75–100 cm (Germaine and Hays 2009), 1.5–2 m (Merril 1977 cited in McAllister et al. 1999), mean depth of 12.9 cm (Corn and Livo 1989[2]). Hine et al. (1981 cited in McAllister 1999) reported that suitable ponds maintain water most years but periodically dry up, thereby eliminating predatory fish. Germaine and Hays (2009) recommended drawdowns in late summer after metamorphosis is completed.

Water depth for winter hibernation. For hibernation, the water must be deep enough not to freeze to the bottom.

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[2] This is the mean depth taken at Sawhill Ponds, Boulder County, on the far western edge of the Lower South Platte River Basin.

Water quality. The permeability of their skin makes amphibians, in general, highly susceptible to toxins in the water (Blaustein et al. 2003). Schlichter (1981 cited in Nichols 2006) found that a pH of no less than 6.0 to be optimal for fertilization and development of leopard frog eggs, and in an experimental preference test, frogs chose a neutral pH (7.0) over 5.5 or less (Vatnick et al. 1999). Vatnick et al. (1999) found 72% mortality of frogs kept in a pH environment of 5.5 for 10 days. Leopard frogs must overwinter in well-oxygenated water, and they apparently cannot survive anoxic conditions, such as mud (Stewart et al. 2004). In overwintering habitat, leopard frogs prefer inflow areas of ponds and other water bodies where dissolved oxygen levels are higher (Smith 2003).

Diet. Adult leopard frogs primarily eat insects and other invertebrates, including crustaceans, mollusks, and worms as well as small vertebrates, such as other amphibians and snakes (references in Smith and Keinath 2005, Nichols 2006). Leopard frog tadpoles are herbivorous and considered primary consumers, eating mostly free-floating algae, but also consuming some animal material (references in Smith and Keinath 2005, Nichols 2006).

Ranking of habitat quality variables. Landscape context is the most important habitat variable, but other wetland-scale habitat variables are also critical for occupancy by leopard frogs (Table 31).

Table 29. Seasonal importance to northern and plains leopard frogs of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland Habitat	Breeding Adult and Tadpole	Adult Foraging (Summer and post–breeding)	Winter	Relative Range of Importance
Natural wetland types				
Beaver pond	√	√		High
Emergent marsh	√	√		High
Playa	√	√		Medium
Riparian wetland (shrub-scrub)	√	√		Medium
Riparian wetland (herbaceous)	√	√		High
Sandbar		√		Low
Stream channel			Probably	Medium-High
Warm water slough	√	√	√	High
Wet meadow		√		High
Impoundments and other human created wetlands				
Irrigation-influenced wet meadow		√		High
Irrigation ditch		√		Low-Medium
Gravel pits	√	√	√	Low-High
Moist soil unit		√		Low-Medium
Recharge pond/Moist soil unit	√	√		Medium
Reservoir	√	√	√	Low-High
Sewage lagoon	√	√		Low-High
Stock pond	√	√		Low-High
Urban runoff ponds	√	√		Low-High

Table 30. Quality (high, medium and low) of key habitat quality variables for northern and plains leopard frogs in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	**Value**		
	High	**Medium**	**Low**
Absence of predatory fish and/or bullfrogs			
Breeding wetlands	Predatory fish and/or bullfrogs absent	Very few predatory fish and/or bullfrogs	Predatory fish and/or bullfrogs abundant
Dominant vegetation			
Breeding wetlands	Sedges, rushes, cattails		Dense woody vegetation
Adult foraging	Grasses and sedges		Dense woody vegetation
% emergent vegetation			
Breeding wetlands	51–90%	31-50%	10-30%
Adult foraging	30–90%		25-30% or 91-100%
Landscape context			
	All 3 habitat types within 1–2 km; space between habitat with herbaceous vegetation > 1 m; free from contaminants	All 3 habitat types within 5 km; space between partially unvegetated or with vegetation > 1 m; trace contaminants	All 3 habitat types > 5 km; space between unvegetated or with vegetation > 1 m; contaminated
% water within 8 km	> 2% other wetlands on landscape	1-2% other wetlands on landscape	< 1% other wetlands on landscape
Size of habitat			
Breeding wetlands	30–60 m diameter		
Adult foraging	Not well known		
Wintering	Large and deep enough that water does not freeze solid		
Sunlight exposure			
Breeding wetlands	Exposed enough to warm water	Mostly shaded	Fully shaded
% Total canopy cover > 2m	0-30%	31-50%	51-100%
Vegetation height			
Breeding wetlands	< 1 m	1-2 m	> 2 m
Adult foraging	15–50 cm	51–100 cm	> 1 m
Water depth			
Breeding wetlands	66–100 cm	1-2 m	10-65 cm
Adult foraging	0-10 cm	11-20 cm	21-30 cm
Wintering	> 100 cm		90-100 cm
Water quality			
Breeding wetlands	pH = 6.1-7 No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Cloudy or sheen of oil
Adult foraging	pH = 6.1-7		

Table 30, continued.

Habitat Quality Variable	Value		
	High	Medium	Low
Water quality			
Wintering	pH = 6.1-7 No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Cloudy or sheen of oil

Table 31. Importance, ranking, and EPA monitoring level of key habitat quality variables for northern and plains leopard frogs in the Lower South Platte River Basin, Colorado.

	Importance				EPA Level		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Breeding/tadpole wetlands							
Landscape context	1	√			√		
Absence of predatory fish and bullfrogs	2	√					√
Water quality	3	√					√
Water depth	4	√					√
Exposure to sunlight	5	√				√	
% emergent cover	6		√			√	√
Vegetation height	7		√				√
Size of habitat	8			√	√		
Dominant vegetation	9			√			√
Adult foraging wetlands							
Landscape context	1	√			√		
Vegetation height	2	√					√
Water depth	3	√					√
Water quality	4	√					√
% emergent cover	5		√			√	√
Dominant vegetation	6		√				√
Size of habitat	7			√	√		
Over-winter wetlands							
Landscape context	1	√			√		
Water depth	2	√					√
Water quality	3	√					√
Size of habitat	4	√			√		

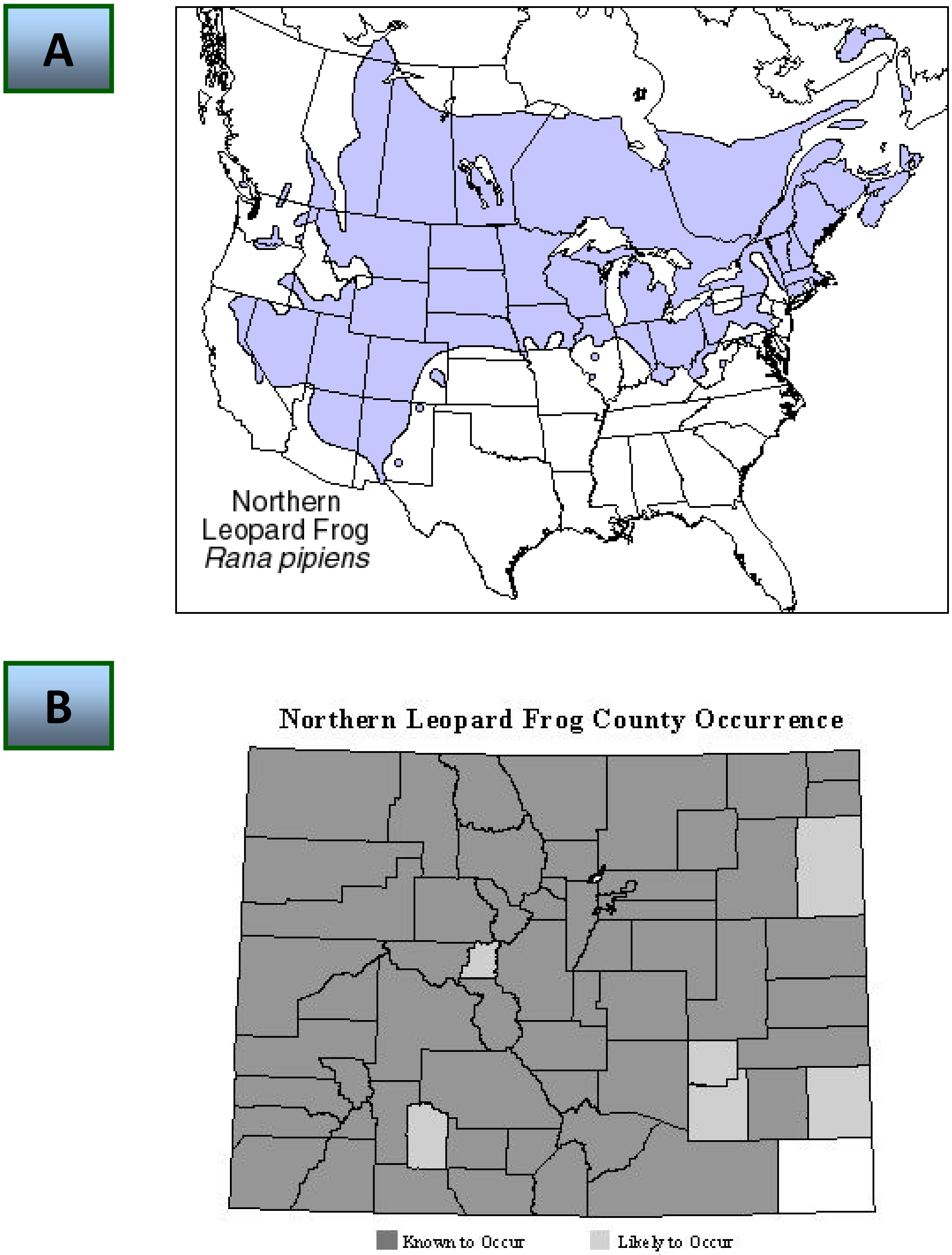

Figure 12. **Distribution of northern leopard frog**
(A) in the United States and Canada (from Idaho Herps 2008) and (B) in Colorado (from NDIS 2012).

A

B

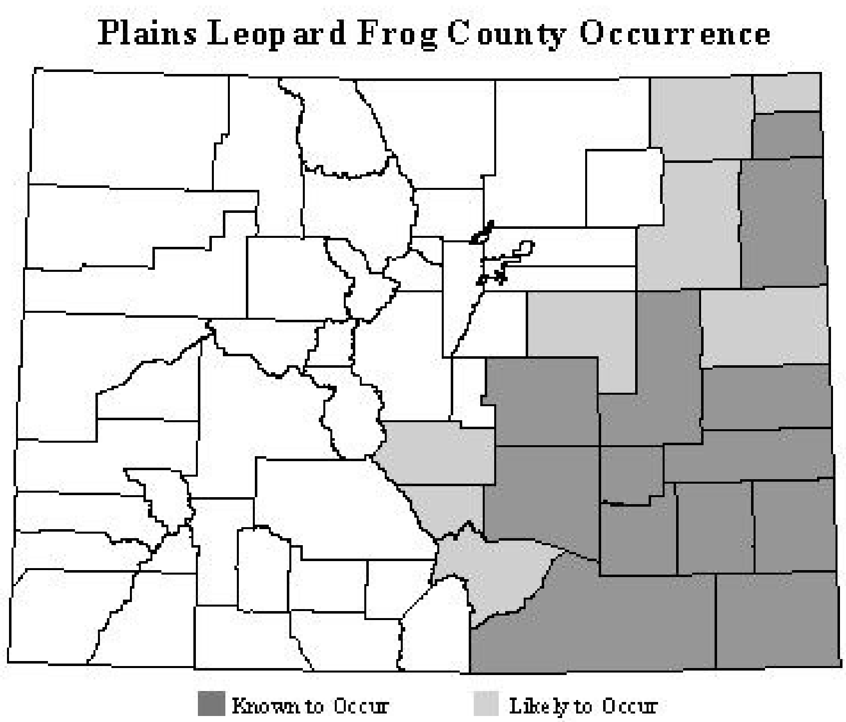

Figure 13. Distribution of plains leopard frog
(A) in the United States and Canada (from Smith and Keinath 2005) and (B) in Colorado (from NDIS 2012).

3.2.8 Red-sided Garter Snake

Range, population status, conservation status. The red-sided garter snake (*Thamnophis sirtalis parietalis*), also called the common garter snake (T. Jackson, pers. comm.),[3] is found in Canada and the western United States, with a disjunct distribution in the western United States (Figure 14a). In Colorado, they are found throughout much of the LSPRB (Figure 14b) and are a species of concern. The abundance of red-sided garter snakes is mostly unknown (WGFD 2010b). Population declines of other garter snakes, such as *Thamnophis elegans*, which consume mostly amphibians, have apparently been tied to amphibian declines (Matthews et al. 2002). Because the red-sided garter snake eats primarily amphibians (Kephart 1982), it is possible that, likewise, populations of red-sided garter snakes are associated with populations of amphibians.

Wetland habitats. Garter snakes hibernate during the winter, up to seven or eight months in the more northern parts of their range (Aleksiuk 1976, Garstka et al. 1982, O'Donnell et al. 2004). While they are active, they are wetland-dependent, occupying most of the wetland habitats within the LSPRB (Table 32).

Key habitat quality variables. Surprisingly little information is available in the literature on habitat preferences of red-sided garter snakes. Therefore, much of the information contained herein was obtained by Tina Jackson, Herpetologist for Colorado Parks and Wildlife, who confirmed the paucity of information. This information is summarized in Table 33.

Ranking of habitat quality variables. The ranked importance of habitat variables for red-sided garter snakes is summarized in Table 34.

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[3] The taxonomy of garter snakes and separation into subspecies based on color has been questioned because of the wide variety of color morphs in single localities (Mooi et al. 2011).

Table 32. Seasonal importance to red-sided (common) garter snakes of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland Habitat	Spring Ice Thaw–mid May	Summer	Fall Sept.–Ice Formation	Winter	Relative Range of Importance
Natural wetland types					
Beaver pond	√	√	√	Absent	High
Emergent marsh	√	√	√	Absent	High
Playa	√	√	√	Absent	Low-High
Riparian wetland (shrub-scrub)	√	√	√	Absent	Med-High
Riparian wetland (herbaceous)	√	√	√	Absent	High
Sandbar	√	√	√	Absent	Low
Warm water slough	√	√	√	Absent	High
Wet meadow	√	√	√	Absent	High
Impoundments and other human created wetlands					
Irrigation-influenced wet meadow	√	√	√	Absent	High
Irrigation ditch	√	√	√	Absent	Low-Med
Gravel pits	√	√	√	Absent	Low
Moist soil unit	√	√	√	Absent	Low-Med
Recharge pond/Moist soil unit	√	√	√	Absent	Med-High
Reservoir	√	√	√	Absent	Low
Sewage lagoon	√	√	√	Absent	Low-High
Stock pond	√	√	√	Absent	Low-High
Urban runoff ponds	√	√	√	Absent	Low-High

Table 33. Quality (high, medium and low) of key habitat quality variables for red-sided (common) garter snakes in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	**Value**		
	High	**Medium**	**Low**
Dominant vegetation			
	Emergents-sedges-grasses- anything that provides cover		
% emergent cover			
	61-100%	41-60%	20-40%
Interspersion			
	< 1:1		
Landscape context			
	Close connection between upland hibernacula and wetlands		Landscape fragmented by unsuitable habitat
Size of habitat			
	Larger is better		
Water quality			
	pH = 6.1-7 No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Cloudy or sheen of oil

Table 34. Importance, ranking, and EPA monitoring level of key habitat quality variables for red-sided (common) garter snakes in the Lower South Platte River Basin, Colorado.

	Importance				**EPA Level**		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
% emergent cover	1	√					√
Landscape context	2	√			√		
Interspersion	3		√			√	√
Size of habitat	4		√		√		
Water quality	5		√				
Dominant vegetation	6			√		√	√

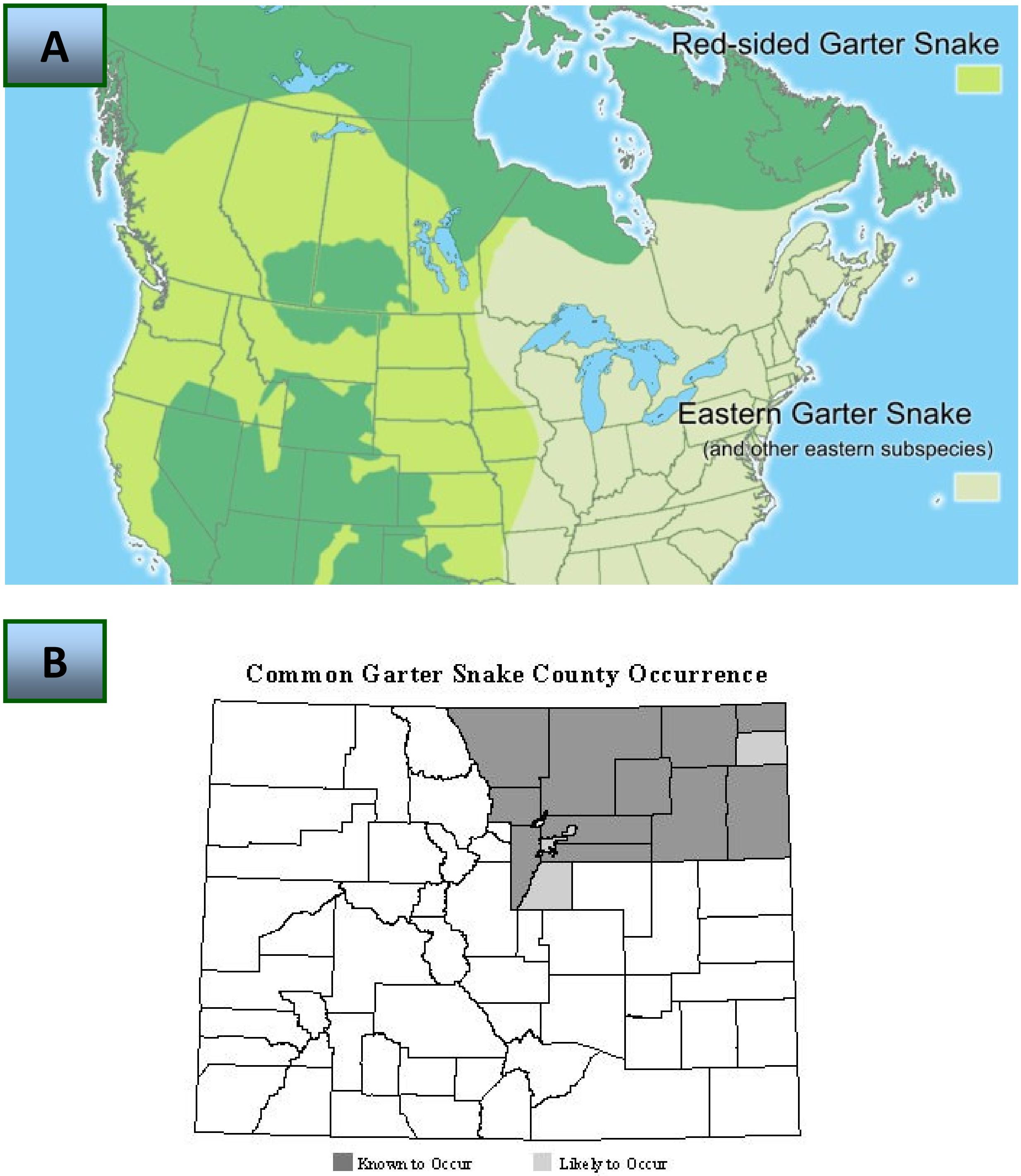

Figure 14. Distribution of red-sided (common) garter snake (A) in the United States and Canada (from Manitoba Herps Atlas 2012) and (B) in Colorado (from NDIS 2012).

3.2.9 Fish Guild

Range, population status, conservation status. The distribution of northern redbelly dace (*Phoxinus eos*) extends across the northern states from Montana to Maine and in Canada from British Columbia through Nova Scotia (Figure 15). Within Colorado, they occur almost entirely in the LSPRB (Figure 15) only in the West Plum Creek area (Nesler et al. 1997), where perhaps they have never been common (Propst and Carlson 1986). The northern redbelly dace is listed as endangered in Massachusetts (MDFW 2008), a species of concern in Montana (MNHP and MFWP 2012b), and threatened in Nebraska (AGC 2007) and South Dakota (SDGFP 2012). It is a state endangered species in Colorado (CPW 2012).

The distribution of brassy minnows (*Hybognathus hankinsoni*) extends across the northern states from Montana to western Vermont and Massachusetts and in Canada from several disjunct locations in the west to Quebec (Figure 16). The LSPRB consists of the main extent of its range in Colorado (Figure 16), except where it has been introduced into the Colorado River (Fuller and Neilson 2012). Propst and Carlson (1986) stated that brassy minnows were historically more common, and Scheurer and Fausch (2002) suggested they have declined since the 1970s. The brassy minnow is a state threatened species (CPW 2012); it is listed as vulnerable in Wyoming (WGFD 2010a) and a "potential" species of concern in Montana (MNHP and MFWP 2012a).

Wetland habitats. The wetland habitats, in addition to stream channels, that northern redbelly dace and brassy minnow occupy within the LSPRB include beaver ponds and warm water sloughs (Table 35). Additionally, brassy minnows are found in irrigation ditches.

Key habitat quality variables. The most important wetland habitat variables to the dace and minnow include dominant vegetation, landscape context, size of habitat, substrate, water depth, and water quality (Table 36).

Dominant vegetation. Northern redbelly dace inhabit areas with emergent vegetation along shorelines, and they use algal mats for spawning (Nesler et al. 1997). Stasiak (2006) found them strongly associated with abundant vegetation and woody debris, and Quist et al. (2005) found submergent vegetation to be the most important predictor for presence of brassy minnow. Similarly, brassy minnows use waters with aquatic vegetation.

Landscape context. Stasiak (2006) mentioned that a critical habitat component for northern redbelly dace is the absence of large predatory fish. The general absence of piscivorous species in beaver ponds may partly explain the dace's strong preference for beaver ponds (Schlosser and Kallemeyn 2000, Stasiak 2006). Brassy minnow persistence is very much tied to deeper pools connected with other habitats (Scheurer and Faushe 2002, Scheurer et al. 2003).

Size of habitat. Northern redbelly dace are found in off-channel habitats only within the West Plum Creek area; size varied greatly from 0.0025-0.1 ha, but all with connections to either West Plum Creek or Garber Creek (Bestgen 1989). Brassy minnows are usually found in smaller tributaries and irrigation ditches (Nesler et al. 1997).

Substrate. Northern redbelly dace prefer silt or sand substrate (Bestgen 1989), whereas brassy minnows prefer a courser gravel substrate (Nesler et al. 1997). However, Propst and Carlson (1986) mentioned that northern redbelly dace inhabit gravel-bottomed waters.

Water depth. Bestgen (1989) reported a northern redbelly dace preference of 0.25–1.3 m water depth; where they inhabited deeper ponds (> 3 m), they tended to congregate in the shallower water near shore. Scheurer et al. (2003) found that for brassy minnows, adequate pool depth varied with position on the landscape, with a water depth of 0.5 m being adequate for minnow persistence in upstream segments, but in lower reaches, minnows have only a 50% probability of persistence in pools with 0.5 m water. Pools with water depths greater than 40 cm are less likely to dry and freeze (Scheurer et al. 2003).

Water quality. Northern redbelly dace prefer clear, cool, slow-moving, well-oxygenated water (Bestgen 1989, Stasiak 2006). Brassy minnows also prefer cool, slow-moving waters and pools. Bestgen (1989) found water < 22°C in all occupied habitats, but some of the areas were thermally stratified and ranged from 18–27°C. Similarly, Stasiak (2006) reported a preference of 21–26°C.

Diet. Northern redbelly dace are omnivorous, feeding on vegetation and small invertebrates throughout the water column (Stasiak 2006). Bestgen (1989) found detritus most important. Brassy minnows are herbivorous scrapers, foraging heavily on algae (Cornell University 2012) and also diatoms (MNNP and MFWP 2012b).

Ranking of habitat quality variables. The ranked importance of habitat variables for the northern redbelly dace and brassy minnow is summarized in Table 37.

