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Inventory of Fens and Rare Fen-Indicator Plant Occurrences at Grand Teton National Park and John D. Rockefeller, Jr. Memorial Parkway

Fen near String Lake at the base of the Teton Mountains. Inset: English sundew *(Drosera anglica)* in flower.
NPS / CNHP

Inventory of fens and rare fen-indicator plant occurrences at Grand Teton National Park and John D. Rockefeller, Jr. Memorial Parkway

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Contents

Page

Contents (continued)

Figures

Figures (continued)

Tables

Page

Abstract

Fens are groundwater-fed, peat-accumulating wetlands that form where the accumulation of organic material exceeds decomposition. While fens are common at northern latitudes, fens in the Rocky Mountains are relatively rare, small features that support numerous rare plant species. Little is known about fens in Grand Teton National Park (GRTE) and John D. Rockefeller, Jr. Memorial Parkway (JODR). While GRTE and JODR are managed for natural resource preservation and recreation, the parks have a history of other land uses and have seen increasing visitors in recent years. To better manage fen resources in GRTE and JODR, the National Park Service funded the Colorado Natural Heritage Program to create a map of potential fens within GRTE and JODR, visit potential fen polygons to verify their status as fens, and survey for rare fen-indicator plant species. The initial map of fens created in the winter of 2022–23 contained 906 potential fens covering 5,208 acres. Field sampling in the summer of 2023 verified 41 fens and 28 peat-accumulating wetlands. The revised map contained 1,016 acres of confirmed or highly likely fens, which were concentrated at elevations below 2,100 m in specific areas of the parks, including Lower Jackson Lake watershed and most of JODR. One hundred and twenty-seven populations of 23 rare fen-indicator plant species were observed either within or near confirmed fens. Rapid vegetation surveys were conducted in 38 confirmed fens. Most were basin fens, several of which contained floating mats, and seven sites were sloping fens. Vegetation composition was overwhelmingly native and indicative of excellent condition. Most sites were dominated by graminoids, specifically sedge *(Carex)* species, and some sites also contained willows *(Salix* spp.*)* and other low shrubs. Quantitative vegetation sampling was carried out in five sites for more precise estimates of species cover. Water chemistry measurements of pH and specific conductance were collected in the field at most sites, and water chemistry samples were collected at five sites for more detailed lab analysis. Water pH ranged from 4.86–8.65 and specific conductance ranged from 1–1105 µS/cm. Most fens were characterized as rich fens, with some considered poor fens and no sites meeting the water chemistry and vegetation classification of extreme rich fen. GRTE and JODR fens are exceptional resources that support numerous rare species. Management plans for the park units should protect and avoid impacting these special habitats and their species so they remain intact into the future.

Acknowledgments

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Introduction

Fens are groundwater-fed, peat-accumulating wetlands that form where the accumulation of organic material exceeds decomposition. Fens have deep organic soils and typically support sedges and low stature shrubs (Rydin & Jeglum 2013; Mitsch & Gosselink 2015). Organic soil is technically defined as a soil where more than half of the upper 80 cm (32 in) is organic soil material (also referred to as peat) (Soil Survey Staff 2022). However, wetlands with shallower peat layers may share similar characteristics (Driver 2010). Accumulation of organic material to this depth requires constant soil saturation and cold temperatures, which create anaerobic conditions that slow the decomposition of organic matter. While fens and other peat-accumulating wetlands are common at northern latitudes (Rydin & Jeglum 2013), Rocky Mountains fens are relatively small features nestled within the landscape where local hydrologic conditions allow for peat accumulation at rates as slow as 20 cm (8 in) per 1,000 years (Chimner 2000; Chimner and Cooper 2002). By storing organic matter in their soils, fens act as carbon sinks. Fens also help to regulate local and regional hydrology by stabilizing base flow through the slow release of groundwater. In addition, fens throughout the Rocky Mountains support numerous rare plant species that are often disjunct from their main populations (Cooper 1996; Cooper et al. 2002; Johnson & Stiengraeber 2003; Lemly et al. 2007; Lemly & Cooper 2011; Heidel et al. 2017). In northwestern Wyoming, Grand Teton National Park (GRTE) and John D. Rockefeller, Jr. Memorial Parkway (JODR) create a favorable template for the development of fens, but little is known about their distribution and floristic diversity.

Human land use activities can have detrimental impacts on fen wetlands, often altering their hydrology to the extent that water levels and associated plant communities are significantly changed or eliminated (Charman 2002). Rocky Mountain fens have been impacted by a variety of land uses, including grazing, recreation, ditching, draining, excavation, flooding, mining activity, and road building (Bocking et al. 2017; Austin & Cooper 2016; Johnston et al. 2012; Chimner et al. 2010; Cooper & McDonald 2000). While GRTE and JODR are managed for natural resource preservation and recreation, the parks have a history of other land uses and have seen increasing visitors in recent years. The Jackson Hole valley at the heart of GRTE has attracted Native people and European settlers for millennia, including homesteaders and dude ranches in the late 1800s and early 1900s (NPS 2019). In the past 15 years, visitation to GRTE increased over 50% to a record of nearly 3.9 million visitors in 2022 (NPS 2024). The long-term maintenance of fens requires protection of both the hydrology and the plant communities that enable fen formation. As visitation increases and visitation patterns change, such as more visitors seeking water sources, vulnerable fen wetlands may need added protection to avoid trampling and other visitor-related disturbances. Future road and trail work could also impinge on fen habitat if their locations are unknown and not considered during planning processes. To better protect fens within the parks, it is necessary to understand the distribution of potential fen habitat on the landscape, verify fen locations in high-priority areas (near roads, trails, and climbing routes), and document the presence and abundance of rare plants in fens to prioritize sites for potential management actions.

Prior to this study, the locations and characteristics of fen habitat in GRTE and JODR were poorly understood. Previous botanical surveys (WYNDD 2022) and vegetation mapping efforts in GRTE and JODR (Cogan et al. 2005) identified fen-obligate plant species or individual fen locations, but no previous study has documented the extent of fen distribution. Intensive fen inventories have been carried out for lands surrounding the parks. Potential fens have been mapped in adjacent Caribou-Targhee National Forest (Smith & Lemly 2020), Bridger-Teton National Forest (Smith & Lemly 2018), and Yellowstone National Park (Lemly 2007). Botanical inventories of fens have been conducted in both adjacent National Forests (Heidel 2019) and in Yellowstone (Lemly & Cooper 2011; Lemly 2007). Further beyond the parks, fens have been studied in the Wind River Range (Cooper & Andrus 1994), the Medicine Bow Mountains (Heidel & Jones 2006), the Big Horn Mountains (Heidel 2011), the Laramie Range (Heidel et al. 2013), and the Beartooth Mountains (Heidel et al. 2017 and studies listed within). To better manage fen resources in GRTE and JODR, the National Park Service (NPS) Inventory Program funded the Colorado Natural Heritage Program (CNHP) to create a map of potential fens within GRTE and JODR, visit ~40 potential fen polygons to verify their status as fens, and survey for rare fen-indicator plant species in and adjacent to confirmed fens. The information developed through this project will assist NPS in all future land use planning efforts for the park units and will bring a greater awareness to the importance of fen wetlands throughout the parks.

Study Area

Geography

The study area for this project included both Grand Teton National Park (GRTE) and John D. Rockefeller, Jr. Memorial Parkway (JODR), two adjacent National Park Service units located in northwest Wyoming. Both parks are completely within Teton County and the Snake River Headwaters River Basin (HUC6: 170401). Jackson, Wyoming, is the largest municipality near the parks, situated immediately south of GRTE. GRTE is significantly larger than JODR, covering 1,250 km^2 (310,000 acres) to JODR's 97 km^2 (24,000 acres). The defining feature of GRTE is the Teton Range, a steep mountain range that towers over Jackson Lake and the stretch of the Snake River valley known as Jackson Hole. Iconic views of the jagged peaks reflected in the lake or looming above floodplain willows and meadows are familiar to many. The elevation in GRTE ranges from 1,925 m (6,320 ft) on the valley floor to 4,200 m (13,775 ft) at the top of Grand Teton. A string of lakes sits at the base of the Teton Range, of which Jackson Lake is the largest at 24 km (15 mi) long and 134 m (438 ft) deep. Jackson Lake is a natural lake fed by the Snake River that was originally carved by glaciation. The lake was enlarged in the early 1900s with the construction of the Jackson Lake Dam to store irrigation water. The park's road network primarily skirts the eastern edge of the lake or cuts through the Snake River valley, providing many opportunities to recreate on the lake's shore and access hiking and climbing routes within the Teton Range.