Table 35. Seasonal importance to northern redbelly dace and brassy minnow of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland Habitat	**Spring Ice Thaw–mid May**	**Summer**	**Fall Sept.–Ice Formation**	**Winter**	**Relative Range of Importance**
Natural wetland types					
Beaver pond	√	√	√	√	High
Stream channel	√	√	√	√	High
Warm water slough	√	√	√	√	Low-medium
Impoundments and other human created wetlands					
Irrigation ditch (brassy minnow)		√			High

Table 36. Quality (high, medium and low) of key habitat quality variables for redbelly dace and brassy minnow in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	**Value**		
	High	**Medium**	**Low**
Predatory fish			
	Absence	Present in very low numbers	Present
Dominant vegetation			
	Algae, algal mats, submergents/emergents		
Landscape context			
	Pools connected to other habitats		
Size of habitat			
	25–1,000 m^2		
Substrate			
	Sand for dace Gravel for minnow		
Water depth (cm)			
	51-150 cm	41-50 cm	
Water quality			
	No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Cloudy or sheen of oil

Table 37. Importance, ranking, and EPA monitoring level of key habitat quality variables for redbelly dace and brassy minnow in the Lower South Platte River Basin, Colorado.

	Importance				**EPA Level**		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Predatory fish absent	1	√					√
Landscape context	2	√			√		
Water depth	3	√					√
Dominant vegetation	4	√				√	√
Water quality	5	√					√
Substrate	6	√					√
Size of habitat	7			√	√		

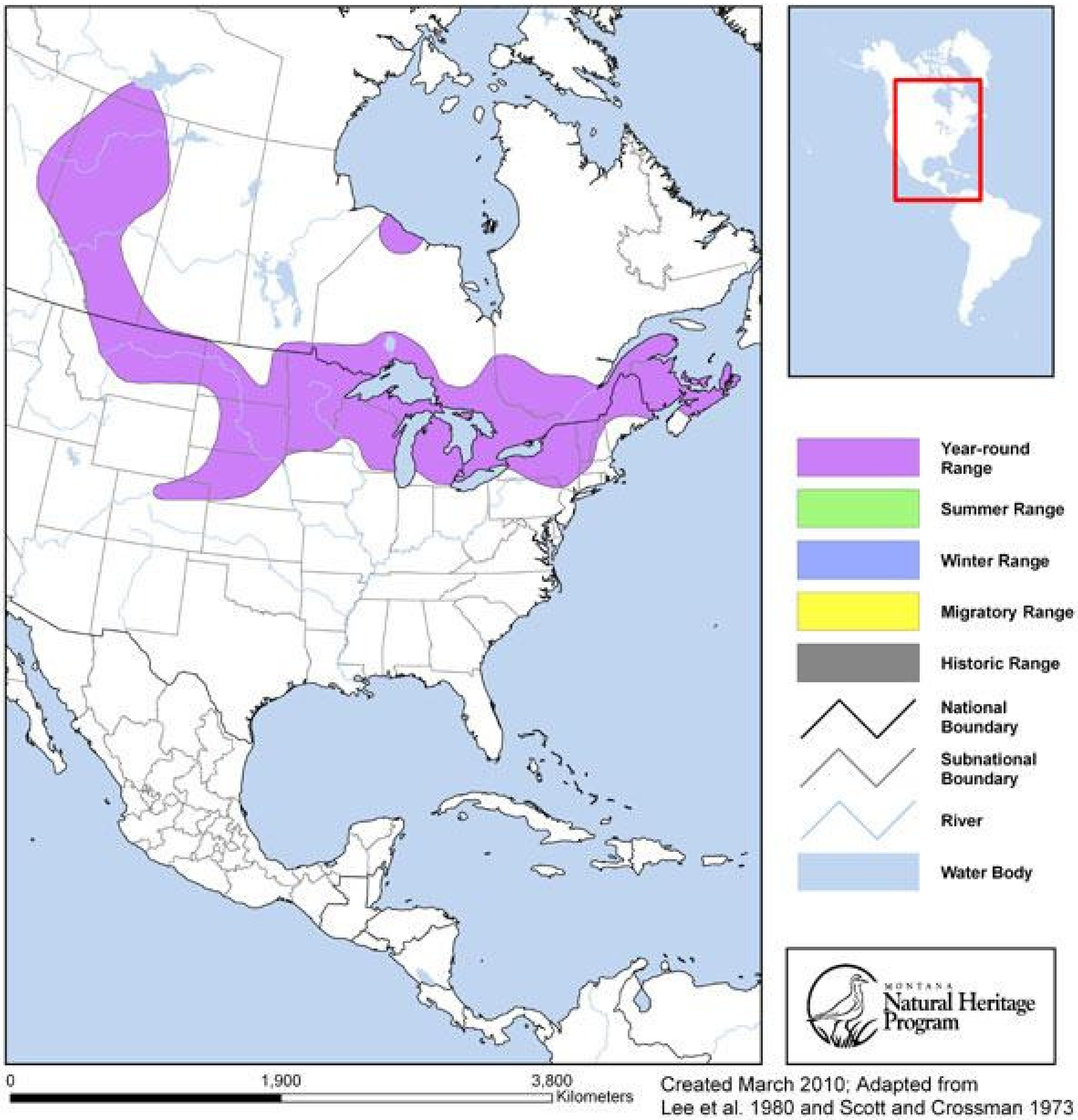

Figure 15. Distribution of northern redbelly dace from MNHP and MFWP (2012b).

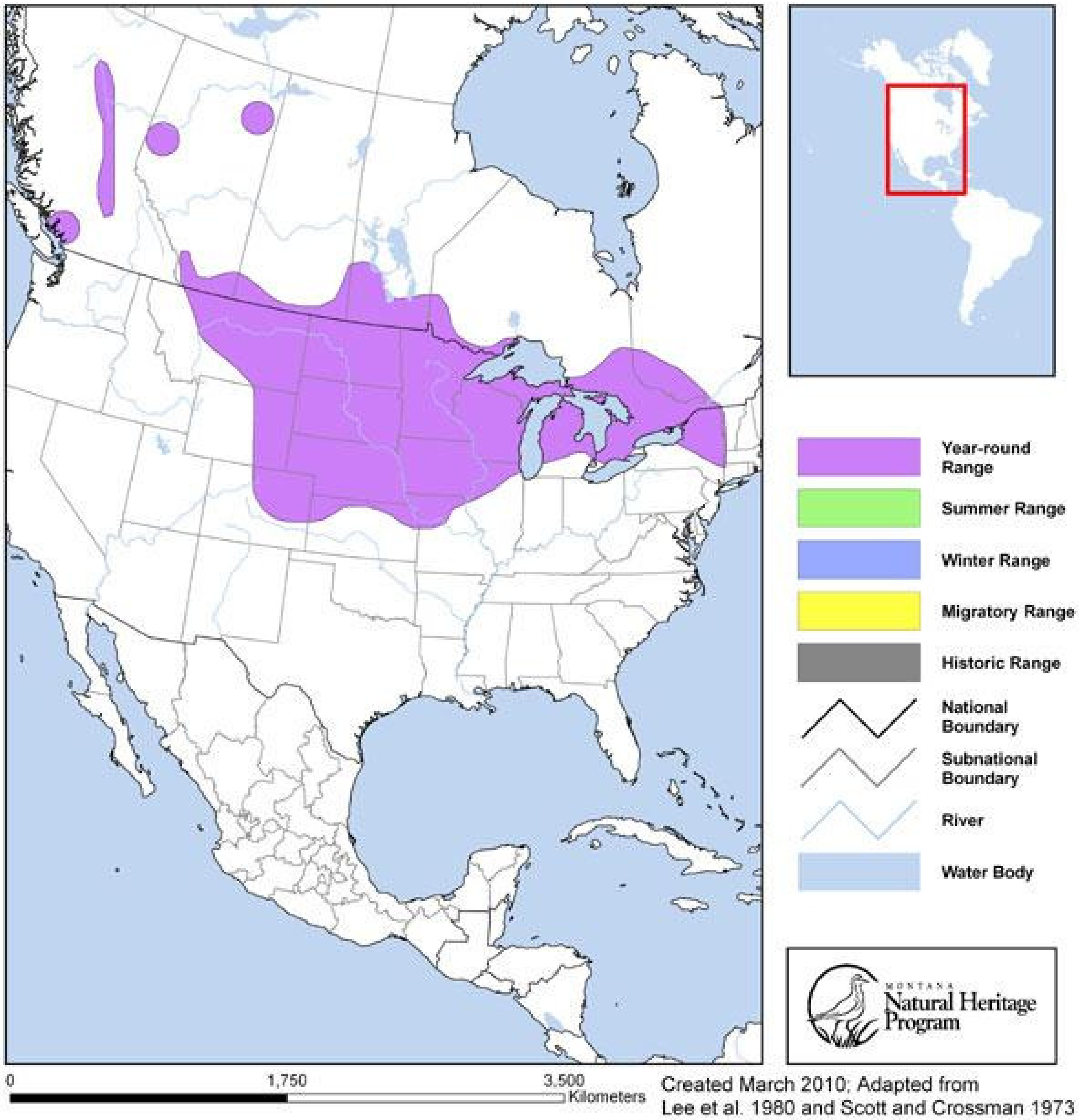

Figure 16. Distribution of brassy minnow from MNHP and MFWP (2012a).

3.2.10 River Otter

Range, population status, conservation status. Northern river otters (*Lontra canadensis*) historically ranged throughout most of the United States and Canada but were extirpated from much of their range in the west, including Colorado (CDOW 2003, Figure 17a). Reintroductions of otter to Colorado began in 1976, and they are now found in small numbers throughout most of western Colorado with a more spotty distribution in eastern Colorado (Figure 17b). They are listed as threatened in Colorado (CPW 2012) and as least concern by IUCN (Sefass and Polechla 2008).

Wetland habitats. Boyle (2006) stated that range-wide, river otters inhabit nearly every aquatic habitat. In the LSPRB, river otters are most likely to occupy beaver ponds, stream channels, and warm water sloughs (Table 38).

Key habitat quality variables. Key variables that determine habitat quality for river otters include landscape context, riparian vegetation, shore complexity, stream order/gradient, stream size, structures and debris, and water depth (Table 39).

Landscape context. Gorman et al. (2006b) reported on average, otter dens were 316 m from and 61 m higher than the closest water. Ostroff (2001 cited in Jeffress et al. 2011) found that otter occupancy was positively associated with the number of wetlands with 300 m of shoreline and the percent of wooded riparian area.

Riparian vegetation. Healthy riparian vegetation provides important cover for otters when moving on land; it also contributes to stream integrity and reduces soil erosion. Larger trees, particularly those that obscure the visual field are preferred (Crowley et al. 2012). Similarly, Jeffress et al. (2011) found that otter occupancy increased with woodland cover. Otters, at least in some populations, seem to select conifers, especially in conjunction with latrine sites (Newman and Griffin 1994, Swimley et al. 1998, Crait and Ben-David 2006, Crowley et al. 2012).

Shore complexity. In general, the greater the shore complexity of ponds and streams, the more likely shallow waters will provide habitat for fish and other prey items (Dubuc et al. 1990, Boyle 2006). Contrarily, Jeffress et al. (2011) found decreased otter occupancy with increased shoreline diversity; however, this finding may have been influenced by large reservoirs in their study area.

Stream order/gradient. Otters seem to prefer lower gradients and higher stream meandering (Melquist and Hornocker 1983, Boyle 2006). Jeffress et al. (2011) also found a strong association between otter occupancy and stream order.

Stream size. River otters prefer long stretches of stream (Dubuc et al. 1990, Boyle 2006).

Structures and debris. Habitat structure complexity is preferred by otters for denning, resting, latrines, and scent-marking. Structures contribute to complexity and can be provided by log jams, stumps and other woody debris, living trees, undercut banks, and rocks. Beaver (*Castor canadensis*) provide many of the woody structures preferred by otter; thus, river otters are often associated with beaver activity (Melquist and Hornocker 1983, Dubuc et al. 1990, Gorman et al. 2006a, Depue and Ben-David 2010). Structures close to water provide opportunities to scent mark, which is critical for their olfactory communication. These structures also provide latrine sites for otter (Newman and Griffin 1994, Swimley et al. 1998, Crait and Ben-David 2006).

Water depth. Otters prefer a diversity of water depths, from deep pools to shallower shores (Boyle 2006, Depue and Ben-David 2010). Latrine sites are associated with adjacent deep water (Swimley et al. 1998).

Diet. Throughout their range, fish comprise the majority of otters' diets; therefore, habitat suitability for otters necessarily includes habitat suitability for fish (Melquist and Hornocker 1983, Crait and Ben-David 2006, Guertin et al. 2010, Crowley et al. 2012). Otters also consume crayfish, mollusks, frogs, snakes, turtles, salamanders, birds, mammals, and fruit (Melquist and Hornocker 1983, Boyle 2006).

Ranking of habitat quality variables. Habitat quality variable are ranked in Table 40.

Table 38. Seasonal importance to river otter of wetland habitats in the Lower South Platte River Basin, Colorado.

Wetland Habitat	**Spring Ice Thaw–mid May**	**Summer**	**Fall Sept.–Ice Formation**	**Winter**	**Relative Range of Importance**
Natural wetland types					
Beaver pond	√	√	√	√	High
Stream channel	√	√	√	√	High
Warm water slough	√	√	√	√	High

Table 39. Quality (high, medium and low) of key habitat quality variables for river otter in the Lower South Platte River Basin, Colorado.

Habitat Quality Variable	Value		
	High	**Medium**	**Low**
Landscape context			
	Near beaver activity & connected with tributaries		Disconnected without beavers
Riparian vegetation			
% Total canopy cover > 2 m	51-100%	31-50%	20-30%
Height of canopy cover > 2 m	> 15 m	5-15 m	0.5-5 m
Shore complexity			
	Diverse and complex; undercut banks		
Stream order			
	> 4th order		< 4th order
Stream size			
	Longer is better; wide		narrow
Structures and debris			
	Log jams and/or beaver activity		
Water depth			
% water > 20 cm	91-100%	81-90%	40-80%

Table 40. Importance, ranking, and EPA monitoring level of key habitat quality variables for river otter in the Lower South Platte River Basin, Colorado.

		Importance			**EPA Level**		
Habitat Variable	**Rank No.**	**High**	**Medium**	**Low**	**1**	**2**	**3**
Landscape context	1	√			√	√	
Structures and debris	2	√					√
Riparian vegetation	3	√				√	√
Shore complexity	4	√					√
Stream size	5		√		√		
Banks	6		√				√
Stream order	7		√		√		
Water depth	8		√		√		

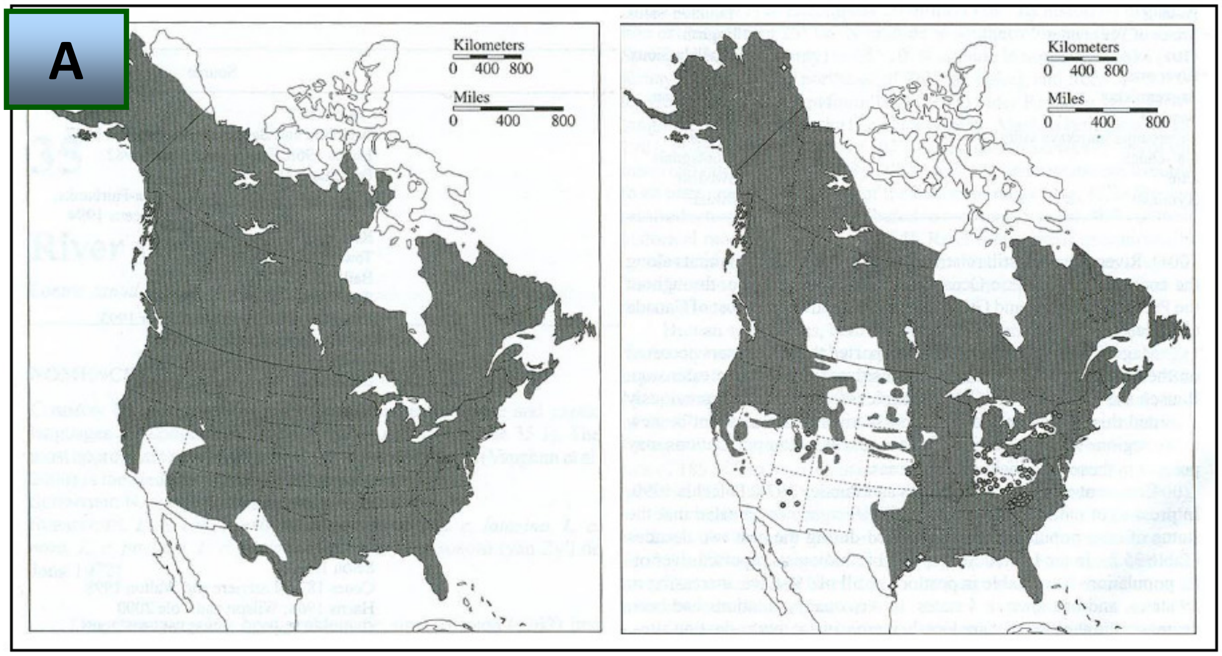

Figure 2. Historical (left) and current (right) distributions of the North American river otter. On the current distribution map, circles represent reintroduction sites. Reprinted from Melquist et al. (2003).

B

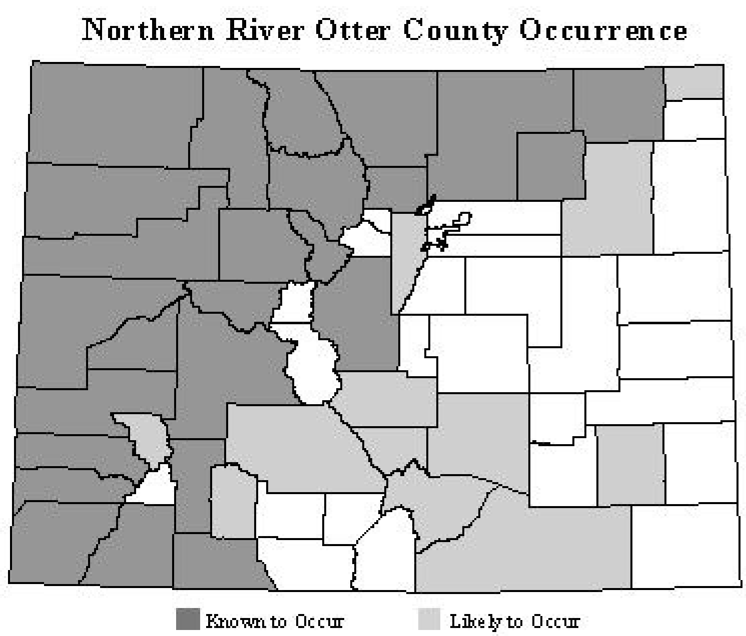

Figure 17. Distribution of river otter
(A) in the United States and Canada (Boyle 2006) and (B) in Colorado (from NDIS 2012).

3.3 Metric Protocols

3.3.1 Key Habitat Quality Variables

Not including food resources, 21 key habitat variables have been identified as either high or medium importance to the 18 priority species under consideration (Table 41). Seven of the 21 variables are important to only to the piping plover or the river otter.

Table 41. Ranked importance of key habitat variables according to the number of CPW priority wetland-dependent species that depend on each feature.

Habitat variable	Number of species with variable as moderate to high importance
Landscape context	18
Size of habitat	16
Water depth	15
Dominant vegetation type	14
Emergent cover (%)	13
Invertebrates	7
Dominant vegetation height	5
Absence of pred. fish/bullfrogs	4
Water quality*	4
Interspersion	2
Residual cover	2
Substrate	2
Sunlight exposure	2
Vegetation density	2
Open sand/gravel	1
Proximity to objects	1
Riparian vegetation (large trees)	1
Shore complexity	1
Stream banks steep	1
Stream order	1
Structures and debris	1

*Number of species directly affected. This does not take into account indirect effects, which may be applicable to other priority species.

3.3.2 Sampling Framework

Most of the key habitat variables can be measured within the existing sample framework used by CNHP. CNHP will use the 10 × 10 m plot configurations suggested by EPA (2011, Figure 18); therefore, all key habitat features that require sampling at plots or along transects should be measured using this sample design.

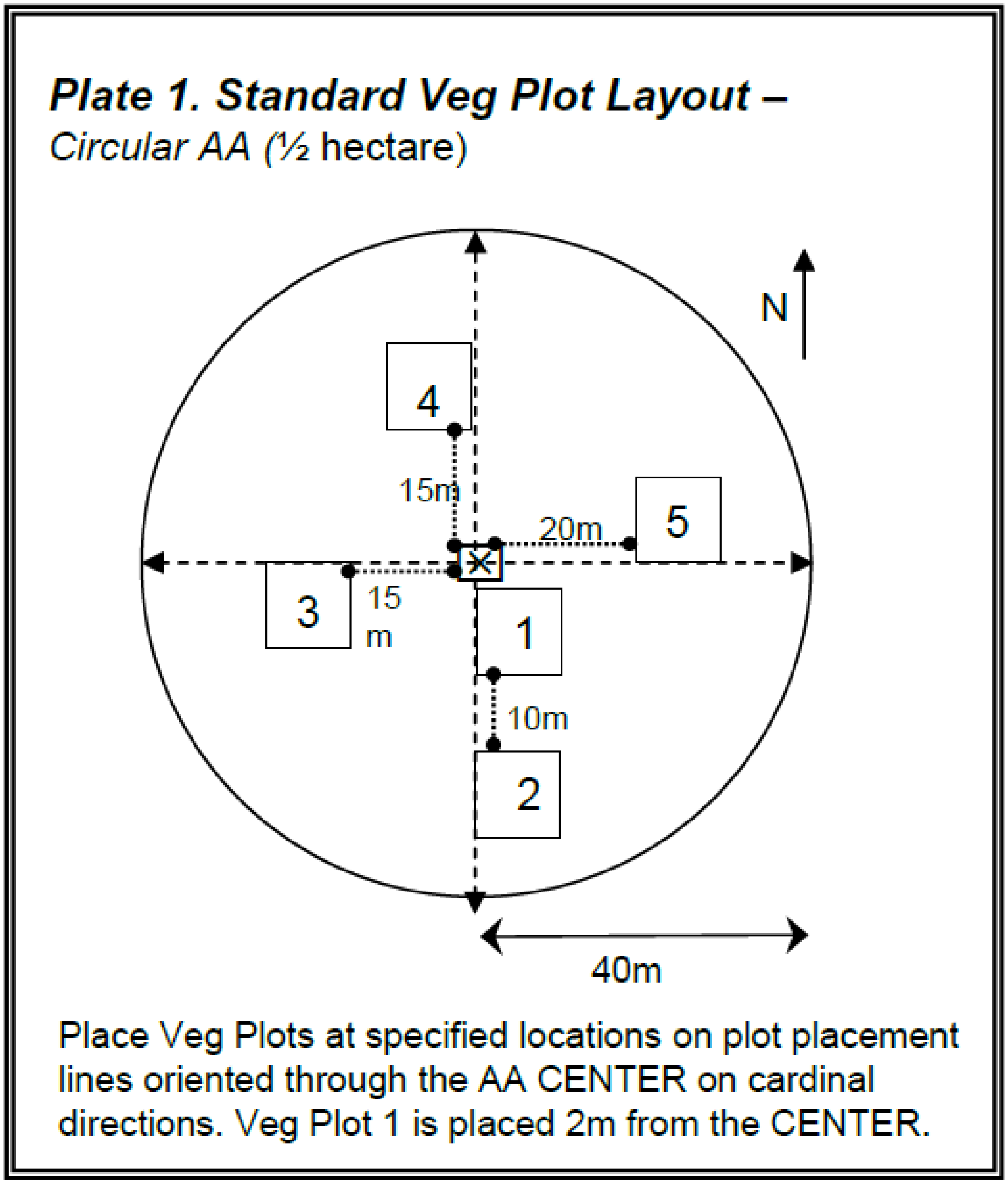

Figure 18. Diagram of one example sampling design adopted by CNHP (from EPA 2011).

3.3.3 Field Protocols for Key Habitat Quality Variables

Many of the habitat quality variables can be assessed at more than one level, depending on the depth of information needed as well as resolution and seasonal timing of aerial photography (Table 42 with more details in Appendix IV). For example, identification of dominant vegetation type can usually be accomplished with rapid assessment. However, in cases where identification to the species level is desired, evaluation of plants, flowers, or seeds in a lab may be required. Percent emergence and interspersion patterns can be assessed at all three levels, depending on resolution of aerial imagery for level 1 and/or confidence in estimations for level 2; in cases where levels 1 and 2 assessments are not adequate, a level 3 assessment may be required.

The information in Table 42 and Appendix IV provided a starting point for discussions on how to most efficiently incorporate important habitat variables for the priority wildlife species into the existing CNHP field protocol. The table and appendix are provided in this final report to document the process, not the final outcome; they have not been altered since they were provided to CNHP as required products in spring, 2011. The final field protocol, resulting from this process, is in the CNHP Final Report.

3.4 Management Practices

Prior to human settlement, particularly European settlement, fire, grazing by native ungulates, and natural climate events were the major forces that set back the natural succession of wetlands (Kantrud 1986). With fire suppression, relatively more continuous grazing, and anthropogenic global climate change, the more natural forces that once shaped conditions of wetlands have been altered. In the absence of forces interrupting natural ecological processes, wetlands tend to progress toward monotypic dense stands of hydrophytes.

Wetland managers have often relied on human-employed mechanical means of setting back succession in order to achieve the desired conditions of wetlands. This requires an adaptive management approach, which requires both a toolbox of management options and monitoring and evaluation to assess whether the actions result in the desired outcome. Recommended management practices that can be used for modifying or maintaining habitat conditions are provided in Appendix V.

Table 42. Summary of protocol recommendations. Protocols for measuring food resources are in Appendix IV.

			EPA Level		
Key Habitat Feature	**Scale of information**	**Recommendations**	**1**	**2**	**3**
Landscape context and land use	1.5, 3, and 8 km from wetland	Buffers should be constructed around wetlands in GIS at 1.5, 3, and 8 km; determine other wetlands, (number, size, type, connectivity), proximity to agriculture, adjacent land use, land ownership.	√	NA	NA
Size of habitat	Entire wetland area	Size of the wetland can be determined by using GIS polygonal measuring tools. If questionable, the size of the wetland obtained in GIS can be verified by walking around the perimeter with GIS tracks on save mode. For larger wetlands, distances across the wetland should be measured with a range finder at angles determined by a compass.	√	√	NA
Water depth	Vegetation plot	If the land manager cannot provide water depth information, water depth should be determined with a measuring stick at vegetation plots, using plots recommended by EPA (2011).	NA	√	√
Dominant vegetation	Vegetation plot	The plant community should be determined by methods already in use by CNHP (Lemly et al. 2011), using plots recommended by EPA (2011).	NA	√	√
% Emergent (or vegetative) cover	Entire wetland area	If good aerial photography is available, Level 1 would be the most ideal method because it involves quantifying rather than estimates. The Level 2 methods of CNHP will provide adequate information to access the value to wildlife. This includes estimating cover of shallow water (< 20 cm) and cover of deeper water (20–100 cm).	√	√	√
Vegetation height	Vegetation plot	Vegetation height should be estimated and placed size classes according methods already in use by CNHP (Lemly et al. 2011), using plots recommended by EPA (2011).	NA	√	√
Water quality	Vegetation plot	pH, conductivity, and temperature should be measured in the middle of the water column, using plots recommended by EPA (2011).	NA	√	NA
Interspersion patterns	Entire wetland area	Patterns of complexity should follow the CNHP protocol (Figure 2), using the best fit of diagrams or other descriptions at the wetland level, such as • Fringe (vegetation around the perimeter of the wetland with central open water) • Partially interspersed (few patches of vegetation in central portion) • Complex (vegetation interspersed in many patches) • Closed (few to no areas of open water)	√	√	√

Residual cover depth	Vegetation plot	Residual cover should be determined with a measuring stick according to methods already in use by CNHP (Lemly et al. 2011), using plots recommended by EPA (2011).	NA	NA	√
Shade/sun (light interception)	Vegetation plot or Assessment Area	Canopy, as a measure of light interception, should be measured directly with a densiometer at plots, using the sampling plot design recommended by EPA (2011). Alternatively, it can be estimated at the Assessment Area level.	NA	√	NA
% open sand or gravel area on sandbar	NA	Percent open sand or gravel area on sandbars should be measured using GIS tools; alternatively it can be determined using the same methods as percent cover (see Appendix 1).	√	NA	NA
Riparian vegetation (woody)	Assessment Area	Presence of woody vegetation should be measured according to CNHP methods: 1. Dominant canopy trees (> 5 m and > 30% cover) 2. Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover 3. Tall shrubs or older tree saplings (2–5 m) 4. Short shrubs or young tree saplings (0.5–2 m)	NA	√	√
Structures and debris	Entire wetland area	Presence or absence of beaver structures, log jams, and debris jams should be noted according to CNHP protocols.	NA	√	NA
Shore complexity	Assessment Area	Presence or absence of backwater sloughs and other features that increase shoreline should be noted according to CNHP protocol.	√	√	NA
Stream banks	Assessment Area	Presence or absence of undercut banks should be noted according to CNHP protocol.	NA	√	NA
Stream length	NA	Stream length should be measured with GIS tools.	√	NA	NA
Stream order	Entire wetland area	Stream order can be determined from maps detailed enough to show all tributaries.	√	NA	NA
Stream width	Entire wetland area	Stream width at bankful should be estimated according to CNHP protocol	√	√	NA

4.0 DISCUSSION

Overall, the area of NWI wetlands represents 3% of the total land in the LSPRB. The number of wetland habitats used by the priority species varied from 1–18, and the area potentially available to the priority species ranged from as little as 1,444 ha (3,567 acres) for the piping plover to 102,612 ha (253,560 acres) for the dabbling duck and frog guilds (Table 43). These figures only approximate the total area of wetlands that represent the habitats known to be used. These figures also suggest nothing about the importance or the condition of the wetlands and whether they are, in reality, occupied by the priority species. Therefore, these area figures are likely an over-estimate of functionally available habitat.

Landscape context is of high importance to all 18 priority species and is, therefore, the most important variable, followed by size of habitat, water depth, dominant vegetation type, and percent of emergent cover (Table 44). Landscape context is important to all the priority species for various reasons, including (1) species requiring several wetland conditions during different life cycles (e.g., frogs and snakes), (2) species requiring several wetland conditions for nocturnal and diurnal activities (dabbling ducks, sandhill cranes, and long-billed curlews), (3) the land use surrounding a wetland has a direct or indirect effect on water quality (affects frogs, fish, and American bittern), and (4) the landscape context affects connectivity of water (affects fish and river otter). Additionally, proximity of other wetlands affects dispersal by waterfowl of wetland plant seeds (Mueller and van der Valk 2002) and other organisms (Charalambidou and Santamaría 2005) that are important prey items. For example, Brusati et al. (2001) found that wetlands created for mitigation purposes had higher recruitment of benthos invertebrates if the wetland was close to other natural wetlands. Naugle et al. (2001) recommended conservation of wetlands on the landscape to both preserve connectivity among wetlands and strengthen the value of habitat in core-protected areas.

The priority species addressed in this report represent only a small proportion of wildlife species that actually use wetland habitat in the LSPRB, and their needs vary. In many cases, the preferred conditions of key habitat variables overlap; in other cases, there is very little overlap. In other words, unless a wetland is very extensive with myriad habitats and habitat conditions, it is unlikely to support all the priority species. Furthermore, some of the priority species are so specialized (e.g., fish, river otter, and piping plover) that they occupy only one or a few habitats that are not occupied by some of the other priority species.

Some investigators have suggested that effective management for a target species or a target guild can benefit other non-target species. When this situation occurs, the target species or guild can be used as a surrogate to predict the effects on other species and, therefore, can be useful for conservation efforts (Noss 1990). Ducks, as flagship species, have often been used to enhance and protect wetland habitat and have been promoted as surrogates for other species, which requires the assumption that what is good for ducks is necessarily good for other species. Many investigators have questioned these assumptions and value of this approach (Simberloff 1998, Lindenmayer et al. 2002). For example, Koper and Schmiegelow (2006) found in Alberta, Canada, ducks could not be used as effective surrogate species for either songbirds or shorebirds because they found no responses to habitat variables that were consistently similar among groups. Koper and Schmiegelow (2006), therefore, emphasized that these assumptions must be validated. However, the groups of species they compared are not ecologically similar. The priority species in this report also diverge ecologically, and the species most ecologically similar were already lumped into guilds (e.g., ducks, frogs, and fish). To illustrate this point and for convenience of looking at overlap among species, conditions for the key habitat variables that promote positive responses are listed in Appendix VI.

Limited management resources will inevitably always restrict monitoring of all target species; therefore, we should strive for practical efforts, based on the best available knowledge. These efforts should be validated to the extent possible through monitoring, followed with evaluation and adjustment through adaptive management approaches.

Close proximity to agricultural fields is important to ducks, sandhill cranes, and curlews, and close proximity to other wetlands is important for ducks, short-eared owls, and frogs.
All priority species, with the exception of American bitterns, seem to prefer vegetation less than 1 m, and many prefer vegetation < 60 cm, such as ducks, piping plover, long-billed curlew, short-eared owl, and adult frogs in foraging areas.

The 18 priority wetland-dependent species considered in this project require a wide array of food resources, including both plant and animal matter. While food resources, per se, are beyond the scope of field data collection for CNHP, some useful information can be gleaned from the data set. Food resources consisting of plant matter can be determined from the list of plant species and relative abundance. For food resources consisting of animal matter, some assumptions can be made. For example, Hornung and Foote (2006) suggested that the complexity and abundance of aquatic plants can be used to predict the occurrence of aquatic invertebrates; they found that biomass of herbivorous invertebrates increased with complexity of the plant community while a more simple plant community supported more predatory invertebrates.

Predators are considered major population regulators but, as with food resources, are beyond the scope of this project. However, some of the same conditions that favor priority species may also favor important predators, including some predatory priority species. For example, similar wetland conditions may attract frogs and red-sided garter snakes, as well as American bitterns that eat frogs and snakes. Introduced predators, such as bullfrogs, also may be attracted to the same wetland conditions as are the priority frog and fish guilds.

In addition to the more local wetland conditions, numerous landscape context variables and forces that extend beyond the LSPRB, such as global climate change, can affect future populations of the CPW priority species. These include, but are not limited to, precipitation, temperature, other weather events (e.g., storms and wind), urban and rural development, energy development, stream flow, floodplain modifications, as well as changes in hydrology, irrigation amounts or techniques, hunting and other recreation, agriculture or grazing, invasive plants, and resources to manage wetlands.

Table 43. Area and percent land used by Colorado Parks and Wildlife wetland-dependent priority species in decreasing order.

Species	Number of habitats used in LSPRB	Area of NWI wetlands used in LSPRB*	% of land covered by used wetlands **
Dabbling duck guild	18	102,612 ha (253,560 acres)	3.01%
Frog guild	18	102,612 ha (253,560 acres)	3.01%
Red-sided garter snake	17	68,557 ha (169,409 acres)	2.01%
Sandhill crane	7	63,938 ha (157,994 acres)	1.88%
Short-eared owl	3	40,957 ha (101,207 acres)	1.20%
Long-billed curlew	3	37,960 ha (93,801 acres)	1.11%
American bittern	6	35,166 ha (86,898 acres)	1.03%
Fish guild	3	16,272 ha (40,208 acres)	0.48%
River otter	3	13,252 ha (32,746 acres)	0.39%
Piping plover	1	1,444 ha (3,567 acres)	0.04%

*Acreage does not include warm water sloughs.
**Percent calculated by dividing the NWI acres of wetland habitat used by the total acreage in LSPRB; therefore, for species (e.g., red-sided garter snake) using upland habitat, the percent does not represent the total acreage used.

Table 44. Qualified and ranked importance of key habitat variables for 18 Colorado Parks and Wildlife wetland-dependent priority species. Variable are ranked according the number of species for which the variable is either of high or medium importance.

	Number of species according to value of variable				
Key habitat variable	High (H)	Medium (M)	Low (L)	H or M	Ranked importance
Landscape context	18	0	0	18	1
Size of habitat	6	10	2	16	2
Water depth	14	1	0	15	3
Dominant vegetation type	11	3	3	14	4
Emergent cover (%)	11	2	0	13	5
Absence of pred. fish/bullfrogs	4	0	0	4	6*
Invertebrates	0	7	0	7	6*
Water quality	4	0	0	4	6*
Dominant vegetation height	5	0	0	5	7*
Interspersion	1	1	1	2	7*
Residual cover	2	0	0	2	7*
Substrate	2	0	0	2	7*
Sunlight exposure	2	0	0	2	7*
Vegetation density	2	0	0	2	7*
Open sand/gravel	1	0	0	1	8*
Proximity to objects	1	0	0	1	8*
Riparian vegetation	1	0	0	1	8*
Shore complexity	1	0	0	1	8*
Stream banks steep	0	1	0	1	8*
Stream order	0	1	0	1	8*
Structures and debris	1	0	0	1	8*

* Tied ranks.

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6.0 APPENDICES

Appendix I. Justification for removing 16 CPW wetland-dependent priority wildlife species from the list for the Lower South Platte River Basin and justification for the original removal of piping plover and river otter, which were placed back on the list.

Boreal toad (*Bufo boreas boreas*): Boreal toads are unlikely to exist with LSPRB due to elevation preferences (CPW 2012, CHA 2012).
Lesser scaup (*Aythya affinis*): Lesser scaup constitute a very small proportion of hunting, and they are not a species of concern.
Piping plover (*Charadrius melodus*): Piping plovers are not known to breed with LSPRB (Nelson 1998c, COBBA 2012, RMBO 2012). RMBO (2012) states, "In Physiographic Area 36 in Colorado, they nest only on reservoirs in the vicinity of the Arkansas River, between Las Animas and Lamar." However, Elliott-Smith and Haig (2004) show an isolated population adjacent to and just south of LSPRB, and NDIS (2012) suggests occurrence within LSPRB. NDIS (2012) cites Andrews and Righter (1992) as their primary source for distribution. Andrews (pers. comm., 1/5/2012) stated,

> "Regarding the five species within the South Platte area: Piping Plover, Snowy Plover, and Least Tern-all would be very rare migrants-not regular or expected, just the occasional vagrant. I have seen each of the species within the area, but very seldom. I am not aware of any breeding nor would I expect any. Lewis's Woodpecker-small numbers (including breeding) in eastern Douglas Co. and Elbert Co.; otherwise a very rare wanderer. Red-naped Sapsucker-regular migrant (in small numbers) throughout in riparian and urban areas (perhaps extremely rarely in winter); I would not expect any breeding.
>
> "As an example from one of the best studied sites within the area, here are the statements we made in our checklist of Barr Lake birds (Andrews, Robert, Robert Righter, Michael Carter, Tony Leukering, and Alison Banks. 2002. *Birds of Barr Lake and Surrounding Areas, 1888 through 1999: An Annotated Checklist*. Rocky Mountain Bird Observatory Ornithological Monograph No. 1):
>
> Snowy Plover: 6 records in April and May, and 4 records from July to October.
> Piping Plover: 1 record in May and 4 in August
> Least Tern: 1 record (from 1907) in early June
> Lewis's Woodpecker: 11 records, scattered throughout the year but mostly spring and fall
> Red-naped Sapsucker: 4 records in April and May, and 12 records in September and October."

In a follow-up, Andrews (pers. comm.., 1/11/2012) stated,

> "The sightings for Barr Lake included all published observations (from journal articles and things like DFO newsletters, etc.), specimens, and any unpublished observations we could get from people. I think they are pretty close to being complete for the 1888–1999 time period. Wetlands at Barr Lake (and probably most other reservoirs in the South Platte basin) are not suitable for these three species. For example, Barr Lake doesn't have islands, nor does it have a bare shoreline in the breeding season, and the same is true for

> most other reservoirs (Jackson, Prewitt, etc.). Riverside has an island (pelicans nest there), but I can't say why none of these of these species nest there. All three of the species (the two plovers and the tern) are too marginal for wetland quality to be much of a concern in this area. It appears as if this part of Colorado has always been marginal for these three species."

Western snowy plover (*Charadrius alexandrinus nivosus*): Western snowy plovers are not known to breed with LSPRB (Nelson 1998d, Page et al. 2009, COBBA 2013, RMBO 2012). NDIS (2012) and Andrews and Righter (1992) suggest very rare occurrences (see pers. comm. with Andrews under piping plover, above). RMBO (2012) states, "Within the Central Shortgrass Prairie in Colorado, they breed on the shores of reservoirs near the Arkansas River between La Junta and Lamar."

Least tern (*Sternula antillarum*): To the best of current knowledge, least terns do not breed within LSPRB (Thompson et al. 1997, Nelson 1998a, Sauer et al. 2011, COBBA 2013, CPW 2012, RMBO 2012). RMBO (2012) states, "In Physiographic Area 36 in Colorado, they nest only on reservoirs in the vicinity of the Arkansas River, between Las Animas and Lamar." NDIS (2012) and Andrews and Righter (1992) suggest only very rare occurrences (see pers. comm. with Andrews under piping plover, above).

Bald Eagle (*Haliaeetus leucocephalus*): Key habitat quality variables for bald eagles are not parameters of wetlands.

Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*): Hughes (1999) and Guilfoyle (2001) indicate that the range of the *occidentalis* subspecies does not overlap with LSPRB.

Lewis's woodpecker (*Melanerpes lewis*): Lewis's woodpeckers generally do not breed within LSPRB (Tobalske 1997, Sauer et al. 2011, Cornell University 2012). Kuenning (1998) reported a few confirmed breeding records in Elbert County; however, the current Colorado Breeding Bird Atlas (2007–2011) reports no Lewis's woodpeckers within LSPRB. NDIS (2012) and Andrews and Righter (1992) suggest very rare occurrences during spring and fall (see pers. comm. with Andrews under piping plover, above).

Red-naped sapsucker (*Sphyrapicus nuchalis*): Barrett (1998a), Sauer et al. (2011), and COBBA (2012) suggest no evidence of breeding within LSPRB, and Walters et al. (2002) suggest no occurrence at any time within LSPRB. NDIS (2012) shows some occurrence in Adams and Elbert Counties, but these occurrences are very unusual (Andrews, pers. comm., see above under piping plover).

Southwestern willow flycatcher (*Empidonax traillii extimus*): The range of the Federally-endangered subspecies, *extimus*, extends only into southern Colorado and does not occur within LSPRB (USFWS 2002, 2012; NDIS 2012).

Southern redbelly dace (*Phoxinus erythrogaster*): NDIS (2012) indicates absence of southern redbelly dace in LSPRB: "In Colorado, one population of southern redbelly dace has been discovered in a single tributary of the Arkansas River in Pueblo (Miller 1982). This small tributary is little more than a small spring which surfaces at the base of a hill, flows alongside a railroad track for about a half mile and then enters the Arkansas River. Single individuals of the southern redbelly dace have been previously collected in 1965 in the Arkansas River in Pueblo and Canon City (J. Seilheimer, personal communication) and by Miller (1982) in Turkey Creek in Pueblo County. It is not known for certain if this population is native to Colorado."[4]

Arkansas darter (*Etheostoma cragini*): NDIS (2012) and CPW (2012) both indicate an absence of Arkansas darters in LSPRB, and that within Colorado, they are found only within the Arkansas River drainage. NDIS (2012) states, "The Arkansas darter has a very restricted natural range. It is only found in tributaries of the Arkansas River in Colorado, Kansas, Missouri and Oklahoma. The species is on the Colorado list of threatened species. In Kansas, the fish is listed as threatened and is classified as rare and endangered in Oklahoma. In Colorado, isolated populations have been found in several spring areas adjacent to the Fountain River south of Colorado Springs and other small tributaries, Rush Creek and Big Sandy Creek, of the Arkansas River on the eastern portion of Colorado (Miller 1984). The Arkansas darter is the only darter found in the Arkansas River Drainage, and is native to Colorado (Ellis 1914)."

Plains orangethroat darter (*Etheostoma spectabile*): NDIS (2012) indicates an absence of Plains Orangethroat Darters in LSPRB: "The species is rather widespread in the central part of the United States ranging from Michigan to Tennessee south to Texas and into Colorado. In Colorado, the species is restricted to, and the only darter found in, the Republican River Basin on the eastern side of the state. The orangethroat was the second most abundant species in the Republican Basin (Cancalosi 1980)." CPW Native Aquatic Species Biologist, Boyd Wright, stated, "Plains orangethroat darter are found in the North and South Fork Republican River…they are not found in the South Platte River basin" (pers. comm.. 1/9/2011).

River otter (*Lontra canadensis*): Although shown as occurring within LSPRB, NDIS describes the range as follows: "They occur in the Colorado, Gunnison, Piedra, and Dolores rivers. Tracks and other sign of otters have also been found in the Poudre and Laramie drainages in Larimer County. " Scott Wait (CPW biologist) believes occurrence of river otters in LSPRB is "possible but unlikely" (pers. comm.. 1/9/2012). Eric Odell (CPW biologist) in a personal communication (1/9/2012), stated, "We have had reports of otters on the lower S Platte, but as you suggest, only one confirmed sighting will 'light up' the map. I would not say that the Lower South Platte is important to river otter populations in Colorado."

Dwarf shrew (*Sorex nanus*): NDIS (2012) suggests and absence of dwarf shrews in LSPRB and states, "The dwarf shrew is known from the Southern Rocky Mountains at elevations above 1,680 m (5,500 ft). Armstrong et al. (1973) reported a total of 81 dwarf shrews collected at elevations of 1,600 to 3,050 m (5,300–10,000 ft) in the Arkansas River drainage. Hoffmeister (1967) and Spencer (1975) have captured the dwarf shrew at Mesa Verde and Durango." NatureServe (2012) also suggests absence in LSPRB.

Meadow jumping mouse (*Zapus hudsonius*): Meadow jumping mice are riparian species but do not rely on riparian wetlands. They rely on scrub-shrub and logs.

Yellow mud turtle (*Kinosternon flavescens*): NDIS (2012) states, "Nebraska south to northern Mexico, west to southern Arizona (Iverson 1989); disjunct populations in Illinois, Iowa, and Missouri. Occurs in eastern Colorado in the Republican, Arkansas, and Cimarron River drainages at elevations below 5,000 feet (1,525 m)." CHA (2012) shows most occurrences of yellow mud turtles in Yuma County.

[4] Many citations for literature referenced are not provided on the NDIS website. Therefore, references within quotes from this website are not included in the Literature Cited section.

Appendix II. Wetland habitat types in Lower South Platte River Basin.

Natural wetlands

Beaver pond: impoundment created by beaver dam, usually made of mud and woody plant material.

Emergent marsh: shallow water wetland that is frequently or continuously inundated and supports herbaceous plants adapted to saturated conditions; can be isolated or along reservoirs and other water bodies.

Playa: isolated depressional wetland with distinctive wet and dry seasons, fed by precipitation and runoff.

Riparian wetland – dominated by herbaceous plants: wetland adjacent to stream; flooded intermittently, seasonally, or permanently; fed by water from the stream either above or below ground; dominated by herbaceous phreatophytic plants.

Riparian wetland – dominated by shrub-scrub: wetland adjacent to stream; flooded intermittently, seasonally, or permanently; fed by water from the stream either above or below ground; dominated by woody phreatophytic shrubs.

Sandbar: accumulation of sand and/or gravel within a river channel; often maintained by scouring action.

Stream channel: area of river confined by banks and a streambed.

Warm water slough: slowly moving shallow water adjacent to river; source originates from ground water; in winter water temperature warmer than in river and under normal conditions does not freeze during winter.

Wet meadow: grassy areas saturated at or near the surface for part of the year.

Impoundments and other human-created wetlands

Irrigation-influenced wet meadow: meadow receiving surface or subsurface irrigation waters.

Irrigation ditch/canal: excavated canal that supplies water to dry land.

Gravel pits: steep-sided excavation, usually in association with gravel mining operations; may or may not have sloped wetlands on fringe.

Moist soil unit: managed wetland with dike and water control structure; manipulated to flood intermittently or seasonally to maximize production of moist-soil annual and/or perennial herbaceous plants; sometimes planted with crops that provide seeds, vegetation, and/or roots that benefit wetland-dependent species.

Recharge pond: diked shallow water impoundment on ephemeral drainage designed to retime S. Platte River flows into Nebraska according to legal mandates.

Reservoir: impoundment used to store and regulate water for agricultural or municipal use; usually > 5 acres.

Sewage lagoon: impoundment fully contained by dikes and receiving domestic/industrial/agricultural effluent; usually near urban areas or feedlots; rectangular or square in shape

Stock pond: diked pond on ephemeral drainage in pasture or prairie; used for watering livestock; usually created by humans and < 5 acres.

Urban runoff ponds: pond that capture effluent from urban storm runoff

Appendix III. Field Key to Wetland Habitat Types in Lower South Platte River Basin. Last updated May 24, 2013.

Wildlife habitat types are small to large-scale patches on the landscape that represent important and distinct habitat zones for wildlife species. The primary divide within the key is between natural and human-created habitat types. There may be several habitat types within a wetland or riparian area, or there may only be one. To be called out as a separate habitat type within a mosaic of vegetation, each patch must be ***>0.1 ha***. Keep this criterion in mind as you read through the key. A small puddle with a few cattails does should not be classified as an emergent marsh.