JODR is located immediately north of GRTE and south of Yellowstone National Park and serves as a connection between the two famous parks (Figure 1). JODR is a natural transition between the peaks of the Teton Range, which gradually taper at their northern end in JODR, and the edge of the Yellowstone Plateau volcanic field. The Flagg Ranch lodge and campground are located along the main highway through JODR and is an access point for hiking and fishing in the area. Grassy Lake Road extends west from Flagg Ranch deeper into JODR. The road is gravel for most of its length and is far less traveled than the main highways in either GRTE or Yellowstone but offers hiking and camping for visitors who want more solitude.

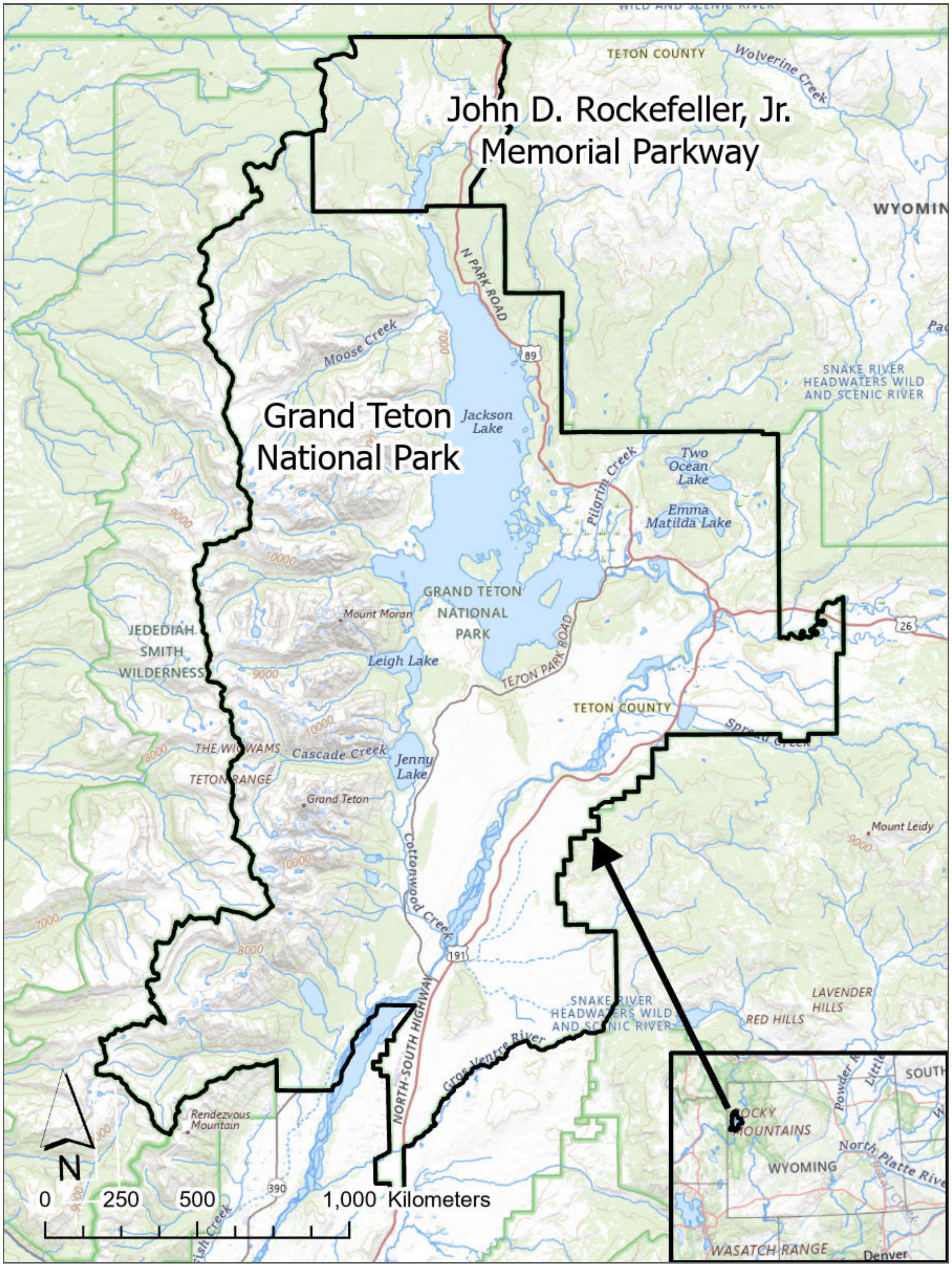

Figure 1. Map of Grand Teton National Park (GRTE) and John D. Rockefeller, Jr. Memorial Parkway (JODR). Inset map shows GRTE and JODR in northwest Wyoming.
NPS / CNHP

Vegetation

Vegetation in GRTE is driven by abrupt changes in elevation and hydrology (Cogan et al. 2005). Lower elevation uplands are dominated by sagebrush flats, while the Snake River floodplain and its tributaries contain open cottonwood forests, dense willow shrublands, and flooded meadows. Dominant upland species in this zone include low sagebrush *(Artemisia arbuscula),* mountain big sagebrush *(Artemisia tridentata* ssp. *vaseyana)* and bitterbrush *(Purshia tridentata)*. Cottonwoods *(Populus angustifolia* and *P. balsamifera),* alder *(Alnus incana),* and willows *(Salix* spp.) over grasses and sedges *(Carex* spp.) characterize the wetter valleys. As elevations climb, the mountain slopes are dominated by evergreen forests whose species composition varies with elevation. Lodgepole pine *(Pinus contorta)* and aspen *(Populus tremuloides)* forests are common in the montane zone between 1980–2285 m (6500–7500 ft), with Douglas-fir *(Pseudotsuga menziesii)* stands on south-facing slopes and along mesic drainages. The subalpine zone between 2285–2895 m (7500–9500 ft) is dominated by Engelmann spruce *(Picea engelmannii)* and subalpine fir *(Abies lasiocarpa)*, though dry slopes at high elevations can support whitebark pine *(Pinus albicaulis).* Streams cutting through canyons in the steep mountains also support willow and sedge species, but the steep topography in GRTE does not allow extensive wetland development in the subalpine zone, unlike some mountain ranges. Treeline occurs at approximately 3050 m (10,000 ft) and vegetation above this threshold is characterized as tundra, dominated by cold-hardy, low-growing grasses, sedges, forbs, and dwarf shrubs. JODR's topography lacks the steep mountains of GRTE and is primarily forested with more extensive wetland development along streams and where groundwater discharges from fissures in the bedrock.

The National Park Service (NPS) and U.S. Geological Survey (USGS) have partnered since the 1990s on the USGS–NPS Vegetation Mapping Program to create detailed vegetation maps of all park units. The GRTE and JODR vegetation map was created in 2005 based on two years of field data collection and high-resolution aerial photography interpretation (Figure 2) (Cogan et al. 2005). Detailed information on the vegetation of both park units is available through this project at: https://www.nps.gov/im/vmi-grte.htm.