1a. Wetland habitat that is predominately natural, though may be degraded or otherwise influenced by human activities..**GO TO KEY 1: Natural Wetland Habitat Types**

1b. Wetland habitat that is created or significantly modified by human activities (e.g., impounded, excavated, diked), even if for habitat enhancement.......................... **GO TO KEY 2: Human-Created Habitat Types**

KEY 1: Natural Wetland Habitat Types

1a. Habitat not associated with flowing water bodies (e.g., small streams, large rivers, or their floodplains).... **2**

1b. Habitat associated with a flowing water body (e.g., a small stream, large river, or their floodplain) **4**

2a. Isolated depressional wetland with distinctive wet and dry seasons, fed by precipitation and runoff..**Playa**

2b. Wetlands lacking distinctive wet and seasons.. **3**

3a. Shallow water wetland that is frequently or continuously inundated and supports herbaceous plants adapted to saturated conditions. Typically a mix of open water and vegetation, but may be completely vegetated. Can be isolated or along reservoirs (in this case, the reservoir in not natural, but the marsh vegetation is naturalized along the shore).. ....**Emergent marsh**

3b. Herbaceous wetland area saturated at or near the surface for part of the year. Typically dominated by grasses or sedges...**Wet meadow**

4a. Open water habitat (even if partially or mostly vegetated) with obvious evidence of past or current beaver activity impounding water; dam usually constructed with woody plant material and mud ....**Beaver pond**

4b. No evidence of past or current beaver activity impounding water **5**

5a. Flowing water habitat within the floodplain or within the confines of a stream or river channel. May be partially or mostly vegetated, but water still flows through or over **6**

5b. Habitat associated with or adjacent to flowing water, but does not contain flowing water except in overbanking floods. Woody vegetation on the margins of open water bodies also keys here (i.e., reservoir edges) **8**

6a. Slowly moving shallow water adjacent to river. Source originates from ground water and moves slowly toward river. There is no obvious upstream connection to the primarily river channel. Water present all year and in wither, water temperature warmer than river and typically does not freeze. Only found on the South Platte River floodplain from Greeley to the state line. Not associated with smaller streams.. **Warm water slough**

6b. Habitat within the confines of the ordinary high water line of a stream or river. If overly vegetated (see sand bar below), it may not be apparent that the habitat is within the ordinary high water line **7**

7a. Area of stream or river that is confined by banks and streambed. If not a primary river or stream channel, there is an obvious upstream and downstream connection to the primary channel (i.e., not a warm water slough). May be covered with water or be exposed sediment. In some cases, exposed stream or river channels may be vegetated if flow is not regular. .... **Stream or river channel**

7b. Accumulation of sand and/or gravel within a river channel, often maintained by scouring action. Generally only associated with large rivers that can transport significant volumes of sediment. Can become densely vegetated with willows and other vegetation if scouring does not occur for several years. If this is the case, the underlying sand and gravel may not be obvious. If a willow stand is immediately within the river channel, it is likely growing over a sand bar. This should be classified as a sand bar and not as riparian vegetation. .... **Sand bar**

8b. Natural shallow water wetland within the floodplain that is frequently or continuously inundated and supports herbaceous plants adapted to saturated conditions. Typically a mix of open water and vegetation, but may be completely vegetated. .... **Emergent marsh**

8b. Wetland area within the floodplain that is not frequently or continuously inundated. Vegetation may be herbaceous or woody. **9**

8a. Wetland are adjacent to stream; flooded intermittently, seasonally, or permanently; fed by water from the stream either above or below ground; dominated by herbaceous phreatophytic plants. .... **Riparian wetland (herbaceous)***

8b. Wetland area adjacent to stream; flooded intermittently, seasonally, or permanently; fed by water from the stream either above or below ground; dominated by woody phreatophytic shrubs. .... **Riparian wetland (shrub / forested)***

*Note: Wetland habitat features only apply to actual wetlands, not non-wetland riparian areas and cottonwood gallery forests. For non-wetland areas, use either “open mesic vegetation” for herbaceous areas and “cottonwood gallery” for wooded areas.

KEY 2: Human-Created Habitat Features

1a. Open, herbaceous meadows receiving surface or subsurface irrigation waters. Includes herbaceous meadows created through direct flood irrigation or indirect irrigation runoff, tail waters, return flow, or ditch seepage .... **Irrigation-influenced wet meadow**

1b. Not as above **2**

2a. Permanent open water. *[Not likely to be included as sample points in the Lower South Platte project due to water depth.]* **3**

2b. Seasonal open water, may be dry at any point in season depending on water management. May be partially or entirely vegetated or clear of vegetation **5**

3a. Impoundment that is fully contained by dikes and receiving domestic/industrial/agricultural effluent; usually near urban areas or feedlots; rectangular or square in shape .... **Sewage lagoon**

3b. Open water habitat that is not diked on all sides **4**

4a. Steep-sided excavation, usually within a floodplain, association with current or past gravel mining operations. May or may not have sloped wetlands on fringe. If gravel pit has been restored, sloping sides may be more gradual and vegetated. Look at the larger landscape context to determine whether a wetland likely originated as a gravel pit. *[Restored or reclaimed gravel pits may be included in the Lower South Platte project if water levels are not too high.]* .... **Gravel pit**

4b. Impoundment used to store and regulate water for agricultural or municipal use; usually > 5 acres. *[Vegetated shores around reservoirs would be classified as emergent marsh.]* .... **Reservoir**

5a. Excavated canal that supplies water to and across dry land. In some cases, it may be difficult to distinguish irrigation canals from warm water sloughs and other natural side channels, as natural channels are sometimes used to convey water and hand-dug irrigation canals can, over time, take on natural features. Look at the larger landscape context, the straightness of the channel (natural channels have more curves while ditches are straighter), and the path of water flow (natural channels follow the most direct path while ditches often cut across contours) to make an educated guess. .... **Irrigation ditch/canal**

5b. Human-created habitat without flowing water **6***

6a. Wetland designed and managed for the benefit of wildlife or for recharge to the South Platte River (wildlife habitat may be a secondary goal or not at all). *[The following habitat types represent two ends of a continuum and there is significant grey area in between. If it is clear from discussions with a landowner that the wetland being sampled is one or the other, use the specific name. If it is not clear, call the wetland a **managed wetland**.]* **7**

6b. Impounded or excavated open water feature (pond) designed for a variety of purposes. May or may not be vegetated. May be dry at time of sampling **8**

7a. Managed wetland with dike and water control structure; manipulated to flood intermittently or seasonally to maximize production of moist-soil annual and/or perennial herbaceous plants; sometimes planted with crops that provide seeds, vegetation, and/or roots that benefit wetland-dependent species. .... **Moist soil unit**

7b. Diked shallow water impoundment designed to retime South Platte River flows into Nebraska according to legal mandates. .... **Recharge pond**

8a. Pond designed to capture urban storm water runoff. May be vegetated or not. .... **Urban runoff pond**

8b. Pond used for fishing or other recreational purpose .... **Recreational pond**

8c. Diked pond associated with and used to water livestock .... **Stock pond**

*Note: Checking with the landowner or land manager regarding purpose and use may be required to differentiate these habitat features.

Appendix IV. Metric protocols for key habitat variables from literature.

Below are some details of how others have assessed each key habitat variable with comments and recommendations for use in the Lower South Platte River Basin. The comments and recommendations are summarized in Table 42 for convenience.

Landscape context

Level 1. Buffers should be constructed around wetlands in GIS at 1.5, 3, and 8 km. The following information within these buffers will help determine habitat quality for priority wildlife species:

1. Other wetlands
   a. Number
   b. Size
   c. Type
   d. Connectivity
2. Agricultural land; if possible distinguishing between
   a. Crops
   b. Grazing
3. Land uses (e.g., urban, industrial, energy sector, agriculture)
4. Land ownership (e.g., private, public, conservation easements)

Levels 2 and 3. Not applicable

Percent emergent cover

Level 1. With aerial photography or satellite imagery taken during the growing season, measurements of percent emergent cover will be accurate and relatively rapid. The images can be evaluated using several programs together (Rehm and Baldassarre 2007), or they can be evaluated entirely in Adobe Photoshop® (Ortega et al. 2002).

Level 2. Many investigators have used ocular estimates to describe percent of emergent cover in wetlands (Euliss and Harris 1987; Merendino et al. 1992, Ratti et al. 2001, Pearse et al. 2011). These estimates are subjective but may be less prone to large errors when the estimates are placed into categories. The following categories have been used:

Categories of percent emergent cover							References
0–1%	1–10%	10–25%	25–50%	50–75%	75–100%		Edwards and Otis 1999
<1%	1–5%	6–25%	26–50%	51–75%	76–95%	>95%	Naugle et al. 2000 Webb et al. 2010 Fairbairn and Dinsmore 2001
0–10%	11–25%	26–50%	51–75%	>75%			Mulhern et al. 1985

<33% 33–66% >66%	Ritter and Savidge 1999

Level 3. Ocular estimates in sample plots (≤ 1 × 1 m^2) at random points or in a systematic grids have been used by several investigators in conjunction with data collection of other variables, such as plant species (Heaven et al. 2003, DeBerry and Perry 2004).

Comments and recommendations (at the entire wetland area scale). If good aerial photography is available, Level 1 would be the most ideal method because it involves quantifying rather than estimates. The Level 2 methods of CNHP will provide adequate information to access the value to wildlife. This includes estimating cover of shallow water (< 20 cm) and cover of deeper water (20–100 cm).

Water depth

Level 1. Not applicable

Level 2. In some cases, asking the land owner or land manager about water depth may reveal ranges of water depth both within the wetland and during different times of the year.

Level 3. Below are several methods for determining water depth.
Bolduc and Afton (2004): A measuring stick was used to measure water at three random plots. "Locations of sampling stations were determined using random numbers to select distances and angles from an observation blind that fell within the pond area, up to a distance of 200 m from the blind."
Germaine and Hays (2009): "We estimated maximum pond depth by noting high-water marks on shoreline vegetation. We measured actual pond depths by wading to pond center…"
Hornung and Foote (2006): A measuring stick was used to measure water at three plots in each wetland. "Three sub-sampling locations were established at each wetland using a stratified random design: randomly selected along a transect that ran parallel to the wetland shore and was one third the entire shoreline length."
Rotella and Ratti (1992): "Water depth was recorded 1 m to the east, south, and west of permanent stakes in each wetland…"

Wet meadows. To measure water depth in wet meadows, Riffell et al. (2001) measured water in depressions between hummocks at a point closest to their sampling station. "Each bird-sampling transect was divided into 50-m segments. Within each segment, four habitat- sampling radii were established radiating from the center of that segment. Five sampling points were located at 10-m intervals along each of the habitat-sampling radii (total of 20 points per 50-m segment of each bird transect)."

Comments and recommendations (measured at the vegetation plot scale). If the land manager cannot provide water depth information, water depth should be determined with a measuring stick at vegetation plots, using plots recommended by EPA (2011).

<u>Dominant vegetation</u>

Level 1. Not applicable

Level 2.
<u>Thorn and Zwank (1993)</u>: "Nine managed impoundments on the refuge were classified as one or more of four different plant zones: annuals (wild millets, sprangletop and smartweeds); saltgrass; alkali-three-square bulrush; and cattail-hardstem bulrush. Type and amount of the dominant plant zone within each impoundment were estimated from aerial photographs and subsequently verified by visual ground truthing."

Level 3.
<u>Hornung and Foote (2006)</u>: "Three sub-sampling locations were established at each wetland using a stratified random design: randomly selected along a transect that ran parallel to the wetland shore and was one third the entire shoreline length…Two adjacent 1-m2 quadrats were established at each sub-sampling location, extending from the shoreline toward the center of the wetland. Aquatic plants were identified to species."
<u>Rollo and Bolen (1969)</u>: "The vegetation immediately surrounding the playa lakes in the study areas was sampled using a modification of the "step point" method (Evans and Love 1957). Random lines of 10 paces in length and radiating at 5 pace intervals from the water's edge were used as transects to characterize the vegetation. At each step on the transects the nearest plant was tallied. The vegetation of each of three lakes was sampled with 2500 points in total. The data from each site were combined to estimated an abundance rating for each species."

Wet meadows. Riffell et al. (2001): "Each bird-sampling transect was divided into 50-m segments. Within each segment, four habitat- sampling radii were established radiating from the center of that segment. Five sampling points were located at 10-m intervals along each of the habitat-sampling radii (total of 20 points per 50-m segment of each bird transect)…. Within each frame, we recorded the presence or absence of graminoid vegetation (grass or sedge), cattail (*Typha* spp.), bulrush (*Scirpus* spp.), floating vegetation, submersed vegetation, willow (*Salix* spp.), alder (*Alnus* spp.), open water pockets, and moss."

Comments and recommendations (measured at the vegetation plot scale). The plant community should be determined by methods already in use by CNHP (Lemly et al. 2011), using plots recommended by EPA (2011). The plant community should be placed in the following cover classes: 1: trace 2: <1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%.

<u>Size of habitat</u>

Level 1. Size of the wetland can be determined by using GIS polygonal measuring tools.

Level 2. If questionable, the size of the wetland obtained in GIS can be verified by walking around the perimeter with GIS tracks on save mode. For larger wetlands, distances across the wetland should be measured with a range finder at angles determined by a compass.

Level 3. Not applicable

Comments and recommendations (at the entire wetland area scale).

<u>Vegetation height</u>

Level 1. Not applicable

Level 2.
<u>Mulhern et al. (1985)</u>: "Vegetation height was assigned to one of five classes (0–0.25 m, open water and low mat vegetation; 0 .25–0.50 m, wet meadow vegetation; 0.5–1.0 m, sedge [*Carexs* p.] and white-top grass (Scholochloafestuacaea]; 1.0–2.0 m, cattail [*Typha latifolia*]; and 2.0 m, shrubs and trees)."

Level 3.
<u>Hines and Mitchell (1983)</u>: "A vegetation transect consisting of 20, 20 X 50-cm quadrats spaced at 1.8-m intervals was established on each artificial island after the 1973 nesting season. We recorded the height of vegetation and the canopy cover of all plants > 10 cm."
<u>Joyner (1980)</u>: "Mean height of the peripheral terrestrial vegetation was calculated by picking 50 random locations around the perimeter of each pond. At each location, terrestrial vegetation was measured at 0.3, 1.0, and 3.0 m from the water's edge along 3- m linear transects constructed perpendicular to the shoreline."
<u>Shaffer et al. (2006)</u>: "A transect was established lengthwise through the center of each island. Parallel transects were then established on either side of the center transect halfway between the center transect and the island shore, for a total of 3 transects…We also categorized the vegetation within 15 cm of each transect point into 1 of 10 vegetation classes (after Willms and Crawford 1989): 1) tall and dense forbs, 2) tall and dense grass, 3) short and sparse forbs, 4) short and sparse grass, 5) tall and sparse forbs, 6) tall and sparse grass, 7) short and dense forbs, 8) short and dense grass, 9) shrub, and 10) unvegetated."
<u>Smith et al. (2004)</u>: "…we established 5 200-m transects during August of each year to determine plant species frequency and vertical vegetative cover. We used a 10- cm-diameter circular plot at each 5-m interval along the transect and… We used a profile board (Nudds 1977) 2.4 m high, and 15 cm wide, divided into 6 40-cm · 15-cm sections to determine vertical cover."
<u>Zicus et al. (2006)</u>: "We established 3 sampling clusters along the longest straight-line diagonal across a field. We established sampling-cluster starting points at the 3 quarter-points along the diagonal, and permanently marked these with stakes. Each sampling cluster had 4 sampling points that were 20 m north, east, south, and west of a starting point. At each sampling point, we measured vegetation height"

Wet meadows. Riffell et al. (2001) measured height of vegetation in wet meadows along sampling segments (see above, under *water depth* section, for selection of sampling segments).

Comments and recommendations (measured at the vegetation plot scale). Vegetation height should be estimated and placed in size classes according to methods already in use by CNHP (Lemly et al. 2011), using plots recommended by EPA (2011). Vegetation height should be placed in the following size classes according to CNHP protocol: 1: <0.5 m 2: 0.5–1m 3: 1–2 m 4: 2–5 m 5: 5–10 m 6: 10–15 m 7: 15–20 m 8: 20–35 m 9: 35–50 m 10: >50 m.

Water quality and pH

Level 1. Not applicable.

Level 2. Merendino et al. (1992) did not find any significant differences between measurements of pH and conductivity taken directly in the field and a subset of water samples sent to a chemical laboratory.

Level 3. Not applicable.

Comments and recommendations (measured at the vegetation plot scale). pH, conductivity, and temperature should be measured in the middle of the water column, using plots recommended by EPA (2011).

Interspersion

Interspersion is a concept that describes patterns of vegetation cover and water in terms of both amount (as a ratio of cover:water) and pattern (shapes of vegetation within the wetland); both are important for some wildlife species.

Level 1. With aerial photography or satellite imagery taken during the growing season, the images can be evaluated using Adobe Photoshop® (Ortega et al. 2002, see Appendix 1).

Level 2. Many investigators have used estimates in the field to describe cover:water ratios and complexity of patterns
Mulhern et al. (1985): Mulhern et al. placed patterns into categories of (1) uniform, (2) partially interspersed, and (3) heavily interspersed.
Murkin et al. (1997): Murkin et al. described patterns as (1) little open water, (2) hemimarsh (50:50 interspersed cover:water), and (3) little vegetation.
Ratti et al. (2001): Ratti et al. described patterns as "(1) closed marsh, (2) hemimarsh, (3) marshes with central expanses of open water surrounded by wide bands of emergent cover, and (4) open marshes (>95% open water or bare soil)."

Level 3. Some investigators have worked with interspersion patterns that were manipulated in the field.
Kaminski and Prince (1981): Kaminski and Prince worked with manipulated designs of 30:70, 50:50, and 70:30.
Smith et al. (2004): Smith et al. placed manipulated interspersion ratios into categories of 25:75, 50:50, and 75:25.

Comments and recommendations (at the entire wetland area scale). Patterns of complexity should follow the CNHP protocol (Figure 2), using the best fit of diagrams or, if a pattern is not represented on the diagram, using other descriptions at the wetland level, such as

- Fringe (vegetation around the perimeter of the wetland with central open water)
- Partially interspersed (few patches of vegetation in central portion)
- Complex (vegetation interspersed in many patches)
- Closed (few to no areas of open water)

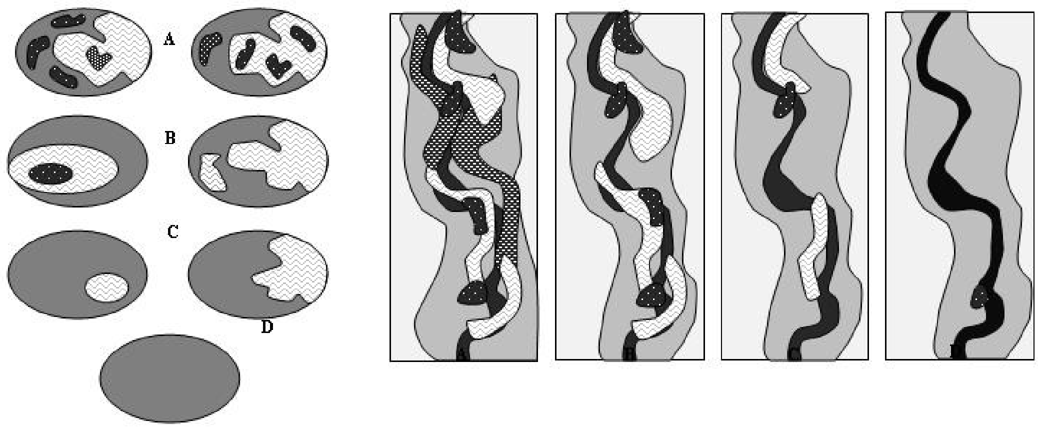

Figure 2. Diagrams used to describe interspersion patterns.

Shade/sun

Level 1. Not applicable.

Level 2. This feature helps determine if solar radiation is adequate to warm waters sufficiently for frogs eggs to develop. In smaller wetlands where large trees can shade all or most of the water, it would be useful to estimate the percent of overstory canopy covering the wetland.

Level 3. Not applicable.

Comments and recommendations (measured at the vegetation plot scale or estimated at the Assessment Area scale). Canopy, as a measure of light interception, should be measured directly with a densiometer (Nuttle 1997) at plots, using plots recommended by EPA (2011). Alternatively, it can be estimated at the Assessment Area scale.

Residual cover depth

Levels 1 and 2. Not applicable.

Level 3. Residual cover (dead vegetation from the previous year) can be measured in the same ways that vegetation height is measured (Grove et al. 2001).

Comments and recommendations (measured at vegetation plot scale). Residual cover should be determined with a measuring stick according to methods already in use by CNHP (Lemly et al. 2011), using plots recommended by EPA (2011).

Key Habitat Feature Unique to Piping Plover

Percent open sand or gravel area on sandbar

Level 1. Percent open sand or gravel area can be determined using tools in GIS.

Levels 2 and 3. Not applicable.

Comments and recommendations. Percent open sand or gravel area on sandbars should be measured using GIS tools; alternatively it can be determined using the same methods as percent cover (see Appendix 1).

Key Habitat Features Unique to River Otter

The following key habitat features are meant to be measured only in riparian areas.

Structures and debris

Level 1. Not applicable.

Level 2.
Dubuc et al. (1990): "We recorded the location and condition of each beaver house and dam encountered. Beaver impoundments were considered active if dams showed recent mudding (i.e., building or repair) and water levels were being maintained."
Swimley et al. (1998). Swimley et al. recorded presence or absence of flood debris, logs, and beaver structures within 100-m stream sections.
Newman and Griffin (1994): Newman and Griffin recorded presence or absence of beaver lodges or dens within a 5-m radius of otter latrine sites.

Level 3. Not applicable.

Comments and recommendations (at the entire wetland scale). Presence or absence of beaver structures, log jams, and debris jams should be noted according to CNHP protocols.

Riparian vegetation

Level 1. Not applicable.

Level 2.
Edwards and Otis (1999): Edwards and Otis placed patches of vegetation into height categories of (1) low 0–2 m, (2) medium 2–6 m, and (3) high > 6 m.
Level 3.
Crowley et al. (2012): Crowley et al. measured the diameter at breast height (DBH) of all trees within 5.64-m-diameter half circles.

Comments and recommendations (at the Assessment Area scale). Presence of woody vegetation should be measured according to CNHP methods:

1. Dominant canopy trees (>5 m and > 30% cover)
2. Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover
3. Tall shrubs or older tree saplings (2–5 m)
4. Short shrubs or young tree saplings (0.5–2 m)

Shore complexity

Level 1.
Dubuc et al. (1990): "Mean shoreline diversity was calculated by dividing the perimeter of each water-body by its total area (Hays et al. 1981:83) and averaging that value for all wetlands and deep water habitats within a watershed."
Swimley et al. (1998). Swimley et al. recorded presence or absence of backwater sloughs within 100 m-stream sections.

Level 2.
Newman and Griffin (1994): Newman and Griffin recorded river otter latrine sites as "point of land, isthmus, mouth of permanent stream, or none of the above."

Level 3. Not applicable.

Comments and recommendations (at the Assessment Area scale). Presence or absence of backwater sloughs and other features that increase shoreline should be noted according to CNHP protocol.

Stream length

Level 1. Stream length can be determined using tools in GIS.

Levels 2 and 3. Not applicable.

Comments and recommendations. Stream length should be measured with GIS tools.

Banks

Level 1. Not applicable.

Level 2.
Swimley et al. (1998). Swimley et al. recorded presence or absence of undercut banks within 100-m stream sections.

Level 3. Not applicable.

Comments and recommendations (at the Assessment Area scale). Presence or absence of undercut banks should be noted.

Stream order

Level 1. Stream order can be determined from maps detailed enough to show all tributaries.

Levels 2 and 3. Not applicable.

Comments and recommendations (at the entire wetland scale). Stream order should be determined from maps detailed enough to show all tributaries.

Stream width

Level 1. Stream width should be determined using GIS tools.

Level 2. If stream width has changed since the most recent aerial photography available, it should be measured in the field with a range finder.

Level 3. Not applicable.

Comments and recommendations (at the entire wetland scale). Stream width at bankful should be estimated according to CNHP protocol.

Protocols for optional sampling food resources in Lower South Platte River Basin

Invertebrates

Levels 1 and 2. Not applicable.