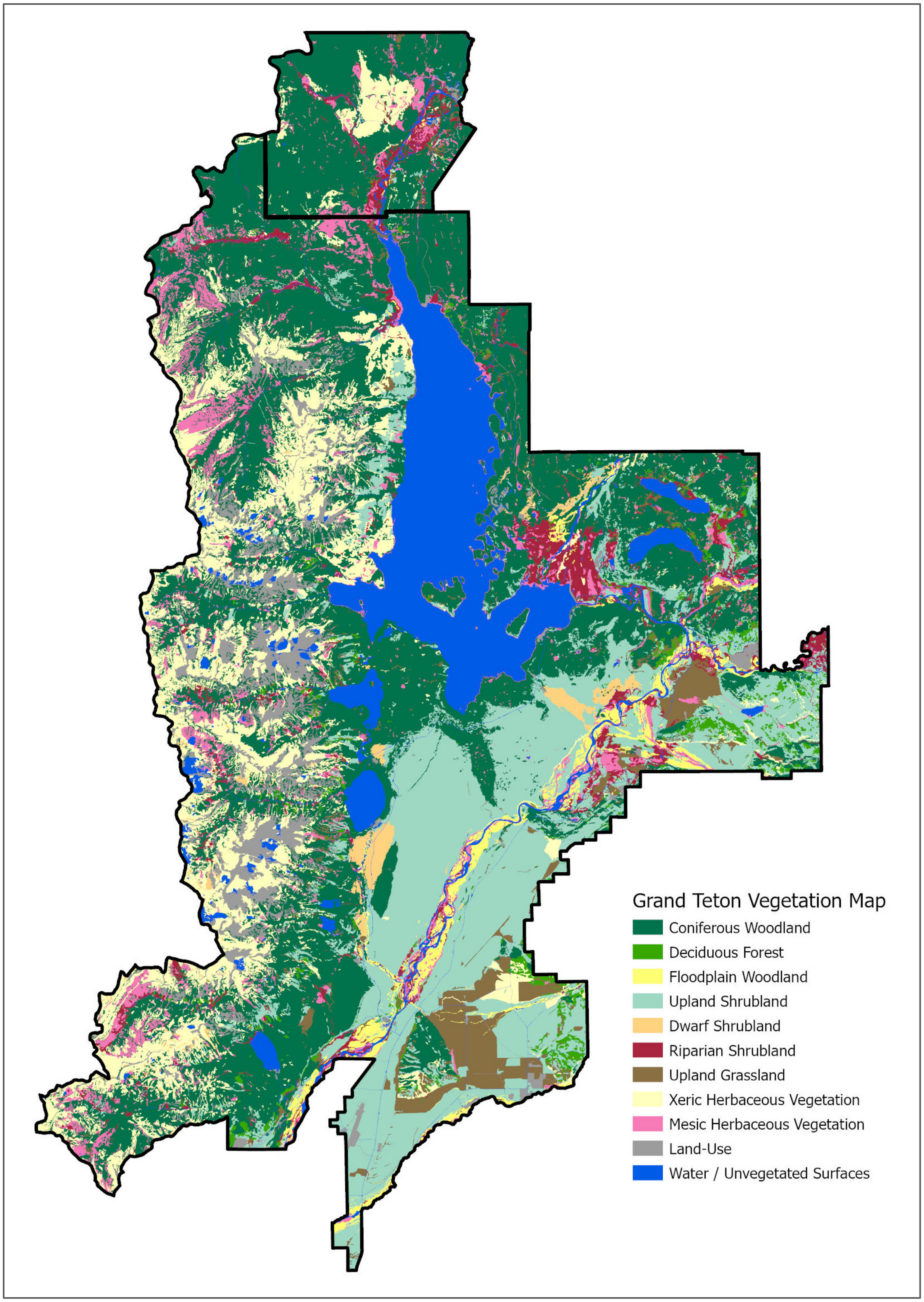

Figure 2. Vegetation map of GRTE and JODR symbolized by dominant vegetation type. Data from Cogan et al. 2005.

NPS / CNHP

Climate

GRTE and JODR have a continental climate with dry, warm summers and cold, moist winters. Annual precipitation in GRTE and JODR varies by elevation from 38–63 cm (15–25 in) in the Jackson Valley to >170 cm (70 in) in the high peaks. Most annual precipitation falls as snow and snowpack peaks in late spring. Two snow telemetry (SNOTEL) stations are located near the study area, one west of GRTE at Grand Targhee (site #1082) at 2820 m (9,260 ft) elevation and one at the north end of JODR along the Snake River (site #764) at 2100 m (6,900 ft) elevation. Average annual precipitation is 130 cm (51 in) at the Grand Targhee station and 89 cm (35 in) at the Snake River station based on 1990–2020 data (NWCC 2025). Summer average daily temperatures in GRTE peak at 25°C (78°F) in July and summer nighttime lows can still be below 4°C (40°F). Winter highs are around -5°C (low 20s°F) and lows hover around -18°C (0°F). Abundant snow in the mountains and valleys melts slowly over spring and summer, percolates into the groundwater, and flows into Jackson Valley and surrounding smaller watersheds, providing excellent hydrologic conditions for wetland and fen formation.

Geology

Geology is on full display within GRTE and JODR (Figure 3), and this geology influences the wetlands that form within the parks. Three dominant geologic forces have shaped the landscape we see today. Seismic activity, including splitting and uplifting along the north-south Teton fault, started approximately 9 million years ago and created the dramatic Teton Range (USGS 2024; KellerLynn 2010). The displacement between the uplifted mountain range to the west and the downthrown block to the east, which created the Jackson Hole valley, was more than 7000 m (23,000 ft) in relief (Cogan et al. 2005 and sources cited within). In time, erosive forces scraped material from the mountains and deposited it into the valleys, filling them to their present elevation. In particular, glaciation as recent as 10,000 years before present carried significant material that shaped the current valleys. While fens can occur in a variety of geologic settings, in Wyoming, glaciation is often a significant factor in the formation of fens (Knight et al. 2014). In addition to uplift from faulting and glaciation, the third major force in the landscape is volcanism from the Yellowstone caldera just north of the parks. Three massive eruptions in the past 2.1 million years formed the current Yellowstone caldera and adjacent features. These eruptions left behind extensive layers of tuff, welded rock made of ash, pumice, and rock fragments exploded during eruptions (USGS 2023). These layers are particularly significant in JODR, which lies on the edge of the Yellowstone Plateau volcanic field. But volcanic material from these eruptions also moved into GRTE through erosion, alluvial processes, and repeated eras of glaciation.

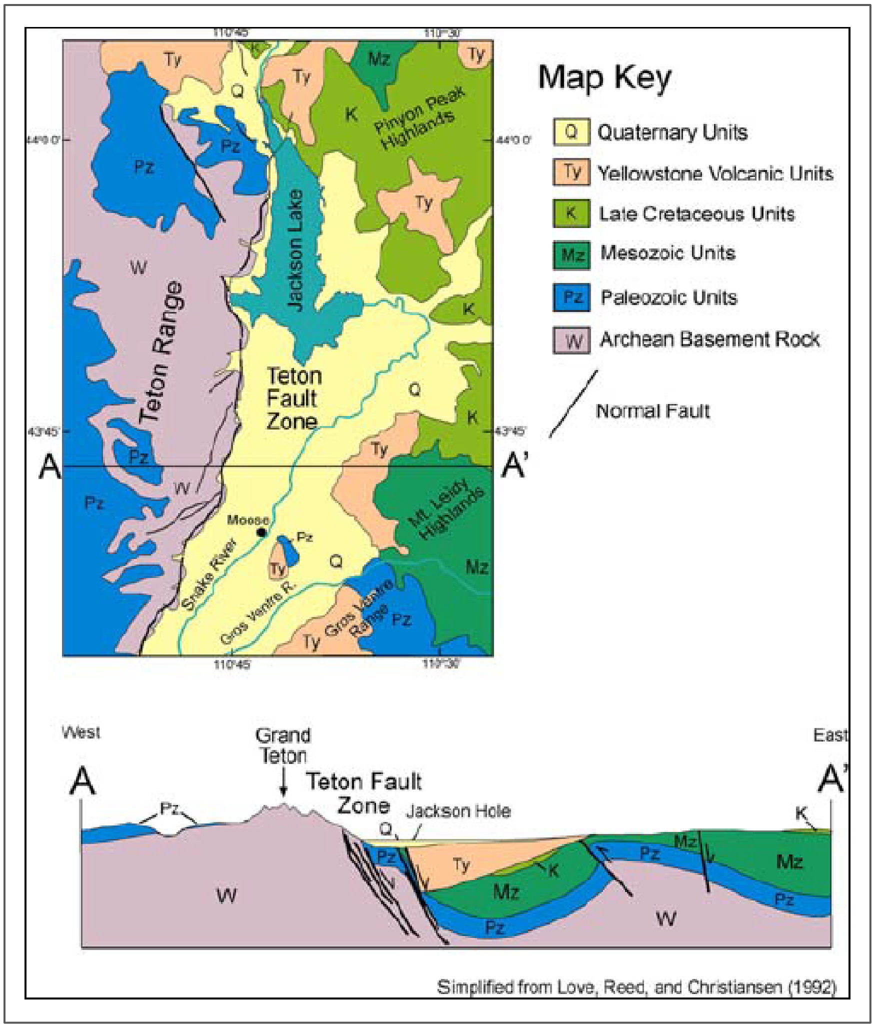

Figure 3. Simplified geologic map of GRTE and JODR. Map reproduced from Cogan et al. 2005.
NPS / CNHP

Methods

Mapping and field sampling of fens within GRTE and JODR was conducted in three phases: 1) preliminary fen mapping, 2) field sampling to verify fens and inventory rare plants, and 3) revision of the preliminary map based on field observations. Preliminary mapping took place during the winter of 2022–23 in advance of the 2023 summer field seasons, field sampling took place during July and August 2023, and revision of the preliminary map took place during the winter of 2023–24.

Preliminary Fen Mapping Methods

During the winter of 2022–23, potential fens in GRTE and JODR were identified by analyzing digital aerial photography and topographic maps. Fens occur most frequently at the base of slopes where groundwater expresses to the surface or in basins where organic material accumulates and gradually fills ponds and small lakes (Cooper & Wolf 2015). In aerial photography, fens can be identified by mottled brownish-green colors, rather than the bright green colors of more productive wetland systems. Fens may contain small pools of water or be located on the margin of ponds or small lakes. They can occur on the edge of mountain stream valleys, but not on the floodplains of larger rivers, where the scour action of periodic flooding would prevent peat accumulation.

True color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2004, 2009, 2011, 2013, and 2019 were used in conjunction with color-infrared imagery from 2011, 2013, and 2019. High (but variable) resolution World Imagery from Environmental Systems Research Institute (ESRI) was also used. To focus the initial search, where possible, all wetland polygons mapped by the U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) program in the 1980s with a "B" (saturated) hydrologic regime were isolated from the full NWI dataset and examined.[1] Wetlands mapped as Palustrine Emergent Saturated (PEMB) and Palustrine Scrub-Shrub Saturated (PSSB) were specifically targeted, as they can be the best indication of fen formation, and every PEMB and PSSB polygon in the study area was checked. However, photo-interpreters were not limited to the original NWI polygons and also mapped any fens they observed outside of B regime NWI polygons (see Table 1 for fen characteristics).

Potential fen polygons were hand-drawn in ArcGIS 10.6 based on the best estimation of fen boundaries. In most cases, this did not match the exact boundaries of the original NWI polygons because the resolution of current imagery is far higher than was available in the 1980s. The fen polygons were often a portion of the NWI polygon or were drawn with different but overlapping boundaries. This will provide NPS the most accurate and precise representation of fens, as opposed to estimates based on the NWI polygons themselves. Each potential fen polygon was attributed with a confidence value of 1, 3 or 5 (Table 1). Each fen location for the purposes of this report is a single potential fen polygon. Potential fen polygons of different confidence levels may be adjacent or nested within each other and together represent a larger fen complex (Figure 4).

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[1] For more information about the National Wetland Inventory and the coding system, please visit: http://www.fws.gov/wetlands/.

Table 1. Confidence levels in the initial map of potential fens.

Confidence	Description
5	Likely fen. Strong photo signature of fen vegetation (brownish-green colors, mottled texture), fen hydrology (small areas of open water, saturated soils), and good landscape position (base of slope or depression). All likely fens should contain peat of 40 cm or more throughout the entire area of the mapped feature.
3	Possible fen. Some fen indicators are present (vegetation signature, topographic position, ponding or visibly saturated substrate), but not all indicators are present. Some indicators may be weak or missing. Possible fens may or may not have the required peat depth of 40 cm but may have patchy or thin peat throughout.
1	Low confidence fen. At least one fen indicator is present, but weak. Low confidence fens are saturated wetland areas that do not show peat signatures in aerial photography but may contain fen or peat.

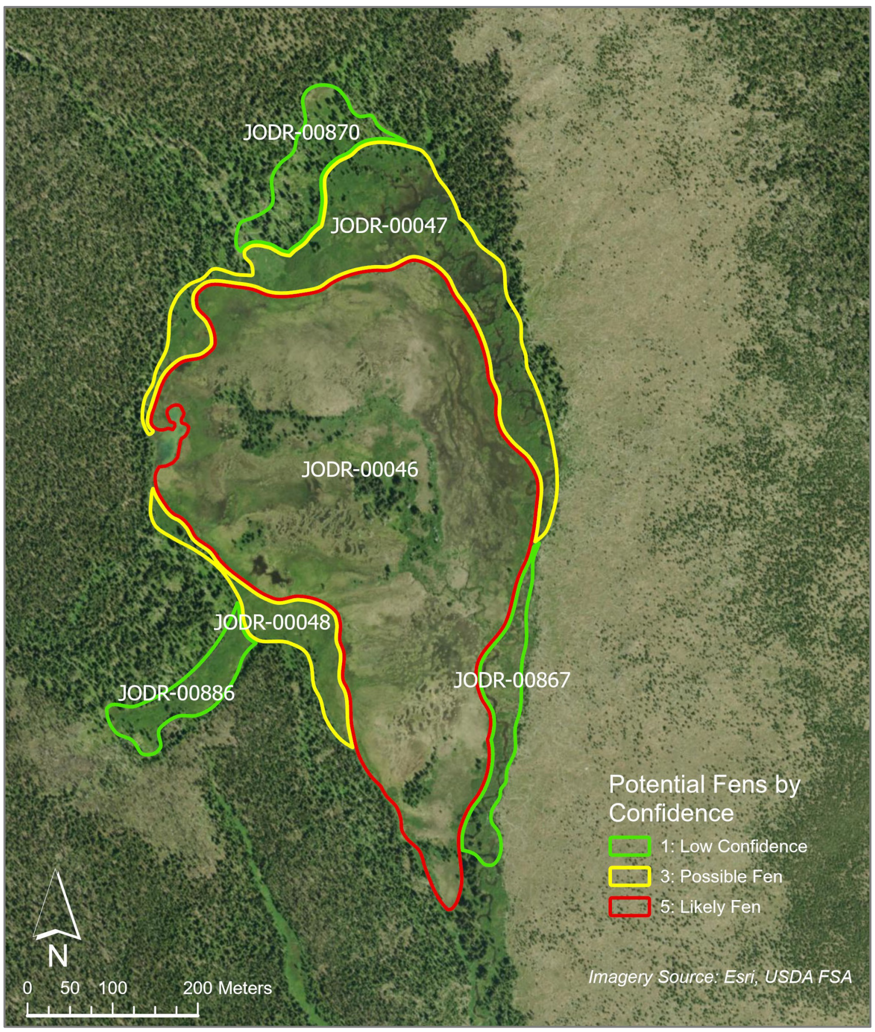

Figure 4. Example of initial potential fen mapping showing polygons of various confidence levels within one complex in JODR.

NPS / CNHP

In addition to existing NWI mapping, several auxiliary datasets were also used to identify potential fens. Those included topographic maps from the USGS, spring locations from the National Hydrography Dataset (NHD), vegetation mapping data from the NPS Vegetation Mapping Program (Cogan et al. 2005), and surficial geologic layers (Love et al. 1992). Lastly, a list of rare vascular plant species indicative of fen habitats was developed by Bonnie Heidel, Botanist with the Wyoming Natural Diversity Database (WYNDD; Appendix A). All known locations of the rare fen-indicator species in GRTE and JODR were obtained from WYNDD (WYNDD 2022) and the Rocky Mountain Herbarium (RMH; RMH 2022) and examined in aerial photography to determine if the site appeared to be a fen. While all species on the target list could occur in fens, they were not all fen-obligates, meaning some species could occur in other habitats as well as fens. The known locations were used to ensure that all known occurrences in what appeared to be fen habitat were included in the potential fen map.

Along with the confidence rating, any justifications of the rating or interesting observations were noted, including beaver influence, floating mats, springs or human stressors. CNHP also used geology layers to identify potential extreme rich fens influenced by calcareous groundwater. Extreme rich fens develop most frequently where groundwater inputs emerge from calcareous geologic layers such as limestones and dolomites.