Level 3.
Many investigators have successfully used a wide variety of methods (e.g., Ashley et al. 2000, Bolduc and Afton 2004, de Szalay et al. 2003, Elmberg et al. 2003, Gray et al. 1999, EPA. 2002, Hornung and Foote, 2006, Joyner 1980, Kaminski and Prince 1981). EPA (2002) and Frederickson and Reid (1988) published thorough comparisons of protocols.

Comments and recommendations. Samples should be taken at vegetation plots, using the plot sampling design of EPA (2011). Ideally, collections would occur at least monthly, March through October.
<u>Benthic invertebrates</u>: A 12-cm-diameter core sampler (should be 25–30 cm long) sunk to a depth of 10 cm and sieved through a 500-µm screen will capture benthic macro-invertebrates (>0.5 mm). A 2.5-cm-diameter core sampler sunk to a depth of 2 cm and sieved through a 63-µm screen will capture benthic meiofaunal invertebrates (0.06–0.5 mm, Bolduc and Afton 2004).
<u>Water-column invertebrates</u>: A 500-µm mesh sweep net with a 20-cm opening, swept through a total length of 20 m with upward vertical sweeps will capture aquatic macro-invertebrates in the water column equivalent to 6 m^2 (Bolduc and Afton 2004).
<u>Invertebrates on emergent vegetation and in wet meadows</u>: Sweep nets (as described above) should be used to sweep vegetation in wet meadows and through emergent vegetation above the water column. To be consistent with sweeps in the water column, the total length of sweeps should be 20 m, e.g., 10 sweeps of 2 m each. In very dense emergent vegetation, such as cattails, where sweeping is not practical, invertebrates should be sampled with activity traps (de Szalay et al. 2003). Activity traps should be constructed with one-liter plastic bottles and funnels (de Szalay et al. 2003). Activity traps are typically checked 24 hours later (de Szalay et al. 2003).
<u>Preservation</u>: Invertebrates collected through aerial sweeping should be placed directly in jars of 95% ethanol (Joyner 1980). All material remaining in nets or sieves should be preserved in jars of 10% buffered formaldehyde and labeled with collection site and date. In the lab, before samples are identified, they should be washed according to Ashley et al. (2000), who rinsed with tap water samples in a 425-µm screen to strain out detritus and fine sediments; they separated invertebrates by floating in saturated sucrose solution, rinsed in dionized water, and stored in 70% isopropanol; alternatively 95% ethanol can be used.
<u>Identification</u>: Identification of invertebrates to the family level is adequate for management purposes (Fredrickson and Reid 1988). Some invertebrates might not be identified at a lower level than phylum. For example, Bolduc and Afton (2004) suggested, "Invertebrates were identified as the follows: (1) Diptera, Mollusca, and Decapoda to the family level, (2) other Insecta and Arthropoda to order, (3) Annelida, and Granuloreticulosa to class, and (4) Nematoda were not identified further." Resources for identification could include Colorado State University classrooms and/or work-study students or student volunteers.
<u>Biomass calculations</u>: Biomass for each classification unit or size unit should be calculated by either comparing with known values in the literature or by drying a known number of individuals

(e.g., 30 individuals) at 105° C for 24 hours (Kaminski and Prince 1981) and weighing. Biomass should be averaged from invertebrate weight unit (e.g., mg)/L per wetland per sampling round (Hornung and Foote 2006).

<u>**Seeds**</u>

Levels 1 and 2. Not applicable.

Level 3.
Reinecke and Hartke (2005): "Measurement of Seed Availability—During mid-October, we went to all 35 second-sample plots in each impoundment, clipped inflorescences within a 0.25-m^2 frame, and collected soil cores with a depth and diameter of 10 cm. We soaked soil cores in a 3% solution (1:32) of hydrogen peroxide (H_2O_2) for 3–5 hrs to disperse clays (Bohm 1979:117) and conducted a test to ensure the oxidizing agent H_2O_2had no effect on the mass of barnyard grass (*Echinochloa crusgalli*) seeds (K. J. Reinecke and K. M. Hartke, unpublished data). We washed samples with water over a set of 2 or 3 sieves, depending on the amount and coarseness of plant detritus. The set included a No. 5 (4 mm) or No. 10 (2 mm) sieve combined with a No. 45 (355 µm) sieve. After removing seeds from the coarse sieve(s), we dried material remaining in the No. 45 sieve. We then used a second set of 3 sieves to separate large (retained by No. 35 [500 µm] or No. 20 [850 µm] sieves) and small seeds (retained by No. 45 sieve). We removed large seeds from the first 2 sieves and determined mass (to the nearest 0.1 mg) after drying for 48 hrs at 50°C. Then, we distributed material retained by the No. 45 sieve uniformly over a numbered grid of 100 equal sized cells and drew a random subsample of 25. We used a binocular microscope to remove small seeds from the selected cells. After determining dry mass of small seeds in the subsample, we multiplied by 4 to estimate the mass of small seeds in soil cores. We calculated total mass of seeds in soil cores as the sum of the masses of large and small seeds. After airdrying plant inflorescences, we held them over the 3 sieves used to separate large and small seeds, and threshed out the seeds they contained. After drying and weighing seeds from inflorescences, we added the mass of seeds in soil cores and the mass of seeds in inflorescences to create a response variable (in kg/ha) for estimating mean seed availability."

<u>Smith et al. (2004)</u>: "We determined seed production by clipping 25 0.5 × 0.5-m quadrats in monotypic stands of moistsoil species in each playa (Haukos and Smith 1993). We separated seed and vegetation of each species in the field and then dried it in the laboratory at 40°C to a constant mass. Weighed samples of each species were converted to kg/ha and multiplied by the estimated area of each species to estimate total production of each species in each playa. We then transformed seed biomass data to duck-use days (DUD) (Reinecke et al. 1989, Haukos and Smith 1993) as an index of carrying capacity for each playa."

Comments and recommendations. Samples should be taken at vegetation plots, using the plot sampling design of EPA (2011). Ideally, collections should occur monthly May through September. Clippings from 0.5 × 0.5-m quadrats should be processed according to Smith et al. (2004), above, in situations where the seeds are uncontaminated by other materials. If the seeds need to be rinsed, the methods of Reinecke and Hartke (2005) should be used.

Submergents

Level 1. Not applicable.

Level 2.
Riffell et al. (2001) and Isola et al. (2000) recorded presence or absence within 1 × 1 m sampling frames. Heitmeyer (1986) recorded presence and taxonomy of submergent plants (*Ceratophyllum*, *Chara*, *Lemna*. *Najas*, and *Potamogeton*). Hornung and Foote (2006) measured the height of submergents. Capers (2003) counted rooted stems and identified species, and Monda and Ratti (1988) identified species within 1 × 1 m floating sampling frames.

Level 3. Not applicable.

Comments and recommendations. Information on presence or absence of submergent vegetation, along with identification, if present, should be taken at vegetation plots, using the plot sampling design of EPA (2011). Ideally, collections should occur monthly May through September.

Tubers

Levels 1 and 2. Not applicable.

Level 3.

Brasher et al. (2007): "We estimated tuber biomass by excavating soil in plots to a depth of 10 cm, but we sampled for tubers only in wetlands where we observed the growth of tuber-producing species (Table 1). We rinsed excavated soil through sieves (mesh sizes 5 [4.0 mm] and 18 [1.0 mm]) to expose and facilitate removal of tubers. We collected by hand all submerged aquatic vegetation in the water column of our plot when located in standing water. We sorted submerged aquatic vegetation to identify and retain only plant parts and species valued as food resources for ducks (Table 1). We dried seeds, tubers, and submerged aquatic vegetation to constant mass at 50° C and weighed to nearest 0.01 g."

Taylor and Smith (2005): "We sampled belowground rhizome and tuber mass along 4 permanent transects, which were randomly established on each field perpendicular to feeder canals and irrigation flow direction. Along these transects we randomly established 10 permanent paired sampling locations consisting of a 0.5-m circular exclosure (unconsumed mass) and an adjacent sampling site without an exclosure (consumed mass). After the flooding sequence was completed for each block each year, we took a 15 × 15 × 15-cm soil sample (Gutman and Watson 1980) from within the exclosure and a paired adjacent open sampling location. We washed tubers and rhizomes free of soil, separated them by species, oven-dried them to constant mass, and weighed them to the nearest 0.1 g. We termed the difference between the amount of food in the exclosure and open sample as use (i.e., consumption)."

Comments and recommendations. Samples should be taken at vegetation plots, using the plot sampling design of EPA (2011). Ideally, collections should occur monthly May through

September. Tubers should be excavated, using 15 × 15 × 15-cm soil samples (Taylor and Smith 2005). The tubers should be rinsed of soil, dried at 50° C, and weighed to the nearest 0.01 g. Tubers should be sorted from soil samples taken.

Appendix V. Recommended common management practices for changing or maintaining habitat conditions. From Gammonley et al. 2012.

Disking: It is the most intense disturbance of wetland vegetation used in managing wetlands. Disking destroys both the erect stems as well as breakup the extensive rhizome system that keeps plants alive during dry conditions. The USFWS observations show that mallards, northern pintails, white fronted geese, and Canada geese choose "managed wetlands where significant amounts of vegetation remain. Snow geese select wetlands (including disked areas) where the majority of the site is open water. http://www.fws.gov/rainwater

Excavation: The processes of removing and altering the landscape for the purpose of creating or restoring a site for wetland use. Excavation usually includes three processes. Excavation of soil and vegetation, removal and transport of unwanted materials, and deposition of these materials. When excavating in a wetland, care should be taken to minimize use of heavy machinery. Whenever possible, place heavy equipment on stabilization mats to reduce unwanted damage to the surrounding landscape. If at all possible, work when the ground is frozen and during low flow and low wind periods.

Haying: This management practice is used to manage vegetation types where ungulates refuse to graze (e.g. weed patches), or where prescribed burning is not practical (e.g. in close proximity to domestic structures). Results of haying may include, killing invasive tree seedlings, and creating firebreaks for future prescribed burns. Haying is generally delayed until after mid-July to reduce depredation of nests and nesting birds. http://www.fws.gov/rainwater

High Diversity seeding/planting: The term "high diversity seeding" includes harvesting, processing and sowing large numbers of native species in an attempt to return the plant community as close as possible to its pre-cultivation condition. Their objective is to manage uplands for warm season, grass-dominated plant communities with a diverse mix of other cool- and warm-season grasses, sedges, rushes, and broadleaf forbs. This process can be used where wet meadow plant communities are lacking in wetlands that would benefit from seeding of sedges, rushes, and wetland grasses. http://www.fws.gov/rainwater/management/reseeding.htm

Hydrologic Manipulation: Hydrologic processes that are artificially implemented to improve wetland functions. Water level manipulation may be used to increase or decrease salinity; stimulate germination and growth of moist-soil plants; decrease turbidity; increase production of invertebrates; recycle nutrients; alter the density of vegetation; control disease; and increase viable resources for target species (e.g. migratory birds). Hydrologic control can be achieved by the use of weirs (solid structures that maintain a minimum water level), dikes (impoundments), control gates, and pumps. The USFWS recommends using a cover: water ratio of about 50:50 across the entire wetland. (WPIF, date unknown).

Mechanical Control of Woody Vegetation: The means of cutting, sawing, clipping, mowing and uprooting of woody vegetation. The hand tools most commonly used for this technique are the mattock, heavy hoe and grubber. Mulching machines or tractor-mounted mowers and brush-hogs may also be used for spot cutting on larger vegetation such as willow and tamarisk.

Mowing: This management technique can be useful on small scale wetlands or artificially created wetlands (e.g. reservoirs surrounded by extensive marshes) during the winter months. At this time, water levels are typically at their lowest levels, yielding thick layers of ice. Robust emergent vegetation (e.g. cattails) can be clipped just above the ice so that spring flooding restricts the oxygen supply to the root zone. As a result, many of the plants do not resprout, allowing other emergent species to thrive (WPIF, date unknown).

Prescribed Burning: Prescribed burning in wetlands can be used to remove old vegetation; create open water areas; expose the soil profile for new germination; release nutrients that are bound in dead vegetation; remove exotic plant species; and create a mosaic of vegetation types. http://www.fws.gov/rainwater

Spraying/Chemical Treatment: The purpose is to remove undesirable plants, e.g., cattails monocultures, and invasive weeds.

Tree Removal: This management technique is primarily use on prairie wetlands (e.g. Rainwater Basin of Nebraska). In doing so, the USFWS uses tree removal around wetlands to increase the amount of upland grasslands. The North American Breeding Bird Survey reports that 70% of the 29 species characteristic of North American prairies has experienced a decline in population. A portion of that decline is attributed to the small area of remaining grassland parcels and the increasing number of trees found within the grasslands. http://www.fws.gov/rainwater

Ungulate Grazing: The purpose for grazing wetlands for [wildlife is]…to economically manage the type and abundance of plants. The USFWS strives for habitat which has abundant wetland plant seed, aquatic invertebrate substrate, and at least 50% open water when flooded one foot deep. http://fws.gov/rainwater/management/grazing.htm

Appendix VI. Conditions of habitat variables that promote positive responses by CPW priority species.

Species	Qualifiers	Value: High	Medium	Low
Absence of predatory fish and/or bullfrogs				
Frogs	Breeding wetlands	Predatory fish and/or bullfrogs absent	Very few predatory fish and/or bullfrogs	Predatory fish and/or bullfrogs abundant
Fish		Absence	Present in very low numbers	Present
Dominant vegetation				
Ducks	General type	Grasses, sedges, rushes submergents, and other seed-producing plants	Herbaceous plants that provide little to no food resources for ducks	Willows and other woody shrubs
Ducks	Structure	Soft and easy to move through	Courser, more rigid, and dense	Woody or stiff and dense
Bittern		Cattails/Bulrush/Sedges/ Reed grasses/Bur-reeds	Other tall/medium emergents	Short (e.g., sedges) or no emergents
Crane	Feeding	Grasses, sedges, crops (particularly corn stubble)		Dense woody vegetation
Plover		Sparse grasses clumps preferred	Denser grasses	Woody vegetation
Curlew	Playas	Sparse, short, soft		Dense, tall, woody
Curlew	Wet meadows	Open, short grasses		Trees/high grass
Owl		Grasses	Fields with woody vegetation	Trees (but will occasionally roost in trees)
Frogs	Breeding wetlands	Sedges, rushes, cattails		Dense woody vegetation
Frogs	Adult foraging	Grasses and sedges		Dense woody vegetation
Snake		Emergents-sedges-grasses-anything that provides cover		Dense woody vegetation
Fish		Algae, algal mats, submergents/emergents		
Dominant vegetation height				
Bittern		1-2 m	0.5- < 1 m	< 0.5 m
Crane	Feeding	< 0.5 m	.05-1 m	1-2 m
Curlew		Short (< 50 cm)	Medium (50–100 cm)	Tall (1-5 m)
Owl		30–60 cm		> 60 cm

Appendix VI, continued.

Species	Qualifiers	Value: High	Medium	Low
Dominant vegetation height				
Frogs	Breeding wetlands	< 1 m	1-2 m	> 2 m
Frogs	Adult foraging	15–50 cm	51–100 cm	> 1 m
% emergent/vegetation cover				
Ducks	Diurnal	21–50%	5–20%	< 5% or > 50%
Ducks	Nocturnal	61–80%	21–60%	10-20%
Ducks	Reservoirs/gravel pits	> 5%	1–5%	0%
Bittern		61–80%	31–60% or 81-100%	15–30%
Crane	Roosting	0–20%	21–40%	> 40%
Plover		0–5%	6–10%	11-20%
Curlew	Playas	0-33%	34-50%	50-70%
Owl		Close to 100%		
Frogs	Breeding wetlands	51–90%	31-50%	10-30%
Frogs	Adult foraging (herbaceous)	30–90%		25-30% or 91-100%
Garter snake		61-100%	41-60%	20-40%
Interspersion (see diagram)				
Ducks	Diurnal	C or D	B	A or E
Ducks	Nocturnal	C or D		A or B or E
Bittern		B or C or D		A or E
Crane	Roosting	A	B or C	D or E
Landscape context				
Ducks	% water within 8 km	> 2%	1-2%	< 1%
Ducks	Distance to agricultural fields, especially corn	< 8 km	8-16 km	> 16 km
Ducks	Distance to roosts (Known locations)	< 8 km	8-16 km	> 16 km
Bittern	Distance to pollution or urban area	> 200 m	150-200 m	< 150 m

Appendix VI, continued.

Species	Qualifiers	Value High	Medium	Low
Landscape context				
Crane	% water within 8 km	> 2%	1-2%	< 1%
Plover		Along river with natural flow regimes and ungrazed		Sites away from river (less successful)
Curlew	% water within 8 km	> 2%	1-2%	< 1%
Curlew	% irrigated hay pastures within 8 km	35-70%		< 35%
Curlew	% grassland within 8 km	35-70%		< 35%
Owl	% grassland within 8 km	35-70%		< 35%
Owl		Juxtaposition of large grasslands and wetlands; ungrazed		
Frogs		All 3 habitat types within 1–2 km; space between habitat with herbaceous vegetation < 1 m; free from contaminants	All 3 habitat types within 5 km; space between partially unvegetated or with vegetation < 1 m; trace contaminants	All 3 habitat types > 5 km; space between unvegetated or with vegetation < 1 m; contaminated
Frogs	% water within 8 km	> 2%	1-2%	< 1%
Snake		Close connection between upland hibernacula and wetlands		Landscape fragmented by unsuitable habitat
Fish		Pools connected to other habitats		
Otter		Near beaver activity & connected with tributaries		Disconnected without beavers
% open sand or gravel area				
Plover		Near 100% open		Less than open
Proximity to large object, e.g., rocks, logs				
Plover	Near nests	Close	More distant	Far
Curlew	Near nests	Close	More distant	Far

Appendix VI, continued.

Species	Qualifiers	Value High	Medium	Low
% Residual cover				
Bittern		41–60%	21–40% or 61-100%	10–20%
Owl	For nesting	41-60%	21-40%	10-20%
Riparian vegetation				
Otter	% Total canopy cover > 2 m	51-100%	31-50%	20-30%
Otter	Height of canopy cover > 2 m	> 15 m	5-15 m	0.5-5 m
Shore complexity				
Otter		Diverse and complex; undercut banks		
Size of habitat				
Ducks	Size of wetland: Beaver ponds,, emergent marshes, playas moist soil unit, recharge ponds	> .8 ha	.2–.8 ha	< .2 ha
Ducks	Size of wetland: reservoirs, wet meadows/riparian wetlands	> 8 ha	4–8 ha	< 4 ha
Bittern	Size of wetland	>10 ha	5–10 ha	1-5 ha
Crane roosting	Size of wetland	50–150 m from shore OR >1 ha	26–50 m from shore OR 1 ha	15-25 m from shore OR < 1 ha
Plover		The bigger the better; > 20 m wide	15–20 m wide	< 15 m wide
Curlew	Size of habitat	> 20 ha	5–20 ha	3-5 ha
Owl	Size of habitat	> 100 ha	50–100 ha	25-50 ha
Frogs	Breeding wetlands	30–60 m diameter		
Frogs	Adult foraging	Not well known		

Appendix VI, continued.

Species	Qualifiers	Value High	Medium	Low
Size of habitat				
Frogs	Wintering	Large and deep enough that water does not freeze solid		
Snake		Larger is better		
Fish		25–1,000 m^2		
Stream order				
Ducks		5^{th} or 6^{th} order	3^{rd} or 4^{th} order	1^{st} or 2^{nd} order
Otter		> 4th or lower gradients		< 4th order
Stream size				
Otter		Longer is better Wide		narrow
Structures and debris				
Otter		Log jams and/or beaver activity		
% Submergent vegetation				
Ducks		31-60%	11-30%	0-10%
Substrate				
Fish		Sand for dace Gravel for minnow		
Sunlight exposure (measured as % Total canopy cover > 2m)				
Frogs	Breeding wetlands	0-30%	31-50%	51-100%
Water depth (cm)				
Ducks		10-30 cm	31–60 cm	> 60 cm
Bittern		5-20	21-100	<5 or 100-120
Crane	Roosting	5–20 cm	20–40 cm	> 40 cm or dry
Crane	Feeding	Usually dry or shallow hummocks		
Plover		dry		
Curlew	Playas	0–16 cm	17-18 cm	> 19 cm
Curlew	Wet meadows	0 or hummocks		
Owl		0 cm	1-2 cm	3-20 cm

Appendix VI, continued.

Species	Qualifiers	Value: High	Medium	Low
Water depth (cm)				
Frogs	Breeding wetlands	66–100 cm	1-2 m	10-65 cm
Frogs	Adult foraging	0-10 cm	11-20 cm	21-30 cm
Frogs	Wintering	> 100 cm		90-100 cm
Fish		51-150 cm	41-50 cm	
Otter		deeper better		Shallow
	% water > 20 cm	91-100%	81-90%	40-80%
Water quality				
Frogs		pH = 6.1-7 No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Acidic or contaminated with herbicides, pesticides, N loading Cloudy or sheen of oil
Snake		pH = 6.1-7 No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Acidic or contaminated with herbicides, pesticides, N loading Cloudy or sheen of oil
Fish		Clear, cool, slow moving No visual evidence of turbidity or other pollutants	Turbidity and/or pollutants limited to small area	Cloudy or sheen of oil

APPENDIX B: CNHP WETLAND MAPPING PROCEDURES

COLORADO NATURAL HERITAGE PROGRAM WETLAND MAPPING PROCEDURES

Prepared by:

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Version Date: March 29, 2013

Scope of Document

This document was prepared by the Colorado Natural Heritage Program (CNHP), a research unit of the Warner College of Natural Resources and Colorado State University. It describes procedures used by CNHP to map wetlands in Colorado. All wetland mapping conducted by CNHP is in collaboration with the U.S. Fish and Wildlife Service (USFWS)'s National Wetlands Inventory (NWI) Program and follows the Federal Geographic Data Committee (FGDC)'s most recent standards for wetland mapping (FGDC 2009).

There are two primary types of wetland mapping carried out by CNHP:

1) Conversion of original NWI paper maps to digital polygonal data. The original NWI paper maps were produced in the 1970s and 1980s and are currently available as either hard copy paper maps or scanned images, but are not available as digital polygonal data. CNHP works in partnership with the NWI program to convert these hard copy maps to geo-referenced digital polygonal data. Polygons and attributes are not updated or corrected in this process, except in cases where the original attribute is now considered an invalid code. When converting original NWI mapping, CNHP is responsible for the accurate representation of the original mapping in a digital form, but not for the accuracy of how well the data represent wetlands on the ground.

2) Creation of new, updated digital NWI maps delineated in ArcGIS and based on the most recent aerial photography available. When delineating newly updated NWI maps, CNHP is responsible for all aspects of accuracy and precision.

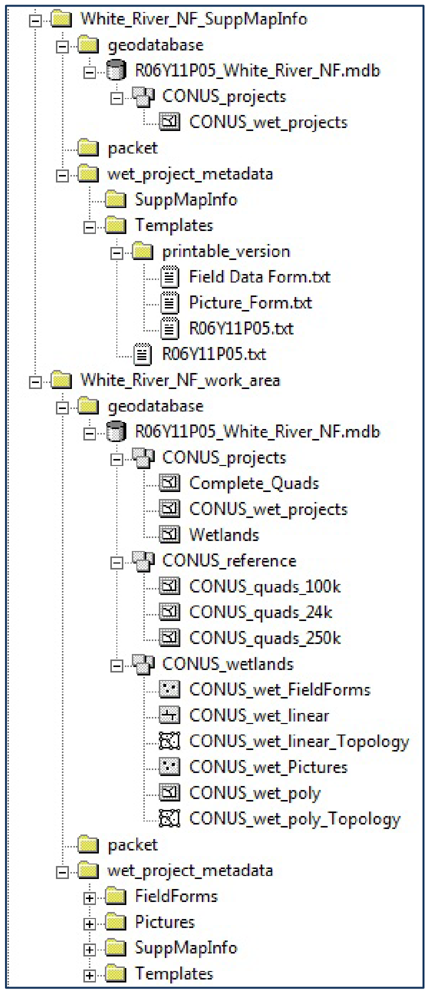
This document is primarily intended as an internal communication tool for CNHP's Wetland Mapping Specialists. Certain sections, therefore, may lack background information of interest to external readers. More information is available upon request.

Funding for CNHP's wetland mapping projects has come from a variety of partners, including U.S. Environmental Protection Agency (EPA), U.S. Forest Service (USFS), Bureau of Land Management (BLM), and National Academy of Science (NAS)'s Transportation Research Board (TRB). Non-Federal matching support has come from Colorado Parks and Wildlife (CPW), Great Outdoor Colorado (GOCO), Colorado Department of Transportation (CDOT), and Colorado Water Conservation Board (CWCB).

Table of Contents

A. Project Check-out/Prep Work

1. ***Checkout Project Area from NWI:*** Choose the quads in the project area. Merge and dissolve into a single polygon shape. Submit to Regional NWI Coordinator Kevin Bon (Kevin_Bon@fws.gov). Kevin will reply with a "Checkout Packet" which will include documentation, a database with the checkout area, any existing wetland shapes and supplemental layers. Below is a view of the file structure in ArcCatalog.



2. ***Identifying Priorities/Intermediate Deadlines:*** These must be known early in the planning stages before mapping begins. Once the project area is divided into sets (see below) it can be very confusing to split sets or complete single quads for an intermediate data request. If priority areas or intermediate deadline exist (i.e., if the sponsor requests a certain set of the data before the entire project is complete) these should be flagged and the project area should be divided accordingly.

3. ***Aerial Imagery for New Mapping Updates:*** New mapping updates will be based on the most current digital aerial photography available. In most cases, this imagery will be obtained from the USDA Farm Service Agency, Aerial Photography Field Office in Salt Lake

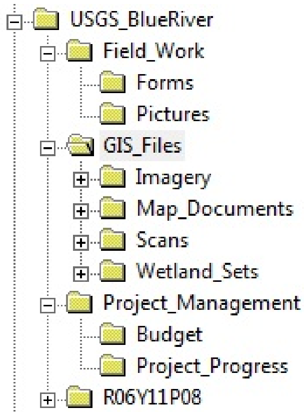
City, Utah (http://www.apfo.usda.gov). In special circumstances, imagery may be provided by a project sponsor for a specific project area. The imagery used must be color infra-red (CIR) and must meet all requirements stated in the FGDC standard for wetland mapping (FGDC 2009). The minimum imagery needed to perform new mapping updates is CIR imagery for the year the wetland mapping is being updated to, and CIR imagery for one other year. Two or more additional years is preferable, as having multiple years available (such as a drought year and wet year) supports more accurate water regime determination.

4. ***Tracking Project Progress:*** Progress on each mapping project is tracked in an Excel spreadsheet. Several template versions are located on the CNHP Server at P:\Wetland_Mapping\SupportFiles\Project_Progress_Templates. Three types exist: 1) Double_Scan_Quads, 2) Single_Scan_Quads and 3) New_Mapping_Updates. Slightly different intermediate steps warrant multiple versions. Projects with quads in more than one of these statuses should have the quads broken up and worked on separately and progress recorded in each respective spreadsheet. An additional, Full_Project_Progress spreadsheet should be created to track overall progress.

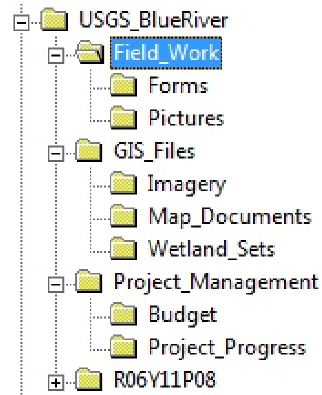
5. ***Dividing Project Area:*** It is usually not feasible to work continuously on a single feature class for a project area; therefore, the quads within the project area are divided into "sets".
    a. When converting original NWI maps to digital polygons, blocks can be made up of four quads in a 2x2 square. A 4x1 linear set can also be created. There is no difference between the two and often the overall project area will determine the correct set structure. Working with more than 4 quads can be very cumbersome and more densely populated quads may want to be divided into smaller sets.
    b. When delineating new wetland features, quads should be dealt with singularly.

6. ***Naming Conventions/File Structure:*** The standard file structure below shows an Old-Digital Conversion project and a New Mapping Update project. The only difference between these two structures is the addition of a "GIS_Files/Scans" folder to hold rasters of NWI maps, if available.

Old-Digital Conversion



New Mapping Update



Daily work should be complete on a local drive (C:\temp) and copied back to the proper location on the P:\ drive at the end of the day. Additional daily or AT LEAST weekly backups should be completed to a third (external) drive. Backup files should be named explicitly with a date (e.g., “Backup\USGS_BlueRiver\7_17_2011”). Naming conventions for the wetland files produced during the procedure:

“ProjectCode”_Set_”#”_wetlands_pre_attribution.shp (after Step 3)
“ProjectCode”_Set_”#”_wetlands_post_attribution.shp
“ProjectCode”_Set_”#”_wetlands_qaqced.shp (ready to be merged)
“Project”_merged_wetlands (post merging)
“Project”_checked_wetlands (after topology and script run)

“ “ are values that change with the set or project.

B. Overview of CNHP ArcGIS Method for Digital Conversion

CNHP uses the ArcScan extension for ArcGIS 10.x to convert rasters (scanned data) into digital vector data. The steps below represent the conceptual process taken to convert raster NWI data into vector data. More detail on each step is spelled out in the following section.

1. Project rasters into NAD83: Albers projection. Extract the data within each individual quad and mosaic 4 to 6 quads worth of data into a set.
2. Use the ArcScan extension to generate vector lines on all the visible lines on the mosaicked raster.
3. Inspect lines that represent linear features (rivers and streams) and merge line segments into complete continuous lines that accurately represent linear wetland features.
4. Attribute the linear features with their NWI wetland code, and populate a field with buffer distance values that correspond to the desired width of linear features.
5. Convert all enclosed features into polygons.
6. Buffer the linear features using the values in the Buffer Distance field.
7. Copy the buffered lines into the feature class created in step 5.
8. Attribute all features with NWI wetland codes.
9. Run topology and QAQC tests as described in Section F and make necessary changes.

C. Work Flow for Digital Conversion of Original NWI Mapping, using ArcScan extension

1. Copy the GDB "Wetlands_Domain.gdb" from P:\Wetland_Mapping > SupportFiles into the appropriate set folder.

2. Load quad TIFFs for the defined set to your map document.

3. For each TIFF:

   - Project in Albers (Data Management Tools > Projections and Transformations > Raster > Project Raster) with the output landing in the geodatabase in the set folder mentioned in step 1.

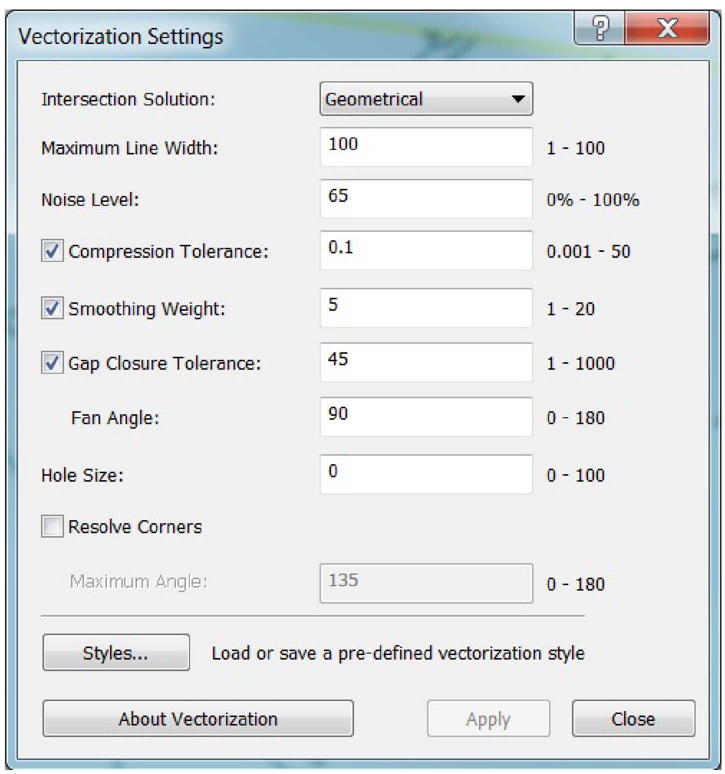
   - Extract each Tiff individually by highlight the quad boundary and extracting by mask (Spatial Analyst Tools > Extraction > Extract by mask).

4. Mosaic rasters together (Data Management > Raster > Raster Dataset > Mosaic to New Raster). Output location should be the GDB in the set folder. Number of bands = 1.

5. Add the 'Lines' blank linear feature class from the GDB to the map.

6. Start an editing session on the linear feature class created in the previous step.

7. Enter the following "vectorization settings" In the ArcScan toolbar drop down menu:



8. Select "Generate Features" under the Vectorization dropdown. Uncheck the box that says "Generate polygons where the maximum line width setting is exceeded." Make sure the mosaic raster is in the ArcScan Raster selection.

9. Examine all linear features to ensure they are smooth and continuous. Manually draw or correct any linears missed or misrepresented during automated processing and merge necessary segments. Once a linear is merged and correct, enter the corresponding code into the "Attribute" attribute field.

10. Close any open polygon lines within the feature class or along the edges.

11. Once you are confident the feature line work is correct, use it to create polygons (Data Management > Features > FeaturetoPolygon). Save the feature class as "ProjectCode_set_XX_pre_attribution" in the GDB.

12. Export all attributed linears to the GDB. Name the output "linears_for_buff_set_X".

13. Enter the correct buffer width for the following categories in the "Buff_Dist" field:
    - Palustrines = 3m (6m)
    - Riverine Perennial (R2/3) = 4m (8m)
    - Riverine Intermittent (R4) = 3m (6m)
    - Lacustrine = 4m (8m)

14. Buffer the "linears_for_buff_set_X" using the "Buffer_Width" field (Analysis > Proximity > Buffer). Name the output 'Linears_Buffered_set_X'.

15. Copy and paste 'linears_buffered_set_X' into the 'ProjectCode_set_XX_pre_attribution' feature class.

16. Add, merge, and correct all polygons.

17. After saving edits and closing your map document, copy your geodatabase to the appropriate folder in P:Wetland_Mapping and name it (ex. 'SRLCC_set_28_wetlands_pre_attribution')

18. In ArcCatalog, apply the domain "Attribute" to the "ProjectCode_set_XX_pre_attribution" feature class. If you notice any common attributes that exist in the current set but are not included in the attribute domain, add those values to the domain.

19. Attribute polygons.

20. QAQC data as outlined in Section F.

D. Process for Attributing Digitally Converted Data

CNHP often uses the help of student work studies, interns and volunteers to attribute the digitally converted original NWI data. The following steps should be taken to ensure correct attribution.

1. Navigate the map document (.mxd) that has been prepared for you and open it. In the table of contents, locate the shapefile you will be editing. It will be named something similar to: "SP_set_32_pre_attribution.shp"

2. Check to make sure the attribution table of this item is ready to edited. Depending on the project you are working on, you will need either a field named Attribute (text, 20 characters) or Old_Code (text, 20 characters). If the field you need is not in the shapefile's table, you can add it by clicking "Adding Field" in the table window's dropdown list.

3. Click on the editor toolbar dropdown list and choose "Start Editing." The next dialog box prompts you to indicate which layer you will be editing, choose the shapefile identified in step 1. If the editor toolbar is not already displayed in your ArcMap, you can add it using Customize > Toolbars > Editor.

4. Check to be sure that snapping is turned on for the layer you are editing. (Editor > Snapping > Snapping window). You may need to check the "use old style snapping" in the editor options if the snapping window is not an available choice.

5. Make sure your display properties are set up to make editing easy. You want the field you are editing to be the displayed label field, and layer visibility should be at about 35% transparency so you can see the raster layer underneath the shapefile you are editing. For symbology I usually go with "Lake" colored because the outline provides nice contrast.

6. Start filling in the "Attribute" (or Old_Code) field. You can type this into the table directly, or open the attributing window by clicking "Attribute" on the editor toolbar. You can use the wetland code handout to understand what the codes mean. All codes are letters, with the exception that riverine and lacustrine systems have a number after their first letter (ie R4SBC).

7. An important rule of wetland mapping is that **no two features with the same attribute can touch each other**. Sometimes a single feature will be incorrectly split by the automated processes that we use to create them – in that case the appropriate solution is to merge the pieces. I set my merge function to Insert as a hotkey, but it can be set to any key, or choosen from the editor dropdown menu. Sometimes the solution to this problem is not so simple – perhaps a linear feature splits a polygon, but that linear feature was overlooked.

   **When in doubt, just attribute a polygon with "??" so it can be reviewed later.

8. Reshape polygons that do not accurately represent the shape on the CONUS scan vectors.

9. When done attributing a shapefile, save edits and stop editing. Save and close the map document, and let me know that set is done.

D. Work Flow for New Mapping Updates

1. Prepare ¼ quad images with mosaic method of choice.

2. Create a line shapefile to add features to.

3. Map smaller streams, channel, canals and linear features, then buffer to the appropriate amount.

4. Create a polygon shapefile to add features to.

5. Begin mapping large water bodies and rivers.

6. Attribute NWI wetland codes (Cowardin et al., 1979) as you go, keeping the following in mind:

    - Map to the image, not historic or predicted.
    - Be conscious of mowing changing the intensity of vegetation signatures.
    - Be conscious of haying changing the texture and color.
    - “Farmed” modifier describes tiled agriculture, not pastureland or mowed areas.

7. Use the Montana Natural Heritage Program’s method of applying LLWW descriptors in a semi-automated fashion to areas of 8-12 quads at a time. The application of LLWW descriptors will be done in a manner consistent with Ralph Tiner’s 2003 Dichotomous Keys and *Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors* (Tiner, 2003).

8. Once finished, save as quad name, copy to the project folder on P: and turn over to other mapper for QAQC’ing.

9. Important things to keep in mind:

    - Examine the wetlands for consistent alignment with features on the imagery.
    - Examine for correct System/Subsystem (mostly lakes and rivers).
    - Examine for correct Class (look for shadows denoting trees and shrubs, look carefully at smaller ponds for aquatic vegetation, and larger lakes for rings of aquatic vegetation).
    - Examine for correct Water Regime (use several dates if possible) compare with reference sites of field visits.
    - Examine for correct Modifiers (only put modifier if confident).
    - Look at large riparian systems carefully for matrix and isolated wetland pockets.

E. Riparian Classification Information Sheet

Riparian Features – Riparian features are mapped at the same time as wetland features. The USFWS defines riparian features as "contiguous to and affected by… lotic and lentic water bodies (rivers, streams, lakes or drainage ways)". The have either distinctly different vegetation (species) or significantly more robust growth. These areas are transitional between uplands and wetlands and can be considered to have a less predictable flooding regime and is often drier than an "A" water regime from NWI.

It is important to consider subsurface flow as well. Sandy washes, wooded draws, etc are affected by collection of water during storm events and/or water tables closer to the surface.

Residential areas can be trickier, as runoff from lawn watering, impervious surfaces, etc often elevate water tables in these areas. Look at the type of tree and proximity to water feature. Golf courses contain many trees and well watered vegetation but are not likely Rp.

Coding: Class is defined by the tallest life form that composes at least 30% of the area. No modifiers are applied to the riparian code. Tilled fields, even those close to rivers and streams are not mapped as riparian.

System	**Rp** (Riparian)		
SubSystem	**1** (lotic-flowing)	**2** (lentic – standing)	
Class	**EM** (emergent)	**SS** (scrub-shrub)	**FO** (forested)

Examples: Rp1FO, Rp1SS, Rp2FO

Common settings: *Rp1SS* – shrubby draw or drainage, often interrupted with drier herbaceous patches or by locations of incision. Shrubs can be dense or not. Often very narrow and linear in appearance. These will often be mapped as a linear feature then buffered out to the appropriate width.

Rp1EM – often along larger R4's with terraces. Often the same type of vegetation as the surround area, but much more robust. Channel scars and swales will usually be and NWI wetland code PEMA or PEMC, so one needs to look broadly.

Rp1EM/Rp1FO – matrix of herb/tree pockets in a larger floodplain. Look closely at denser pockets and the overall % cover to decide a class. Must choose one, DO NOT USE MIXED CODE.

Rp2FO – a ring of trees along a lake with a waterlevel that appears to fluctuate. Look closely at the understory (if visible) to determine if it's really Rp or NWI code PFOA.

F. QA/QC Procedures

CNHP uses the Wetland Data Verification Toolset developed by the U.S. Fish and Wildlife Service National Wetlands Inventory. The tool and its supporting document is available at: http://www.fws.gov/wetlands/Data/Tools-Forms.html

This toolset contains an ArcGIS 10 toolbox with 6 QAQC tests, a geodatabase containing a complete list of all currently valid NWI wetland codes and a PDF set of instructions. All data must clear these tests (or have justifications provided for records that get flagged as errors but are in fact correct) to be accepted by the NWI.

F1. QAQC Work Flow for All Mapping Projects

1. **Run topology (rule: features must not overlap), correct all errors**

2. **Run the "NWI Wetlands Data Verification Toolset version 1206, database version 1110" tool in a custom toolbox:**
   http://www.fws.gov/wetlands/Data/tools/Wetlands-Data-Verification-Toolset-Installation-Instructions-and-User-Information.pdf

3. **QAQC Code description:** Shows up in the form "NNNNNN". "N" means no error.
   C – incorrect wetland code
   U – sliver uplands*
   A – adjacent polygons with same attribute, this test also catches multipart features
   S – sliver wetlands, less than 0.1 acres *
   L – L1 or L2 < 20 acres *
   P – PUB or PAB > 20 acres *
   O – overlapping polygons (topology should render this test moot)

   ** indicates this test is "optional" in the sense that there can be polygons that are correct but not slivers, there can be Lakes less than 20 acres, etc.*

4. **Visual Scan -** new mapping only, see following section F5 for procedure.

F2. Description of the Verification Tests

A brief description of each of the verification functions is provided below.

Code "C" - Incorrect Wetland Codes: This model identifies wetland polygons with incorrect wetland codes, or null or blank values in the 'attribute' field. Bad wetland code and wetland code synonym summary tables are created and stored with your wetlands file geodatabase. The model changes the first character of QAQC_Code = 'C' if the wetland code is bad.

Code "U" - Sliver Uplands: This model identifies upland islands or holes in wetlands that are less than 0.01 acres. These may be actual upland features but are identified as errors as they are typically errors in wetland delineation. The model changes the fourth character of QAQC_Code = 'U', in wetland polygons adjacent to the upland sliver.

Code "A" - Adjacent Wetlands: This model identifies wetland polygons that are adjacent to other wetland polygons with the same 'attribute' and changes the second character of QAQC_Code = 'A'. Adjacent wetlands with the same attribute are not allowed and need to be corrected. This test also highlights multi-part features, which need to be corrected.

Code "S" Sliver Wetlands: This model identifies wetland polygons less than 0.01 acres and changes the third character of QAQC_Code = 'S'. These wetland features exceed the minimum mapping standard for wetlands and should be reviewed. Actual wetland features flagged as sliver wetlands can be justified as correct in the comments field of the QAQC_Summary table.

Code "L" or" P" - Lake and Pond Size: This model identifies Lakes that are less than 20 acres in size and Ponds that are greater or equal to 20 acres in size. It changes the fifth character of QAQC_Code ='L' for small lakes or 'P' for large ponds. These may or may not be errors and can be justified based on water depth of the identified waterbody or small lake portions on the edge of the mapping project area. Comments can be added to the 'comments' field of the QAQC_Summary table for those wetland features flagged that are valid based on depth requirements outlined in the wetlands mapping standards.

Code "O" - Overlapping Wetlands: This model identifies overlapping wetland polygons and changes the sixth character of QAQC_Code = 'O'. The overlapping portions of these polygons are stored in your wetlands file geodatabase as an Overlapping_Polygons feature class to assist in locating these features. This model does not validate topology of the wetlands file geodatabase. The CONUS_wet_poly_Topology layer in your wetlands file geodatabase can be validated using the topology toolbar in ArcMap and also to view the errors. This model and the wet_poly_topology identify the same errors and either can be used. Overlapping wetland features are not allowed in the dataset.

F3. Code Updates

Some wetland codes were used in the original NWI maps that are no longer considered valid. These out of date codes are found on Colorado NWI maps uncommonly, but often enough that CNHP developed a standardized method for conversion. Codes can be checked for validity using the Wetland Code Interpreter available here: http://www.fws.gov/wetlands/Data/Wetland-Codes.html

The following rules have been used to update these out of date codes to valid codes:

Old Classes:

- OW = UB
- BB or FL = US

Old Water Regimes

- D = C
- W = A
- Y = B, C, or A (usually C)
- Z = G, H (P usually gets G, L usually gets H)

F4. QAQC Notes

Water Regimes Available for Each Class (red = default for P systems):

EM – Emergent	Water Regimes = A, B, C, F, G, H, or J
SS – Shrub/Scrub	Water Regimes = A, B, C, F, G, H, or J
FO – Forested	Water Regimes = A, B, C, F, G, H, or J
UB – Unconsolidated Bottom	Water Regimes = H, G, or F
AB – Aquatic Bed	Water Regimes = H, G, F or C
US – Unconsolidated Shore	Water Regimes = C, B, A or J

PAB/PUB and LAB/LUB: Ensure that only lakes and ponds with “apparent” aquatic vegetation are labeled as PAB. Be aware that flooded shrubs can look like aquatic vegetation. Be sure to examine both 2005 and 2009 images.

PEMC/PEMF: Can be confusing in that some PEMF (especially bulrush) can look pale. Examine 2005 true color image. PEMF’s are usually very dark.

Rp1SS/PSSA: PSSA needs to be wet and should be in proximity to other wet areas. Along streams Rp1SS is most common unless back channels, etc. suggest wetter conditions.

CANALS: Be aware of the 10m minimum distance. Larger canals can be labeled R4SB but smaller ones not. If a canal is shallow and significantly vegetated at a swath of 10m and appears to be significantly wet, it could be labeled as a PEM.

DONUTS: Be aware for areas where wetlands form inset, concentric circles to ensure that the inner polygon is “clipped” to remove that area from the larger polygon when analysis is completed.

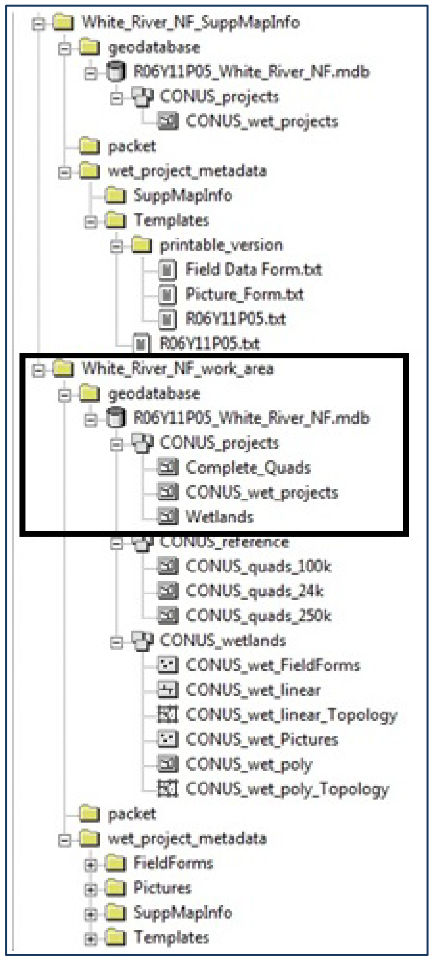
F5. QA/QC Procedures: Visual Inspection on New Mapping

Goal: 100% of features visually inspected by a wetland mapper who did not create the dataset.

1. Examine the wetlands for consistent alignment with features on the imagery.
2. Examine for correct System/Subsystem (mostly lakes and rivers).
3. Examine for correct Class (look for shadows denoting trees and shrubs, look carefully at smaller ponds for aquatic vegetation, and larger lakes for rings of aquatic vegetation).
4. Examine for correct Regime (use several dates if possible) compare with reference sites of field visits.
5. Examine for correct Modifiers (only put modifier if confident).
6. Look at large riparian systems carefully for matrix and isolated wetland pockets.

G. Project Check-in/Data Storage

1. ***Check in Project Area to NWI*** – Import the files properly into the geodatabase provided in the materials originally received from the NWI. The created data should be submitted in the part of the file structure indicated below by the black box. "Complete_Quads" indicates the actually area that was mapped as a feature class of the quads. "Wetlands" is the feature class that contains the attributed wetland polygons. A third feature class could be added for New Mapping Updates if riparian features were mapped. This would be called "Riparian" and be located in the same subfolder.