Once potential fens were mapped, CNHP and park staff collaboratively prioritized areas of the park for verification and ground surveys, with a goal of visiting ~40 polygons. Potential fen polygons were prioritized for sampling if they were: 1) likely fens (confidence level = 5), 2) large in size, 3) accessible from the major road or trail network, and/or 4) contained known locations of rare plants. Park staff also considered management-relevant criteria such as proximity to high visitation areas.

Field Sampling

Field sampling took place over four eight-day sampling periods in July and August 2023. Field methods were modeled after the U.S. Forest Service (USFS) Groundwater Dependent Ecosystem (GDE) field guides (USFS 2022; USFS 2012) so the data would be comparable with surveys conducted on neighboring USFS lands. In March and April 2023, CNHP worked with the USFS and the Springs Stewardship Institute to acquire digital files for an electronic data collection field form developed with ESRI's Survey123 application. CNHP adapted that field form to meet the needs of this project.

At each polygon visited, peat depth was estimated in one or more location with a soil tile probe. If the site was confirmed as a fen (> 40 cm of organic soil), additional data were collected, including site characteristics, photos, and water chemistry. Vegetation data were collected in confirmed fens with two levels of intensity: 1) rapid site evaluations that allowed multiple sites to be visited in one day and 2) quantitative vegetation surveys that took up to a full day per site. Four sites in GRTE and one site in JODR were selected for quantitative vegetation surveys. Methods for each type of data collection are detailed in the following sections.

Peat Depth Estimation

Fens are defined as groundwater-fed wetlands with organic soil. The Natural Resources Conservation Service (NRCS) defines organic soil as follows (Soil Survey Staff 2022):

> *"It is a general rule that a soil is classified as an organic soil (Histosol or Histel) if more than half of the upper 80 cm (32 inches) of the soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic materials."*

Figure 5 shows examples of organic soil cores extracted from fens in other studies. Note the presence of roots and fibrous organic material throughout the soil core. The soil color may be dark brown to reddish brown depending on the source material and the soil material holds together.

Figure 5. Examples of organic soil cores extracted from other studies.
NPS / CNHP

Initially, we planned to extract soil cores from all polygons visited with 5-cm (2-inch) diameter gouge auger to confirm if the polygons were fens. However, permission for soil core extraction was not granted by NPS in time for the 2023 field season. Instead, peat depth was estimated with a soil tile probe, a long thin metal probe that allowed the crews to feel a change in soil texture from soft organic soil material to dense clay or gritty mineral material. Crews also visually and manually assessed the top layer of soil to determine if the soil was organic.

In at least one representative location within each visited polygon, crews inserted the tile probe to estimate the depth of the organic soil or peat layer. If the polygon was small and homogeneous, one probe in the center of the polygons was enough to determine if the polygon contained > 40 cm of organic soil material. If the polygon was large and heterogeneous, the probe was used in multiple locations with different vegetation communities to determine if any portion of the polygon contained organic soil. If the organic soil layer was > 40 cm in at least a portion of the polygon, that portion of the polygon was verified as a fen and additional data were collected. If organic soil material was present but < 40 cm, the site was considered a peat-accumulating wetland, but no other data were collected. If no organic soil material was present, the crew moved on to the next polygon. Peat depth estimations were recorded using a Survey123 form that allowed multiple probes to be recorded per polygon. A GPS waypoint was taken at every soil probe to associate the data with the precise spatial location within the polygon. In addition to the GPS waypoint, a photo was taken of the location for reference.

Data Collected for All Confirmed Fens

For each confirmed fen polygon, basic information was recorded using the Survey123 field form based on the USFS GDE Level 1 Inventory Field Guide (USFS 2022). This includes the following data:

- Polygon ID from the potential fen mapping
- GPS coordinates from the center of the polygon
- Survey date and observers
- Site description (the setting, landform, and landscape context, this information should remain the same over time)
- Site conditions (this is different than the site description and can change between surveys)
- Access directions so that site can be relocated in the future
- Weather and air temperature
- Notes on edits to the polygon boundaries
- Elevation, slope and aspect
- Photographs

Water Chemistry

In one to four locations within confirmed fen polygons and several peat-accumulating wetlands, pH, specific conductance, and temperature of groundwater were measured with a handheld YSI Pro1030 pH meter. The meter was calibrated at least every seven days per the manufactured recommendation and more frequently if readings were outside of normal ranges (pH 5.0–8.0; EC >1000). Water chemistry measurements were taken from groundwater within the soil, if possible. Measurements were also taken in standing and/or flowing surface water. GPS coordinates and a description of the location were recorded on the form. In fens sampled with the quantitative vegetation protocols (see below), a water chemistry sample was collected in a 125-mL Nalgene bottle for lab analysis of cations and anions. All samples were held on ice until submitted to CSU's Soil, Water and Plant Testing Laboratory.

Vegetation Data Collection – Rapid Site Evaluations

In all confirmed fens, a rapid site evaluation was conducted to characterize the dominant vegetation. In these sites, a list of dominant and readily observable vascular plant species with absolute canopy cover > 10% was recorded. Low cover species were also included if observed, but the site was not exhaustively searched for low cover species. The species search was limited to 30 minutes by one trained botanist to minimize the amount of time spent at each site and maximize the number of polygons the crew was able to visit. When all dominant species were identified within a polygon, or 30 minutes of time was spent searching, the canopy cover of listed species was visually estimated using cover classes (Table 2).

Table 2. Cover classes used for rapid site evaluations.

Cover Class	Range
1	Trace (1 or 2 individuals)
2	< 1% absolute canopy cover
3	1 to <2% absolute canopy cover
4	2 to <5% absolute canopy cover
5	5 to <10% absolute canopy cover
6	10 to <25% absolute canopy cover
7	25 to <50% absolute canopy cover
8	50 to <75% absolute canopy cover
9	75 to <95% absolute canopy cover
10	≥95% absolute canopy cover

Nomenclature for all plant species followed USDA PLANTS National Database and all species were recorded in the Survey123 form using the fully spelled out scientific name. Any unknown species were recorded with a unique descriptive name and given a collection number for later identification. Unknown species were collected by the field crew if the species represented > 10% cover over the entire polygon, even if the species appeared to be unidentifiable, in case the same species was encountered in a more developed state at a later site and could be compared with the earlier voucher. Crews also estimated the abundance of bryophyte species in the polygon.

Vegetation Data Collection – Quantitative Vegetation Surveys
In five confirmed fen polygons (one more than initially planned), detailed quantitative vegetation data were collected following methods in the USFS GDE Level II Inventory Field Guide (USFS 2012). In these sites, the area for quantitative data collection was limited to 6,400 m^2 (80 m × 80 m), even though all five sites were larger. Limiting the sampling area was consistent with the medium sized site category listed in the Level II Field Guide, which is considered the maximum area sampleable in one day. Preliminary sampling focal areas were defined in advance for four quantitative sites to ensure the sampling day was as efficient as possible. High water levels in one selected site (Swan Lake) prevented sampling. Two additional sites were selected opportunistically during the field season.

The five sites selected for quantitative sampling, listed below, were large fens that contained known rare plant populations and noticeable microtopographic features such as strings and flarks or floating mats (Figure 6):

- GRTE-00008 (Colter Bay Junction)
- GRTE-00095 (Spread Creek)
- GRTE-00278 (Willow Flats)
- GRTE-00342 (String Lake)
- JODR-00046 (JODR)

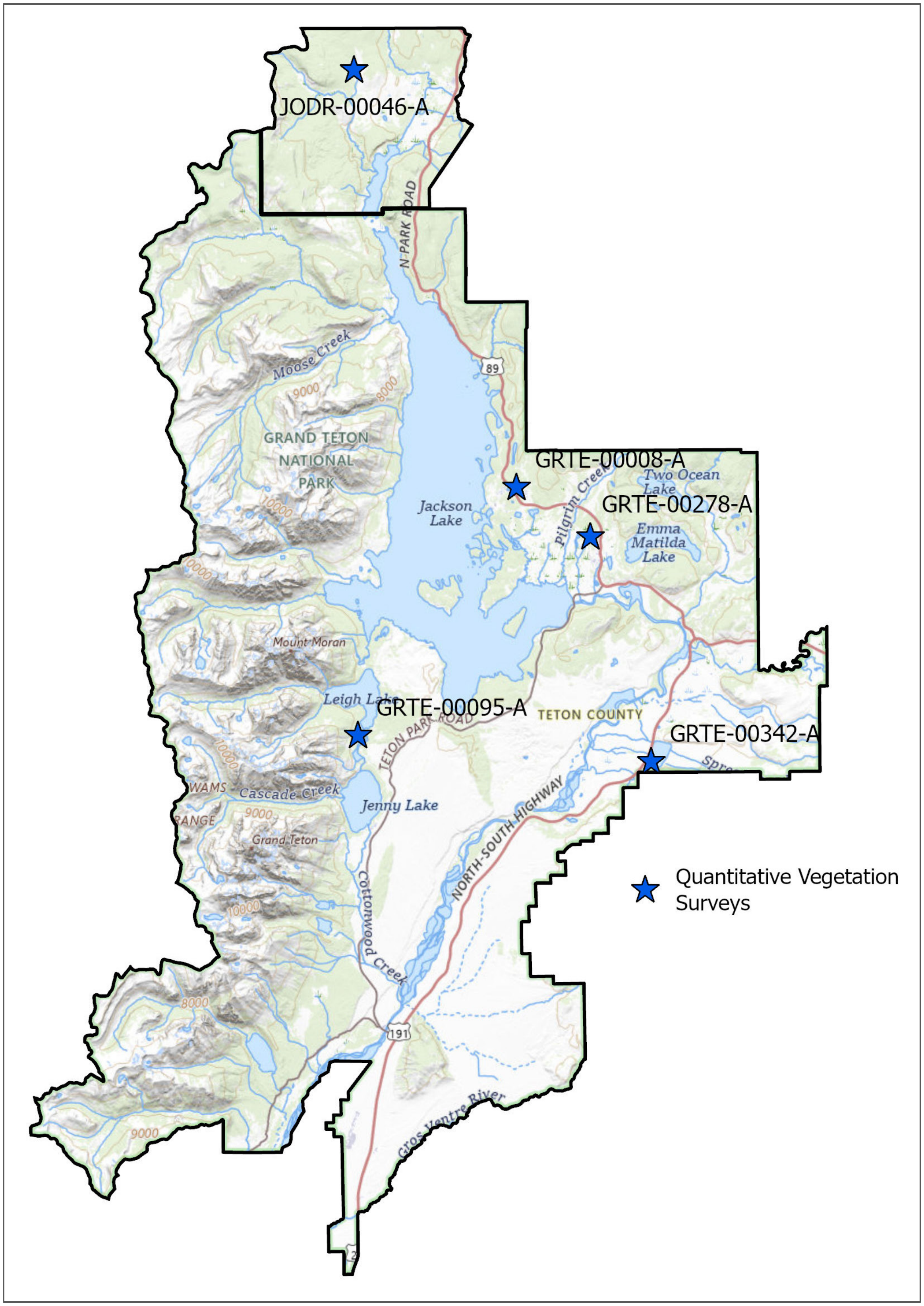

Figure 6. Confirmed fens sampled with quantitative vegetation data collection.
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For each quantitative vegetation survey, an 80 m ×80 m square was delineated near the polygon center. Following guidance in the USFS GDE Level II Field Guide, four 80-m transects were established perpendicular to the long axis of each site at 18-m intervals. The location of the first transect was determined randomly. Along each transect, six 0.5 m x 0.5 m quadrats were used to record the presence and cover of vascular plant species and ground covers. Quadrats were spaced 14 m apart, and the first was randomly located within the first 14 m of the transect. Within each quadrat, the presence of all species observed was recorded, and their absolute canopy cover was estimated. Including all species in the quadrats was a deviation from the USFS Level II Field Guide, which specifies a line intercept for woody cover and a belt transect for tree diameter at breast height (DBH). The modification was made because most shrub species in fens grow as short-statured individuals and trees are not common. Collecting data on all species within the quadrats eliminates the need to carry out additional passes of the transect for woody cover and tree DBH. In addition to recording species presence and cover, the cover of all bryophytes was recorded. Ground cover was determined by identifying ground cover elements located at the four corners of the quadrat, where a pin flag was placed along the inside corner of the quadrat frame and the substrate the pin touches was recorded.

A rapid site evaluation search for all dominant and targeted vascular plant species (see section above) was also carried out for the whole site. This search was conducted prior to collecting data on the transects to familiarize technicians with the dominant species that might be observed in the transects.

Rare Vascular Plant Surveys

In addition to documenting the dominant species in all confirmed fens, crews specifically searched the areas within and adjacent to any potential fen polygons visited for species on the targeted fen-indicator species list (Appendix A). Crews were trained in advance to identify the targeted species and used available information about known populations to help guide the search. Some rare plants were easily identifiable, and others were more difficult. In addition, some rare plants occurred in larger populations, and some occurred as scattered individuals. In the rapid site evaluation, crews limited the additional search time for targeted species to 30 minutes per polygon unless the polygon was large or contained a known targeted species population. When searching for rare species, the crew walked the full polygon, focusing on each different habitat that may support rare species. When a targeted species was identified, the crew collected photos and additional information about the population size and phenology in order to update element occurrence records within the WYNDD database of rare plants. Voucher specimens were collected if the population was large and/or if confirmation of identification was necessary. All physical specimens collected will remain the property of the NPS.

Data Analysis

Post-Field Verification Mapping Revisions and Final Fen Polygons

After all field data were collected, image analysts revisited all potential fen polygons and revised confidence ratings and fen boundaries based on the field data. These revisions expanded the original fen confidence rating by adding a 7 for confirmed fens with > 40 cm of organic soil (peat), a 6 for confirmed peat-accumulating wetlands with organic soil material between 10–40 cm, and a 0 for sites with little to no organic soil material (Table 3). In addition, one fen on the boundary between JODR and Yellowstone National Park sampled in 2005 (Lemly 2007) was classified as a confirmed fen. Vegetation plots sampled in 2002 and 2003 for the GRTE Vegetation Mapping Project (Cogan et al. 2005) were reviewed to determine if any vegetation plots that strongly indicated fens overlapped with unverified potential fen polygons. If so, they were classified as likely fens. All polygons confirmed as non-fens were retained in the dataset to clearly show areas that had been considered and were determined not to be fen. Negative data can be as valuable as the confirmation of fens. However, polygons that were not visited, but shared characteristics of confirmed non-fens were removed from the dataset altogether.

Table 3. Confidence levels in the revised map of confirmed and potential fens.

Confidence	Description
7	Confirmed fen. Site was visited in the field either through this sampling effort or another highly reputable sampling effort. Site is confirmed to be a fen with > 40 cm of peat soil.
6	Confirmed peat-accumulating wetland. Site was visited in the field. Shallow peat soil < 40 cm was observed. Site is not a fen but confirmed as a peat-accumulating wetland.
5	Likely fen. Strong photo signature of fen vegetation (brownish-green colors, mottled texture), fen hydrology (small areas of open water, saturated soils), and good landscape position (base of slope or depression). All likely fens should contain peat of 40 cm or more throughout the entire area of the mapped feature.
3	Possible fen. Some fen indicators are present (vegetation signature, topographic position, ponding or visibly saturated substrate), but not all indicators are present. Some indicators may be weak or missing. Possible fens may or may not have the required peat depth of 40cm but may have patchy or thin peat throughout.
1	Low confidence fen. At least one fen indicator is present, but weak. Low confidence fens are saturated wetland areas that do not show peat signatures in aerial photography but may contain fen or peat.
0	Confirmed non-fen wetland, no peat observed. Site was visited in the field and was determined to have < 10 cm organic soil material.

GIS Analysis of Confirmed and Likely Fens

To interpret and provide context to the data, several analyses were conducted in GIS using the confirmed fens, confirmed peat-accumulating wetlands, and likely fens (collectively referred to as "confirmed and likely fens") along with ancillary data sources. We examined the geographic distribution of these fens by watershed, elevation, mapped vegetation type, and geology. Most analyses were carried out as simple intersects in GIS using the centroids of all confirmed and likely fens and ancillary data layers. Along with GIS analyses, the results section also includes summaries of observations made by the fen mappers during the mapping process.

Analysis of Field Data

Field collected data were analyzed using several different approaches. 1) Occurrences of rare fen-indicator species on the target list were summarized and will be shared with WYNDD to update their information on rare species. 2) Metrics of vegetation composition and cover, including species richness, floristic quality, and cover of various species groups (shrubs, graminoids, forbs, annuals, perennials, native vs. nonnative species, hydrophytic species) were calculated from the rapid site evaluations. Floristic quality was assessed using 'coefficients of conservatism' or C-values, which are numerical ratings (0–10) applied to each species within a state's flora that indicate the species' fidelity to natural habitats and tolerance or intolerance to disturbance (Swink & Wilhelm 1994; Wilhelm & Masters 1996). C-values for Wyoming were assigned by a group of botanical experts convened by WYNDD (Washkoviak et al. 2017). 3) Water quality measurements were summarized and described in the context of the poor to rich gradient of peatland water chemistry (Wheeler & Proctor 2000; Malmer 1986). 4) Species data were related to environmental gradients using a non-metric multidimensional scaling (NMDS) ordination in the *vegan* package in R. Because these data were collected in a rapid survey, they should be regarded as illustrating major trends of common species and assemblages but not precise measurements. 5) Data from quantitative vegetation surveys were also analyzed for composition and cover. Species lists and photographs of each confirmed fen are available in the NPS DataStore (https://irma.nps.gov/DataStore/Reference/Profile/2309743). A compilation of all data for each rare fen-indicator species observed is also available (https://irma.nps.gov/DataStore/Reference/Profile/2309746).

Results

Final Map of Confirmed and Potential Fens

The preliminary mapping phase resulted in 906 potential fen polygons delineated within GRTE and JODR covering 5,208 acres (Table 4). During field verification, crews assessed 102 polygons (11% of polygons, but a much larger share of acreage). Within the 102 polygons visited, crews confirmed 40 fens with > 40 cm of organic soil (confidence level = 7), and 28 peat-accumulating wetlands with 10–40 cm of organic soil (confidence level = 6). One additional polygon on the border of JODR and Yellowstone National Park was designated as a confirmed fen based on a previous study. In some instances, more than one discrete area of fen and/or peat-accumulating wetland was confirmed within a single large potential fen polygon. When this was the case, the boundary of the fen or peat-accumulating wetland was delineated from within the larger polygons and the remaining portion of the polygon was designated as a confirmed non-fen. This resulted in more than one confirmed fen or peat-accumulating wetland with the same code, distinguished with a letter (A, B or C). For example, GRTE-00278 was a very large potential fen polygon in the Willow Flats area. When visited in the field, three distinct areas of organic soil were identified within GRTE-00278 and delineated as confirmed fens labeled GRTE-00278-A, GRTE-00278-B, and GRTE-00278-C. Areas within the original polygon GRTE-00278 with no organic soil were classified as confirmed non-fen.

Table 4. Initial potential fens mapped within GRTE and JODR.

Park Unit	Confidence	Number	Total Acres	Average Size (acres)
TOTAL	5 - Likely fens	107	854	8.0
	3 - Possible fens	253	1,586	6.3
	1 - Low confidence fens	546	2,768	5.1
	Total	906	5,208	5.7

The final map contained 925 polygons covering 4,911 acres (Table 5). Excluding the confirmed non-fens, the map contained 877 confirmed and potential fens covering 3,431 acres (Figure 7). Forty-one confirmed fens covered 285 acres within GRTE and 173 acres within JODR. Twenty-eight confirmed peat-accumulating wetlands covered another 299 acres in GRTE and 46 acres in JODR. The average size of both confirmed fens (11.2 acres) and confirmed peat-accumulating wetlands (12.3 acres) was larger than other confidence levels, except for the confirmed non-fens (30.8 acres). The largest potential fen polygons were located along the main park road in the vicinity of Colter Bay or Willow Flats, and these large polygons were a priority for sampling. Additional large polygons were located in JODR and were also a priority for sampling. Focusing on larger polygons allowed the crew to assess 2,283 acres or nearly 45% of the originally mapped acres.

Table 5. Final confirmed and potential fens mapped within GRTE and JODR.

Park Unit	Confidence [A]	Number	Total Acres	Average Size (acres)
GRTE	7 - Confirmed fens	25	285	11.4
	6 - Confirmed peat-accum. wetlands	18	299	16.6
	5 - Likely fens	40	135	3.4
	3 - Possible fens	165	556	3.4
	1 - Low confidence fens	354	1,149	3.2
	0 - Confirmed non-fens	34	1,434	42.2
	Total	636	3,858	6.1
JODR	7 - Confirmed fens	16	173	10.8
	6 - Confirmed peat-accum. wetlands	10	46	4.6
	5 - Likely fens	35	78	2.2
	3 - Possible fens	65	299	4.6
	1 - Low confidence fens	149	411	2.8
	0 - Confirmed non-fens	14	46	3.3
	Total	289	1,053	3.6
TOTAL	7 - Confirmed fens	41	458	11.2
	6 - Confirmed peat-accum. wetlands	28	345	12.3
	5 - Likely fens	75	213	2.8
	3 - Possible fens	230	855	3.7
	1 - Low confidence fens	503	1,560	3.1
	0 - Confirmed non-fens	48	1,480	30.8
	Total	925	4,911	5.3

[A] Additional detail is provided in the following sections on confirmed fens, confirmed peat-accumulating wetlands, and likely fens. These wetlands are collectively called “confirmed and likely fens.”

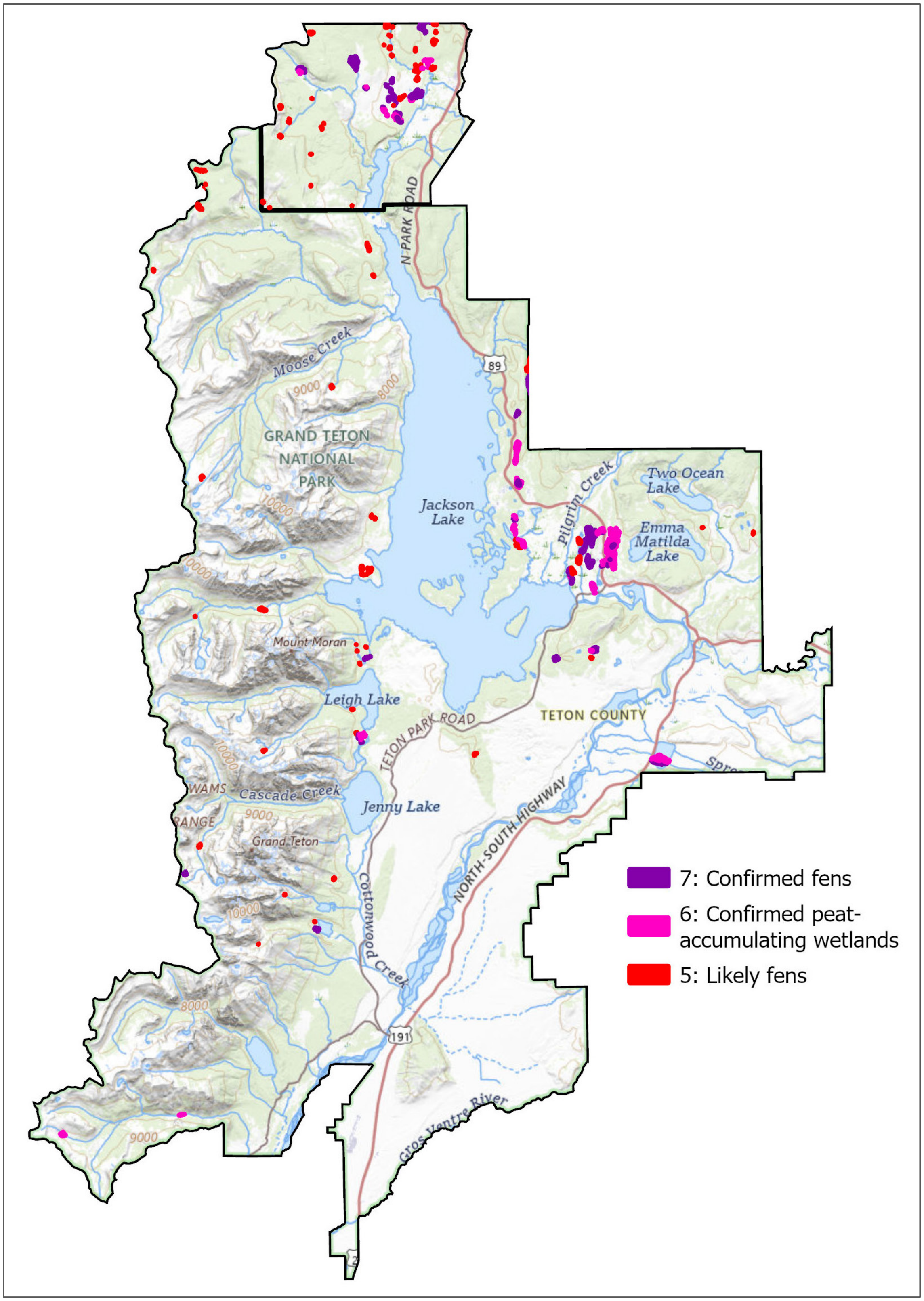

Figure 7. Confirmed and likely fens mapped within GRTE and JODR. Polygon boundaries exaggerated to visually highlight the locations.

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In addition to confirmed fens and confirmed peat-accumulating wetlands, another 75 polygons were considered likely fens (confidence level = 5) due to their landscape position, aerial photo signature, and known plant populations, but were unable to be visited for confirmation (Table 5). Likely fens covered 213 acres across GRTE and JODR. In the following analyses, we grouped confirmed fens, confirmed peat-accumulating wetlands, and likely fens as the wetlands of greatest management interest to GRTE and JODR, and we referred to these collectively as "confirmed and likely fens." Impacts to these 144 wetlands, which cover 1,016 acres, should be avoided.

Another 733 polygons covering 2,415 acres were considered possible or low confidence fens (confidence levels = 3 or 1). These polygons could not be ruled out by remote observation or through aerial image interpretation but are not as likely to be fens as the 144 confirmed and likely fens. Through field observation, 48 polygons covering 1,480 acres were confirmed as non-fens (confidence level = 0) and approximately 90 polygons from the original mapping were removed entirely. Although they were not visited, they matched other areas that were confirmed to be non-fens.

Confirmed and Likely Fens by Watershed, Elevation, Vegetation Type, and Geology

Watershed

Fen distribution with GRTE and JODR was not uniform. Confirmed and likely fens were concentrated in specific areas of the parks (Table 6; Figure 8). Three watersheds stood out for their high number of these features. Lower Jackson Lake (HUC12: 170401010409) in GRTE had 27 confirmed and likely fens covering 461.3 acres. In JODR, Sheffield Creek-Snake River (HUC12: 170401010402) had 38 confirmed and likely fens covering 223.9 acres and Polecat Creek (HUC12: 170401010401) had 22 covering 79.4 acres. These three watersheds alone comprised 60% of individual confirmed and likely fen polygons and 75% of acres. Sorted by acreage, Elk Ranch Reservoir-Snake River (HUC12: 170401010604) was also significant with 7 polygons covering 90.8 acres.

Table 6. Confirmed and likely fens mapped within GRTE and JODR, coded by HUC12 watershed.

Park Unit	HUC12 Watershed Code	HUC12 Watershed Name	Confirmed and Likely Fens	
			Count	Acres
GRTE	170401010304	Lower Pacific Creek	1	0.8
	170401010403	Berry Creek	8	18.2
	170401010404	Moose Creek	3	6.5
	170401010405	Arizona Creek	3	8.0
	170401010406	Upper Jackson Lake	5	27.7
	170401010407	Moran Creek	11	35.4
	170401010408	Pilgrim Creek	1	9.6
	170401010409	Lower Jackson Lake	27	461.3

Table 6 (continued). Confirmed and likely fens mapped within GRTE and JODR, coded by HUC12 watershed.

Park Unit	HUC12 Watershed Code	HUC12 Watershed Name	Confirmed and Likely Fens	
GRTE (cont.)	170401010604	Elk Ranch Reservoir-Snake River	7	90.8
	170401010605	Leigh Lake	8	21.4
	170401010606	Jenny Lake	2	7.6
	170401010607	Cottonwood Creek	5	12.3
	170401030501	Lake Creek	3	13.1
	GRTE total	–	83	718.6
JODR	170401010401	Polecat Creek	22	79.4
	170401010402	Sheffield Creek-Snake River	38	223.9
	JODR total	–	61	297.4
TOTAL	–	–	144	1,016.0

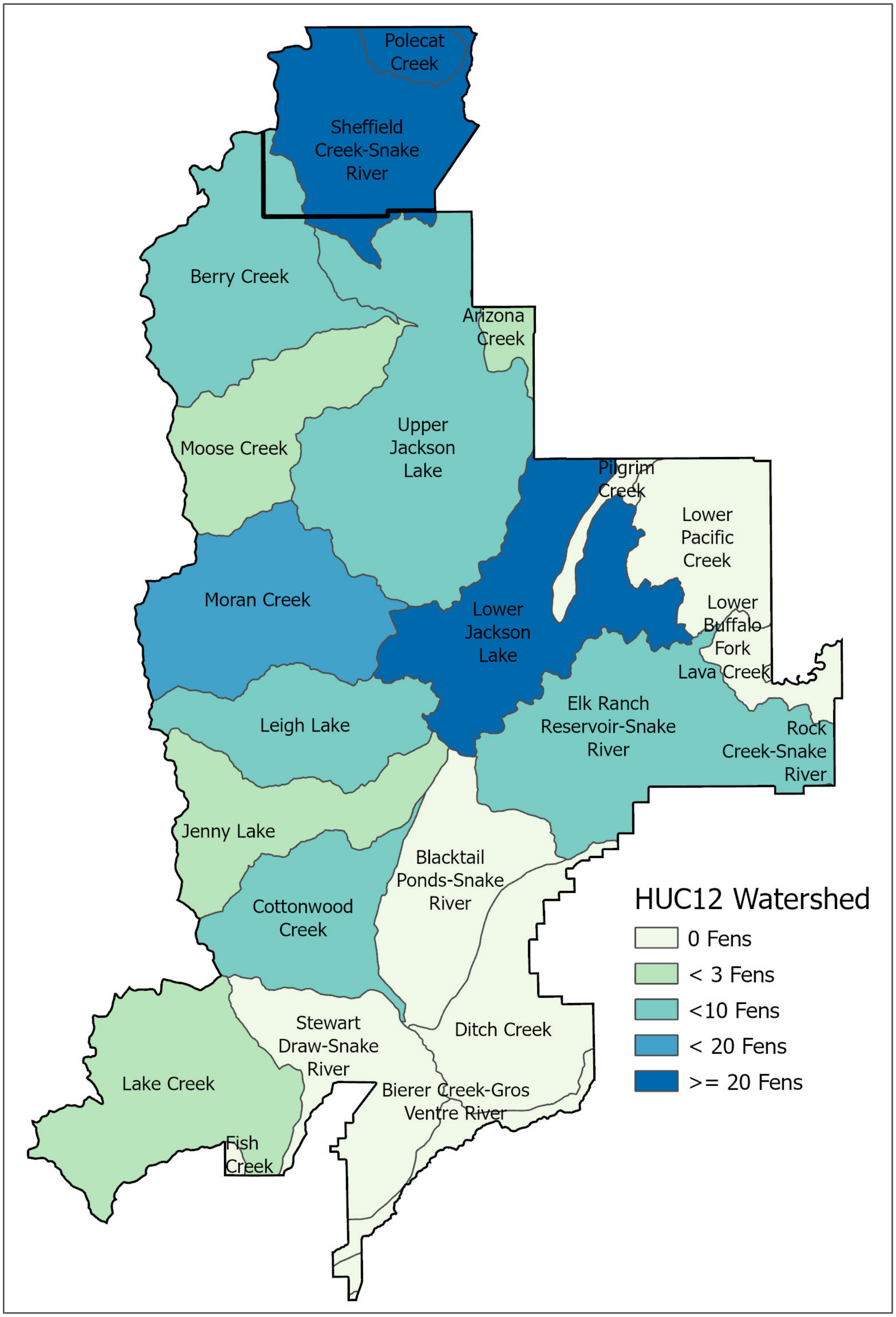

Figure 8. Density of confirmed and likely fens mapped within GRTE and JODR by HUC12 watershed.
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Elevation

From a large-scale, regional perspective, elevation is often an important factor in the location of fens. Fens form where there is sufficient groundwater discharge to maintain permanent saturation. This is most often