2. ***Internal CNHP Wetlands Database*** – For data sharing on relevant projects, an internal geodatabase of wetlands for the State of Colorado will be maintained. After wetland mapping projects are delivered to the client and delivered to the NWI, they will be imported into the Colorado_Wetlands.gdb. The imported wetlands will need to be merged with the existing wetlands. If the imported data is an update, any existing wetland polygons should be clipped by quad boundary and exported with a logical file name. We do not want to delete older mapping, but it should not be included in the internally distributed layer. This dataset will be located at G:\Colorado\Wetlands. The date will be in the file or folder name

such that the most current data can be accessed. No more than 3 copies will exist at any given time in the folder, older copies will be deleted.

H. References

Tiner, R.W. 2003. Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors. U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Northeast Region, Hadley, MA. 44 pp.

Cowardin et al. 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Washington D.C.

APPENDIX C: LOWER SOUTH PLATTE WETLAND ASSESSMENT FIELD FORM

QC________

2013 LOWER SOUTH PLATTE WETLAND CONDITION ASSESSMENT FIELD FORM

LOCATION AND GENERAL INFORMATION

Point Code: ____________________ Site Name: ____ ☐ Level 2.5 OR ☐ Level 3

Date: _________________________ Surveyors: ____ ☐ Team A OR ☐ Team B

General Location: ____ County: ____________________________________

General Ownership: _____________________ Specific Ownership: ____

Directions to Point:

Access Comments (note permit requirement or difficulties accessing the site):

GPS COORDINATES OF TARGET POINT AND ASSESSMENT AREA (NAD 83 UTM Zone _______)

Original Point WP #: _______ Cowardin Code: ________ Target?: ___ Yes ___ No Relation to AA: ___Centered ___Included ___Outside

Dimensions of AA:	
____40 m radius circle	Elevation (m):
____Rectangle, width________ length:_________	Slope (deg):
____Freeform, describe and take a GPS Track	Aspect (deg):

AA-Center WP #: _________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): _____________
(Circle AAs Only)

AA-1 WP #: _________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): _____________

AA-2 WP #: _________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): _____________

AA-3 WP #: _________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): _____________

AA-4 WP #: _________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): _____________

AA-Track Track Name: ____ Area: ____

AA Placement and Dimensions Comments (if AA is moved from original point, note why):

PHOTOS OF ASSESSMENT AREA (Taken at four points on edge of AA looking in. Record WPs of each photo in table above.)

AA-1 Photo #: _____________ Aspect: _____________	Additional AA Photo Range:
AA-2 Photo #: _____________ Aspect: _____________	Comments:
AA-3 Photo #: _____________ Aspect: _____________	
AA-4 Photo #: _____________ Aspect: _____________	(Note range of photo numbers and explain particular photos of interest)

Point Code__________________ QC_________

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

Wetland vs. riparian / non-target inclusions

_________ % AA with true wetland

_________ % AA with non-wetland riparian area

_________ % AA with > 1m standing water

_________ % AA with upland inclusions

Wetland origin *(if known)*

____ Natural feature with minimal alteration

____ Natural feature, but altered or augmented by modification

____ Non-natural feature created by passive or active management

____ Unknown

Ecological System: (see manual for key and rules on inclusions and pick the *best match*) Fidelity: High Med Low

Cowardin Classification Fidelity: High Med Low

(see manual and pick *one each* of System, Class, Water Regime, and optional Modifier for dominant type)

HGM Class (pick *only one*) Fidelity: High Med Low

____Riverine* ____Lacustrine Fringe

____Depressional ____ Slope

____ Flats ____ Novel (Irrigation-Fed)

**Specific classification and metrics apply to the Riverine HGM Class*

RIVERINE SPECIFIC CLASSIFICATION OF THE ASSESSMENT AREA

Confined vs. Unconfined Valley Setting

______ Confined Valley Setting (valley width < 2x bankfull width)

______ Unconfined Valley Setting (valley width ≥ 2x bankfull width)

Stream Flow Duration

______ Perennial

______ Intermittent

______ Ephemeral

AA Proximity to Channel

______ AA includes the channel and both banks

______ AA is adjacent to or near the channel (< 50 m) and evaluation includes one or both banks

______ AA is > 50 m from the channel and banks were not evaluated

Stream Depth at Time of Survey (if evaluated)

______ Wadeable

______ Non-wadeable

MAJOR ZONES WITHIN THE ASSESSMENT AREA (See manual for rules and definitions. Mark each zone on the site sketch.)

Zone 1 Description _____________________________ Dom spp: ____ % of AA: ___________

Zone 2 Description _____________________________ Dom spp: ____ % of AA: ___________

Zone 3 Description _____________________________ Dom spp: ____ % of AA: ___________

Zone 4 Description _____________________________ Dom spp: ____ % of AA: ___________

Zone 5 Description _____________________________ Dom spp: ____ % of AA: ___________

ENVIRONMENTAL AND CLASSIFICATION COMMENTS

Classification Issues (important for sites with low fidelity to one or more classification systems):

AA REPRESENTATIVENESS

Is AA the entire wetland/riparian area? ___ Yes ___ No

If no, is AA representative of larger wetland/riparian area? ___ Yes ___ No

Provide comments:

ASSESSMENT AREA DRAWING

Add north arrow and approx. scale bar. Document **habitat features** and **biotic and abiotic zones** (particularly open water), inflows and outflows, and indicate direction of drainage. Include sketch of vegetation plot and soil pit placement. If appropriate, add a **cross-sectional diagram** and indicate slope of side.

ASSESSMENT AREA DESCRIPTION AND COMMENTS

Overall site description and details on site hydrology, soil, and vegetation.

Optional Note wildlife species observed:

LEVEL 3 VEGETATION AND SOIL DATA COLLECTION

VEGETATION PLOT

GPS COORDINATES AND PHOTOS OF VEGETATION PLOT (Taken at SE-most corner of each vegetation plot.)

Plot 1 WP #: __________ Photo #: _____________ Aspect: _____________

Plot 2 WP #: __________ Photo #: _____________ Aspect: _____________

Plot 3 WP #: __________ Photo #: _____________ Aspect: _____________

Plot 4 WP #: __________ Photo #: _____________ Aspect: _____________

Plot 5 WP #: __________ Photo #: _____________ Aspect: _____________

Additional Veg Plot Photo Range:

Comments:

(Note range of photo numbers and explain particular photos of interest)

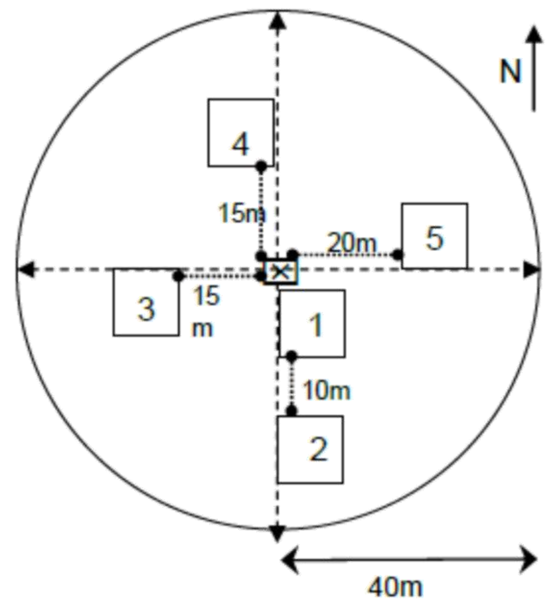
LAYOUT OF VEGETATION PLOT (See reference card for more details. Include vegetation plot on site sketch.)

____ Standard Layout (see figure to right)

____ Wide Polygon Layout (plots on two axes)

____ Narrow Polygon Layout (plots on one axis)

____ Wetland Boundary AA (plots distributed)



Plot Layout Comments (note which plot is treated as residual):

VEGETATION PLOT REPRESENTATIVENESS

Are veg plots representative of AA? ___ Yes ___ No

Provide comments:

Point Code__________________ QC_________

VEGETATION PLOT GROUND COVER AND VERTICAL STRATA					
Plot →					R
Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%					
Cover Class (unless otherwise noted) →	C	C	C	C	C
Ground Cover					
Cover of water (any depth, vegetated or not, standing or flowing)					
Predominant depth of water					
Min depth of water					
Max depth of water					
Cover of exposed bare ground* – soil / sand / sediment					
Cover of exposed bare ground* – gravel / cobble (~2–250 mm)					
Cover of exposed bare ground* – bedrock / rock / boulder (>250 mm)					
Cover of litter (all cover, <u>including under water or vegetation</u>)					
Depth of litter (cm) – average of four non-trampled locations where litter occurs					
Predominant litter type (C = coniferous, E = broadleaf evergreen, D = deciduous, S = sod/thatch, F = forb)					
Cover of standing dead trees (>5 cm diameter at breast height)					
Cover of standing dead shrubs or small trees (<5 cm diameter at breast height)					
Cover of downed coarse woody debris (fallen trees, rotting logs, >5 cm diameter)					
Cover of downed fine woody debris (<5 cm diameter)					
Cover bryophytes (all cover, <u>including under water, vegetation or litter cover</u>)					
Cover lichens (all cover, <u>including under water, vegetation or litter cover</u>)					
Cover algae (all cover, <u>including under water, vegetation or litter cover</u>)					
*Bare ground has no vegetation/litter/water cover, but may have some algae cover. The three categories of bare ground are mutually exclusive and should total ≤100%.					

Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%										
Height Classes 1: <0.5 m **2:** 0.5–1m **3:** 1–2 m **4:** 2–5 m **5:** 5–10 m **6:** 10–15 m **7:** 15–20 m **8:** 20–35 m **9:** 35–50 m **10:** >50 m										
Vertical Vegetation Strata (live or very recently dead) **Cover / Height →**	C	H	C	H	C	H	C	H	C	H
(T1) Dominant canopy trees (>5 m and > 30% cover)										
(T2) Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover										
(S1) Tall shrubs or older tree saplings (2–5 m)										
(S2) Short shrubs or young tree saplings (>2 m)										
(HT) Herbaceous total										
(H1) Graminoids (grass and grass-like plants)										
(H2) Forbs (all non-graminoids)										
(H3) Ferns and fern allies										
(AQ) Submergent or floating aquatics										

Point Code__________________ QC_________

Vegetation Plot Species Table: For four out of five plots, list all species within and overhanging the plot and estimate percent cover for the plot. For the fifth plot, list any *additional* species in the residual "R" column and estimate percent cover for the entire AA.

VEGETATION PLOT SPECIES TABLE												
Plot →											**R**	
Presence / Cover →			**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%												
Scientific Name or Pseudonym (If repeated/common pseudonym, mark with *)	**Coll #**	**Photos**										

VEGETATION PLOT SPECIES TABLE

Plot →											**R**	
Presence / Cover →			**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Classes 1: trace 2: <1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%												
Scientific Name or Pseudonym (If repeated/common pseudonym, mark with *)	**Coll #**	**Photos**										

Point Code__________________ QC_________

SOIL PROFILE DESCRIPTION – SOIL PIT 1 ☐ **Representative Pit?** **Photo #s _____________ GPS Waypoint ______________ (mark on site sketch)**

Depth to saturated soil (cm): ____________ Depth to free water (cm): ______________ ☐ Not observed, if so: ☐ Pit is filling slowly OR ☐ Pit appears dry Settling Time: ___________

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	Remarks

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

SOIL PROFILE DESCRIPTION – SOIL PIT 2 ☐ **Representative Pit?** **Photo #s _____________ GPS Waypoint ______________ (mark on site sketch)**

Depth to saturated soil (cm): ____________ Depth to free water (cm): ______________ ☐ Not observed, if so: ☐ Pit is filling slowly OR ☐ Pit appears dry Settling Time: ___________

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	Remarks

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

Point Code__________________ QC_________

SOIL PROFILE DESCRIPTION – SOIL PIT 3 ☐ **Representative Pit?** **Photo #s** _____________ **GPS Waypoint** ______________ **(mark on site sketch)**

Depth to saturated soil (cm): ____________ Depth to free water (cm): ______________ ☐ Not observed, if so: ☐ Pit is filling slowly OR ☐ Pit appears dry Settling Time: ___________

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	Remarks

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

WATER CHEMISTRY - PH, EC, AND TEMPERATE MEASUREMENTS

Take pH, EC, and water temperature recording at up to four locations within the AA and circle the appropriate characteristics. Take measurements within each habitat feature with open water. Take measurements in soil pits if in a fen. Take GPS Waypoints at each location.

	GPS WP#	Location	Depth (cm)	Surface OR Ground	Standing OR Flowing	Shallow OR Deep	Clear OR Turbid	Open OR Shade	pH	EC	Temp
Site 1				Surface / Ground	Standing / Flowing	Shallow / Deep	Clear / Turbid	Open / Shade			
Site 2				Surface / Ground	Standing / Flowing	Shallow / Deep	Clear / Turbid	Open / Shade			
Site 3				Surface / Ground	Standing / Flowing	Shallow / Deep	Clear / Turbid	Open / Shade			
Site 4				Surface / Ground	Standing / Flowing	Shallow / Deep	Clear / Turbid	Open / Shade			

Water chemistry measurement comments:

Point Code__________________ QC_________

LEVEL 2 ECOLOGICAL INTEGRITY ASSESSMENT FOR COLORADO WETLANDS

1. LANDSCAPE CONTEXT METRICS – Check the applicable box.

1a. LANDSCAPE FRAGMENTATION		
Select the statement that best describes the **landscape fragmentation** within a 500 m envelope surrounding the AA. To determine, identify the largest unfragmented block *that includes the AA* within the 500 m envelope and estimate its percent of the total envelope. Well-traveled dirt roads and major canals count as fragmentation, but hiking trails, hayfields, low fences and small ditches can be included in unfragmented blocks (see definitions).	Intact: AA embedded in >90–100% unfragmented landscape.	
	Variegated: AA embedded in >60–90% unfragmented landscape.	
	Fragmented: AA embedded in >20–60% unfragmented landscape.	
	Relictual: AA embedded in ≤20% unfragmented landscape.	

1b. RIPARIAN CORRIDOR CONTINUITY *(RIVERINE WETLANDS ONLY)*		
For riverine wetlands, select the statement that best describes the **riparian corridor continuity** within 500 m upstream and downstream of the AA. To determine, identify any non-buffer patches (see definitions) within the potential riparian corridor (natural geomorphic floodplain) both upstream and downstream of the AA. Estimate the percentage of the riparian corridor they occupy. *For AAs on one side of a very large river channel,* only consider the riparian corridor on the side of the channel the AA is located.	Intact: >95–100% natural habitat within the riparian corridor both upstream and downstream.	
	Variegated: >80–95% natural within the riparian corridor both upstream and downstream.	
	Fragmented: >50–80% natural habitat within the riparian corridor both upstream and downstream.	
	Relictual: ≤50% natural habitat within the riparian corridor both upstream and downstream.	

Landscape fragmentation and riparian corridor continuity comments:

1c. BUFFER EXTENT		
Select the statement that best describes the **extent of buffer land cover** surrounding the AA. To determine, estimate the percent of the AA surrounded by buffer land covers (see definitions). Each segment must be ≥ 5 m wide and extend along ≥ 10 m of the AA perimeter.	Buffer land covers surround 100% of the AA.	
	Buffer land covers surround >75–<100% of the AA.	
	Buffer land covers surround >50–75% of the AA.	
	Buffer land covers surround >25–50% of the AA.	
	Buffer land covers surround ≤25% of the AA.	

1d. BUFFER WIDTH

Select the statement that best describes the **buffer width**. To determine, estimate buffer width (up to 200 m from AA) along eight lines radiating out from the AA at the cardinal and ordinal directions (N, NE, E, SE, S, SW, W, NW).

1: _____________	5: _____________	Average buffer width is >200 m	
2: _____________	6: _____________	Average buffer width is >100–200 m	
3: _____________	7: _____________	Average buffer width is >50–100 m	
4: _____________	8: _____________	Average buffer width is >25–50 m	
Average width: ________________________		Average buffer width is ≤25 m OR no buffer exists	

1e. BUFFER CONDITION

Select the statement that best describes the **buffer condition**. Select one statement per column. Only consider the actual buffer measured in metrics 1c and 1d.

Abundant (≥95%) relative cover native vegetation and little or no (<5%) cover of non-native plants.		Intact soils, little or no trash or refuse, and no evidence of human visitation.	
Substantial (≥75–95%) relative cover of native vegetation and low (5–25%) cover of non-native plants.		Intact or moderately disrupted soils, moderate or lesser amounts of trash, OR minor intensity of human visitation or recreation.	
Moderate (≥50–75%) relative cover of native vegetation.		Moderate or extensive soil disruption, moderate or greater amounts of trash, OR moderate intensity of human use.	
Low (<50%) relative cover of native vegetation OR no buffer exists.		Barren ground and highly compacted or otherwise disrupted soils, moderate or greater amounts of trash, moderate or greater intensity of human use, OR no buffer exists.	

Buffer comments:

1f. NATURAL COVER WITHIN A 100 M ENVELOPE (SUPPLEMENTAL METRIC)

Using the table below, estimate the percent cover, in scope, of each **natural cover type within a 100 m envelope** of the AA. Natural cover includes both *native and non-native vegetation*. This measure applies to the entire 100 m envelope and not just buffer land covers. Estimate the total combined cover and wetland and upland cover separately. ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Natural Cover Type	*Total Scope*	*Upland Scope*	*Wetland Scope*
Total non-natural land use (development, roads, row crops, feed lots, etc.).			
Total natural cover (breakdown by type below; A-G = total natural).			
A. Deciduous forest			
B. Coniferous forest			
C. Mixed forest type (neither deciduous nor coniferous trees dominate)			
D. Shrubland			
E. Perennial herbaceous (includes hay fields and CRP lands)			
F. Annual herbaceous or disturbed bare (generally weedy)			
G. Naturally bare (open water, rock, snow/ice)			

Natural cover comments (and note the dominant species from above):

A.

B.

C.

D.

E.

F.

G.

LANDSCAPE STRESSORS

Using the table below, estimate the independent and cumulative percent of each **landscape stressor / land use within a 500 m envelope** of the AA. Stressors can overlap and do not need to total 100% (e.g., light grazing and moderate recreation can both be counted in the same portion of the envelope). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Landscape stressor/ Land use categories	*Scope*
Paved roads, parking lots, railroad tracks	
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)	
Domestic or commercially developed buildings	
Intensively managed golf courses, sports fields, urban parks, expansive lawns	
Gravel pit operation, open pit mining, strip mining	
Mining (other than gravel, open pit, and strip mining), abandoned mines	
Resource extraction (oil and gas wells and surrounding footprint)	
Dam sites and flood disturbed shorelines around water storage reservoirs	
Water storage reservoirs – the open water portion	
Reclaimed gravel ponds – often open water (may be difficult to distinguish from reservoirs, but located in floodplains)	
Agriculture – tilled crop production	
Agriculture – permanent crop (hay pasture, vineyard, orchard, tree plantation)	
Vegetation conversion (chaining, cabling, rotochopping, or clear-cutting of woody veg)	
Logging or tree removal with 50-75% of trees removed	
Selective logging or tree removal with <50% of trees removed	
Heavy grazing/browse by livestock or native ungulates	
Moderate grazing/browse by livestock or native ungulates	
Light grazing/browse by livestock or native ungulates	
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	
Moderate recreation or human visitation (high-use trail)	
Light recreation or human visitation (low-use trail)	
Recent old fields and other fallow lands dominated by *non-native* species (weeds or hay)	
CRP lands (grasslands planted with a mix of *native* and *non-native* species)	
Haying of *native* grassland (*not* dominated by non-native hay grasses)	
Beetle-killed conifers	
Evidence of recent fire (<5 years old, still very apparent on vegetation, little regrowth)	
Other:	
Other:	
Other:	

Landscape stressor comments:

2. VEGETATION CONDITION METRICS – *Check the applicable box.*

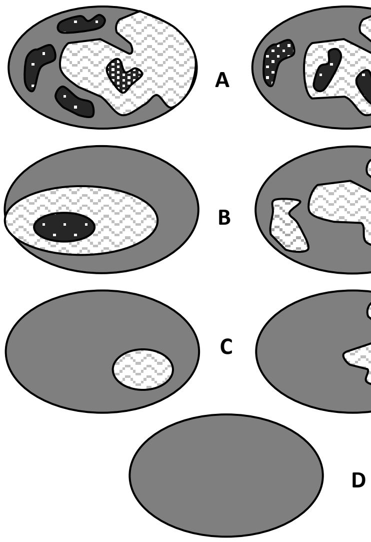
2a-d. VEGETATION COMPOSITION
Vegetation composition metrics can be calculated out of the field based on the species list and cover values. To aid data interpretation, provide comments on composition and **list noxious species identified in field.**

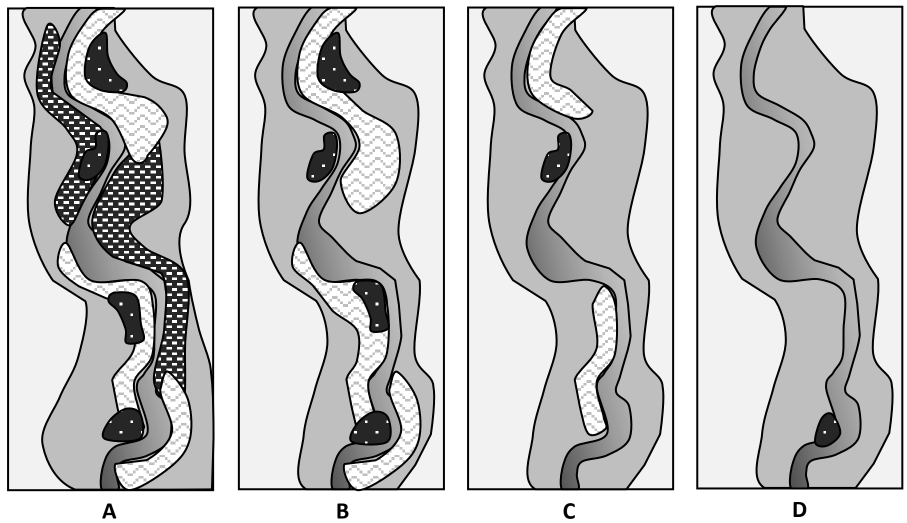
2e. REGENERATION OF NATIVE WOODY SPECIES	
Select the statement that best describes the **regeneration of native woody species** within the AA.	
Woody species are naturally uncommon or absent.	**NA**
All age classes of desirable (native) woody riparian species present.	
Age classes restricted to mature individuals and young sprouts. Middle age groups absent.	
Stand comprised of mainly mature species OR mainly evenly aged young sprouts that choke out other vegetation.	
Woody species predominantly consist of decadent or dying individuals OR >25% of the canopy cover is Russian Olive and/or Salt Cedar.	
Regeneration comments and photo #'s:	

2f. COARSE AND FINE WOODY DEBRIS	
Select the statement that best describes **coarse and fine woody debris** within the AA.	
There are no obvious inputs of woody debris or if woody species are naturally uncommon.	**NA**
AA characterized by moderate amount of coarse and fine woody debris, relative to expected conditions. For riverine wetlands, debris is sufficient to trap sediment, but does not inhibit stream flow. For non-riverine wetlands, woody debris provides structural complexity, but does not overwhelm the site.	
AA characterized by small amounts of woody debris OR debris is somewhat excessive. For riverine wetlands, lack of debris may affect stream temperatures and reduce available habitat.	
AA lacks woody debris, even though inputs are available.	
Woody debris comments and photo #'s:	

2g. HERBACEOUS / DECIDUOUS LEAF LITTER ACCUMULATION	
Select the statement that best describes **herbaceous and/or deciduous leaf litter accumulation** within the AA.	
AA characterized by moderate amount of herbaceous and/or deciduous leaf litter. New growth is more prevalent than previous years'. Litter and duff layers in pools and topographic lows are thin. Organic matter is neither lacking nor excessive.	
AA characterized by small amounts of litter with little plant recruitment OR litter is somewhat excessive.	
AA lacks litter OR litter is extensive and limiting new growth.	
Herbaceous / deciduous litter accumulation comments and photo #'s:	

2h. HORIZONTAL INTERSPERSION OF BIOTIC AND ABIOTIC ZONES		
Refer to diagrams below and select the statement that best describes the **horizontal interspersion of biotic and abiotic zones** within the AA. Rules for defining zones are in the field manual. Include zones of open water when evaluating interspersion.	High degree of horizontal interspersion: AA characterized by a very complex array of nested or interspersed zones with no single dominant zone.	
	Moderate degree of horizontal interspersion: AA characterized by a moderate array of nested or interspersed zones with no single dominant zone.	
	Low degree of horizontal interspersion: AA characterized by a simple array of nested or interspersed zones. One zone may dominate others.	
	No horizontal interspersion: AA characterized by one dominant zone.	





Horizontal interspersion comments (note if lack of interspersion is not related to wetland integrity such as in *Carex*-dominated fens):

VEGETATION STRESSORS WITHN THE AA

Using the table below, estimate the independent scope of each vegetation stressor within the AA. Independent scopes can overlap (e.g., light grazing can occur along with moderate recreation). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Vegetation stressor categories	*Scope*
Unpaved Roads (e.g., driveway, tractor trail, 4-wheel drive roads)	
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	
Logging or tree removal with 50-75% of trees removed	
Selective logging or tree removal with <50% of trees removed	
Heavy grazing/browse by livestock or native ungulates	
Moderate grazing/browse by livestock or native ungulates	
Light grazing/browse by livestock or native ungulates	
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	
Moderate recreation or human visitation (high-use trail)	
Light recreation or human visitation (low-use trail)	
Recent old fields and other fallow lands dominated by *non-native* species (weeds or hay)	
Haying of *native* grassland (*not* dominated by non-native hay grasses)	
Beetle-killed conifers	
Evidence of recent fire (<5 years old)	
Other:	
Other:	

Vegetation stressor comments and photo #'s:

3. HYDROLOGY METRICS – Check the applicable box.

4a. WATER SOURCES / INPUTS

Select the statement below that best describes the **water sources** feeding the AA during the growing season. Check off all *major* water sources in the table to the right. If the dominant water source is evident, mark it with a star (*).

_____ Overbank flooding	_____ Irrigation via direct application
_____ Alluvial aquifer	_____ Irrigation via seepage
_____ Groundwater discharge	_____ Irrigation via tail water run-off
_____ Natural surface flow	_____ Urban run-off / culverts
_____ Precipitation	_____ Pipes (directly feeding wetland)
_____ Snowmelt	_____ Other:

Water sources are precipitation, groundwater, natural runoff, or natural flow from an adjacent freshwater body. The system may naturally lack water at times, such as in the growing season. There is no indication of direct artificial water sources, either point sources or non-point sources. Land use in the local watershed is primarily open space or low density, passive use with little irrigation.	
Water sources are mostly natural, but also include occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic sources include developed land or irrigated agriculture that comprises < 20% of the immediate drainage basin, the presence of a few small storm drains or scattered homes with septic system. No large point sources control the overall hydrology.	
Water sources are moderately impacted by anthropogenic sources, but are still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin or the presence of a many small storm drains or a few large ones. The key factor to consider is whether the wetland is located in a landscape position supported wetland before development and whether the wetland is still connected to its natural water source (e.g., modified ponds on a floodplain that are still connected to alluvial aquifers, natural stream channels that now receive substantial irrigation return flows).	
Water sources are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or another artificial hydrology). Indications of substantial artificial hydrology include developed or irrigated agricultural land that comprises > 60% of the immediate drainage basin of the AA, or the presence of major drainage point source discharges that obviously control the hydrology of the AA. The key factor to consider is whether the wetland is located in a landscape position that likely never supported a wetland prior to human development. The reason the wetland exists is because of direct irrigation, irrigation seepage, irrigation return flows, urban storm water runoff, or direct pumping.	
Natural sources have been **eliminated** based on the following indicators: impoundment of all wet season inflows, diversions of all dry-season inflows, predominance of xeric vegetation, etc. The wetland is in steady decline and may not be a wetland in the near future.	

4b. HYDROPERIOD

Select the statement below that best describes the **hydroperiod** within the AA (extent and duration of inundation and/or saturation). Search the AA and 500 m envelope for hydrologic stressors (see list below). Use best professional judgment to determine the overall condition of the hydroperiod. For some wetlands, this may mean that water is being channelized or diverted away from the wetland. For others, water may be concentrated or increased.

Hydroperiod is characterized by natural patterns of filling or inundation and drying or drawdowns. There are no major hydrologic stressors that impact the natural hydroperiod.	
Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as: small ditches or diversions; berms or roads at/near grade; minor pugging by livestock; or minor flow additions. Outlets may be slightly constricted. Playas are not significantly impacted pitted or dissected. *If wetland is artificially controlled,* the management regime closely mimics a natural analogue (it is very unusual for a purely artificial wetland to be rated in this category).	
Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: ditches or diversions 1–3 ft. deep; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; shallow pits within playas; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. *If wetland is artificially controlled,* the management regime approaches a natural analogue. Site may be passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels.	
Hydroperiod filling or inundation and drawdown of the AA deviate substantially from natural conditions from high intensity alterations such as: a 4-lane highway; large dikes impounding water; diversions > 3ft. deep that withdraw a significant portion of flow, deep pits in playas; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be significantly constricted, blocking most flow. *If wetland is artificially controlled,* the site is actively managed and not connected to any natural season fluctuations, but the hydroperiod supports natural functioning of the wetland.	
Hydroperiod is dramatically different from natural. Upstream diversions severely stress the wetland. Riverine wetlands may run dry during critical times. *If wetland is artificially controlled,* hydroperiod does not mimic natural seasonality. Site is actively managed for filling or drawing down without regard for natural wetland functioning.	

Water source and Hydroperiod comments:

4c. HYDROLOGIC CONNECTIVITY

Select the statement below that best describes the **hydrologic connectivity**.

Rising water has unrestricted access to adjacent areas without levees or other obstructions to the lateral movement of flood waters. Channel, if present, is not entrenched and is still connected to the floodplain (see entrenchment ratio in optional riverine metrics).	
Unnatural features such as levees or road grades limit the amount of adjacent transition zone or the lateral movement of floodwaters, relative to what is expected for the setting, but limitations exist for <50% of the AA boundary. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. Channel, if present, is somewhat entrenched. If playa, surrounding vegetation does not interrupt surface flow.	
The amount of adjacent transition zone or the lateral movement of flood waters to and from the AA is limited, relative to what is expected for the setting, by unnatural features for 50–90% of the boundary of the AA. Features may include levees or road grades. Flood flows may exceed the obstructions, but drainage out of the AA is probably obstructed. Channel, if present, may be moderately entrenched and disconnected from the floodplain except in large floods. If playa, surrounding vegetation may interrupt surface flow.	
The amount of adjacent transition zone or the lateral movement of flood waters is limited, relative to what is expected for the setting, by unnatural features for >90% of the boundary of the AA. Channel, if present, is severely entrenched and entirely disconnected from the floodplain. If playa, surrounding vegetation may dramatically restrict surface flow.	

Hydrologic connectivity comments:

HYDROLOGY STRESSORS WITHIN A 500 M ENVELOPE AND BEYOND

Using the table below, mark the presence of each **hydrology stressor within at least the 500 m envelope of the AA, if not beyond**. Mark whether the stressor is present upstream/slope or downstream/slope of the AA. If known alteration occurs further upstream than 500 m, please explain in comments below.

Hydrology stressor categories	*Within AA*	*Upstream / Upslope*	*Downstream / Downslope*
Dam / reservoir			
Impoundment / stock pond			
Gravel ponds – reclaimed or not			
Spring box diverting water from wetland			
Extensive groundwater wells in the surrounding area			
Pumps, diversions, ditches that move water *out of* the wetland			
Pumps, diversions, ditches that move water *into* the wetland			
Berms, dikes, levees that hold water in the wetland			
Deeply dug pits for holding water			
Weir or drop structure that impounds water and controls energy of flow			
Observed or potential agricultural runoff			
Observed or potential urban runoff			
Flow obstructions into or out of wetland (roads without culverts)			
Dredged inlet or outlet channel			
Engineered inlet or outlet channel (e.g., riprap)			
Other:			
Other:			

Hydrology stressor comments:

4. PHYSIOCHEMICAL METRICS – Check the applicable box.

3a. WATER QUALITY - SURFACE WATER TURBIDITY / POLLUTANTS	
Select the statement that best describes the **turbidity or evidence or pollutants** in surface water within the AA.	
No open water in AA	**NA**
No visual evidence of turbidity or other pollutants.	
Some turbidity or presence of other pollutants, but limited to small and localized areas within the wetland. Water may be slightly cloudy.	
Water is cloudy or has unnatural oil sheen, but the bottom is still visible. *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	
Water is milky and/or muddy or has unnatural oil sheen. The bottom is difficult to see. *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	
Surface water turbidity / pollutants comments and photo #'s: *Turbidity may be natural depending on recent weather patterns and flow timing (i.e., higher flows are often more turbid). Please rank the system as you see it, regardless of whether the turbidity is natural. Make sure to include good notes if you down rank the system and please take photos.*	

3b. WATER QUALITY - ALGAL GROWTH	
Select the statement that best describes **algal growth** within surface water in the AA. Exclude *Chara* (multicellular algae) in estimates of cover.	
No open water in AA or evidence of open water.	**NA**
Water is clear with minimal algal growth.	
Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	
Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen.	
Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see.	
Algal growth comments and photo #'s: *Algal growth may be natural and not necessarily indicative of poor water quality. Please rank the system as you see it, regardless of whether the algae presence appears natural. Make sure to include good notes if you down rank the system and please take photos.*	

3c. SUBSTRATE / SOIL DISTURBANCE	
Select the statement below that best describes disturbance to the substrate or soil within the AA. For playas, the most significant substrate disturbance is sedimentation or unnaturally filling, which prevents the system's ability to pond after heavy rains. For other wetland types, disturbances may lead to bare or exposed soil and may increase ponding or channelization where it is not normally. For any wetland type, consider the disturbance relative to what is expected for the system.	
No soil disturbance within AA. Little bare soil OR bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails OR soil is naturally bare (e.g., playas). No pugging, soil compaction, or sedimentation.	
Minimal soil disturbance within AA. Some amount of bare soil, pugging, compaction, or sedimentation present due to human causes, but the extent and impact are minimal. The depth of disturbance is limited to only a few inches and does not show evidence of altering hydrology. Any disturbance is likely to recover within a few years after the disturbance is removed.	
Moderate soil disturbance within AA. Bare soil areas due to human causes are common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Sedimentation may be filling the wetland. Damage is obvious, but not excessive. The site could recover to potential with the removal of degrading human influences and moderate recovery times.	
Substantial soil disturbance within AA. Bare soil areas substantially degrade the site and have led to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Sedimentation may have severely impacted the hydrology. The site will not recover without active restoration and/or long recovery times.	
Substrate / soil comments and photo #'s:	

PHYSIOCHEMICAL STRESSORS WITHIN THE AA

Using the table below, estimate the independent scope of each physiochemical stressor within the AA. Independent scopes can overlap (e.g., soil compaction can occur with trash or refuse). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Physiochemical stressor categories	*Scope*
Erosion	
Sedimentation	
Current plowing or disking	
Historic plowing or disking (evident by abrupt A horizon boundary at plow depth)	
Substrate removal (excavation)	
Filling or dumping of sediment	
Trash or refuse dumping	
Compaction and soil disturbance by livestock or native ungulates	
Compaction and soil disturbance by human use (trails, ORV use, camping)	
Mining activities, current or historic	
Obvious point source of water pollutants (discharge from waste water plants, factories)	
Agricultural runoff (drain tiles, excess irrigation)	
Direct application of agricultural chemicals	
Discharge or runoff from feedlots	
Obvious excess salinity (dead or stressed plants, salt encrustations)	
Other:	
Other:	

Physiochemical stressor comments:

5. OPTIONAL RIVERINE HYDROLOGY METRICS (use when channel is within ~50 m)

5a. RIVERINE CHANNEL AND BANK STABILITY

Select the statement below that best describes **channel and bank stability** within or near the AA. To determine, visually survey the AA for field indicators of channel equilibrium, aggradation or degradation listed in the table below. Check "Y" for all that apply and "N" for those not observed. Use best professional judgment to determine the overall channel and bank stability.

Condition	Y	N	*Field Indicators*
Indicators of Channel Equilibrium / Natural Dynamism	☐	☐	The channel (or multiple channels in braided systems) has a well-defined usual high water line or bankfull stage that is clearly indicated by an obvious floodplain, topographic bench that represents an abrupt change in the cross-sectional profile of the channel throughout *most* of the site.
	☐	☐	The usual high water line or bank full stage corresponds to the lower limit of riparian vascular vegetation.
	☐	☐	Leaf litter, thatch, wrack, and/or mosses exist in most pools.
	☐	☐	The channel contains embedded woody debris of the size and amount consistent with what is available in the riparian area.
	☐	☐	Active undercutting of banks or burial of riparian vegetation is limited to localized areas and not throughout site.
	☐	☐	There is little evidence of recent deposition of *cobble* or *very coarse gravel* on the floodplain, although recent sandy deposits may be evident.
	☐	☐	There are no densely vegetated mid-channel bars and/or point bars, indicating flooding at regular intervals.
	☐	☐	The spacing between pools in the channel tends to be 5-7 channel widths, if appropriate.
	☐	☐	The larger bed material supports abundant periphyton.
Indicators of Active Aggradation / Excessive Sediment	☐	☐	The channel through the site lacks a well-defined usual high water line.
	☐	☐	There is an active floodplain with fresh splays of sediment covering older soils or recent vegetation.
	☐	☐	There are partially buried tree trunks or shrubs.
	☐	☐	Cobbles and/or coarse gravels have recently been deposited on the floodplain.
	☐	☐	There is a lack of in-channel pools, their spacing is greater than 5-7 channel widths, or many pools seem to be filling with sediment.
	☐	☐	There are partially buried, or sediment-choked, culverts.
	☐	☐	Transitional or upland vegetation is encroaching into the channel throughout most of the site.
	☐	☐	The bed material is loose and mostly devoid of periphyton.
Indicators of Active Degradation / Excessive Erosion	☐	☐	The channel through the site is characterized by deeply undercut banks with exposed living roots of trees or shrubs.
	☐	☐	There are abundant bank slides or slumps, or the banks are uniformly scoured and unvegetated.
	☐	☐	Riparian vegetation declining in stature or vigor, and/or riparian trees and shrubs may be falling into channel.
	☐	☐	Abundant organic debris has accumulated on what seems to be the historical floodplain, indicating that flows no longer reach the floodplain.
	☐	☐	The channel bed appears scoured to bedrock or dense clay.
	☐	☐	The channel bed lacks fine-grained sediment.
	☐	☐	Recently active flow pathways appear to have coalesced into one channel (i.e. a previously braided system is no longer braided).
	☐	☐	There are one or more nick points along the channel, indicating headward erosion of the channel bed.

RATING CRITERIA FOR ALL RIVERINE WETLANDS	
Most of the channel within or near the AA is characterized by naturally dynamic equilibrium conditions, with little evidence of excessive aggradation or degradation.	
Most of the channel within or near the AA is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form.	
There is evidence of severe aggradation or degradation of most of the channel within or near the AA or the channel is artificially hardened through less than half of the AA.	
The channel is concrete or otherwise artificially hardened through most of the AA.	

Channel stability comments (note if channel is unstable due to beaver or recent natural disturbances):

5b. RIVERINE ENTRENCHMENT RATIO (optional guide for if stream may be entrenched)

Using the following worksheet, calculate the average **entrenchment ratio** for the channel. The steps should be conducted for each of three cross sections located in or adjacent to the AA at the approximate mid-points along straight riffles or glides, away from deep pools or meander bends. *Do not attempt to measure this for non-wadeable streams!*

Steps	*Replicate cross-sections* →	*1*	*2*	*3*
1. Estimate bankfull width.	If the stream is entrenched, the height of bankfull flow is identified as a scour line, narrow bench, or the top of active point bars well below the top of apparent channel banks. If the stream is not entrenched, bankfull stage can correspond to the elevation of a broader floodplain with indicative riparian vegetation. Estimate or measure the distance between the right and left bankfull contours.			
2. Estimate max bankfull depth.	Imagine a line between right and left bankfull contours. Estimate or measure the height of the line above the thalweg (the deepest part of the channel).			
3. Estimate flood prone height.	Double the estimate of maximum bankfull depth from Step 2.			
4. Estimate flood prone width.	Imagine a level line having a height equal to the flood prone depth from Step 3. Note the location of the new height on the channel bank. Estimate the width of the channel at the flood prone height.			
5. Calculate entrenchment.	Divide the flood prone width (Step 4) by the max bankfull width (Step 1).			
6. Calculate average entrenchment	Average the results of Step 5 for all three cross-sections and enter it here.			

RATING CRITERIA FOR CONFINED RIVERINE WETLANDS		**RATING CRITERIA FOR UNCONFINED RIVERINE WETLANDS**	
Entrenchment ratio >1.8.		Entrenchment ratio >2.2.	
Entrenchment ratio 1.6–1.8.		Entrenchment ratio 1.9–2.2.	
Entrenchment ratio 1.2–1.5.		Entrenchment ratio 1.5–1.8.	
Entrenchment ratio <1.2.		Entrenchment ratio <1.5.	

Entrenchment ratio comments:

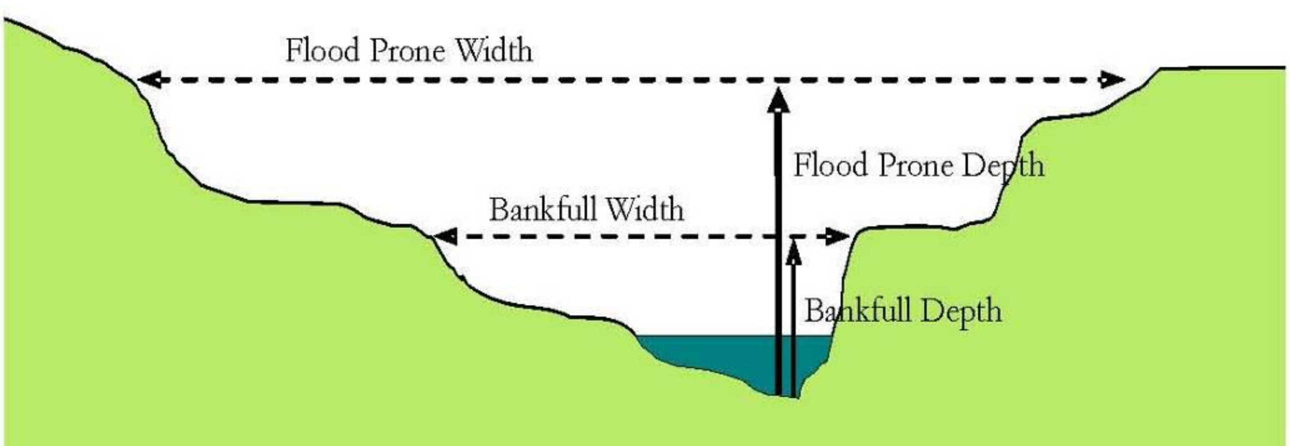


Illustration from Collins *et al.* 2008. California Rapid Assessment Method for Wetlands v 5.0.2

Point Code__________________ QC_________

2013 LOWER SOUTH PLATTE WETLAND CONDITION ASSESSMENT FIELD FORM – HABITAT METRICS

HABITAT TYPES WITHIN THE ASSESSMENT AREA (See manual for rules and definitions. Mark features on the site sketch.)

Habitat type	*% AA*	*Photos*	*Additional riparian structural patches*	*% AA*	*Photos*
1.			Bank slumps or undercut banks		
2.			Active beaver dam		
3.			Beaver canal		
4.			Debris jams / woody debris in channel		
5.			Pools in stream		

DOMINANT VEGETATION BY HABITAT TYPE

Check one box per by habitat type **Habitat Type →**	**1**	**2**	**3**	**4**	**5**
1. Robust wetland herbs (cattail, bulrush, reedgrass, etc.)					
2. Tall sedges, rushes (>20 cm)					
3. Low sedges, rushes (<20 cm)					
4. Tall grasses (>20 cm)					
5. Low grasses (<20 cm)					
6. Annual forbs					
7. Aquatic vegetation (submergent, floating leaves, algae)					
8. Open willows / shrubs					
9. Dense willows / shrubs					
10. Open canopy trees					
11. Closed canopy trees					
12. Other:					

DOMINANT SPECIES BY HABITAT TYPE

List top four dominant species by habitat type **Dominant / Cover →**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**	**D**	**C**
Scientific Name or Pseudonym										

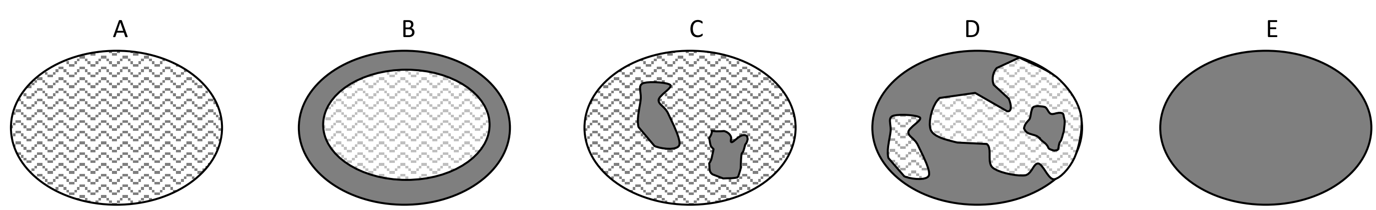
DUCK FOOD BY HABITAT TYPE					
Estimate cover class of all high or med value duck foods **Habitat Type →**	**1**	**2**	**3**	**4**	**5**
High quality duck foods					
Medium quality duck foods					

VERTICAL STRATA BY HABITAT TYPE										
Estimate cover of each stratum **Cover / Height →**	**C**	**H**	**C**	**H**	**C**	**H**	**C**	**H**	**C**	**H**
Height Classes 1: <0.5 m 2: 0.5–1m 3: 1–2 m 4: 2–5 m 5: 5–10 m 6: 10–15 m 7: 15–20 m 8: 20–35 m 9: 35–50 m 10: >50 m										
Canopy cover > 2m **(all woody vegetation > 2m)**										
Shrub and sub-canopy cover **(all woody vegetation < 2m)**										
Total herbaceous cover **(all herbaceous vegetation)**										
% of herbaceous vegetation that is too coarse/dense for animal movement										

GROUND COVER BY HABITAT TYPE					
Actual cover of water (any depth, vegetated or not, standing or flowing)					
Actual cover of water with emergent vegetation					
Actual cover of water with submergent / floating vegetation					
Actual predominant depth of water					
Actual min depth of water					
Actual max depth of water					
Potential cover of water at ordinary high water					
Potential predominant depth at ordinary high water					
Cover of litter (all cover, including under water or vegetation)					
Cover of exposed bare ground – soil / sand / sediment / gravel (can have algae cover)					
Cover of downed coarse woody debris (fallen trees, rotting logs, >5 cm diameter)					

SHALLOW WATER WITH SUNLIGHT BY HABITAT TYPE					
Cover of shallow water (up to 1 m) with the potential for open sunlight					

INTERSPERSION BY HABITAT TYPE					
Interspersion of vegetation and water at time of sampling *(if applicable)**					
Interspersion of vegetation and water at ordinary high water					



A: Open Water	Habitat is essentially not vegetated and covered exclusively by open water
B: Fringe	Habitat has vegetation around the perimeter of the wetland with central open water
C: Partially interspersed	Habitat contains a few vegetation patches in the central portion
D: Complex	Habitat contains vegetation interspersed in many patches
E: Closed	Habitat has few or no areas of open water

**Note: If site is dry, put NA for interspersion.*

COMMENTS BY HABITAT TYPE

Habitat 1

Does the feature extend beyond the AA? ____Yes ____No

Is the portion of the habitat feature within the AA representative of the larger feature? ____Yes ____No

Is the overall size of the feature evident form aerial images? ____Yes ____No

Comments:

Habitat 2

Does the feature extend beyond the AA? ____Yes ____No

Is the portion of the habitat feature within the AA representative of the larger feature? ____Yes ____No

Is the overall size of the feature evident form aerial images? ____Yes ____No

Comments:

Habitat 3

Does the feature extend beyond the AA? ____Yes ____No

Is the portion of the habitat feature within the AA representative of the larger feature? ____Yes ____No

Is the overall size of the feature evident form aerial images? ____Yes ____No

Comments:

Habitat 4

Does the feature extend beyond the AA? ____Yes ____No

Is the portion of the habitat feature within the AA representative of the larger feature? ____Yes ____No

Is the overall size of the feature evident form aerial images? ____Yes ____No

Comments:

Habitat 5

Does the feature extend beyond the AA? ____Yes ____No

Is the portion of the habitat feature within the AA representative of the larger feature? ____Yes ____No

Is the overall size of the feature evident form aerial images? ____Yes ____No

Comments: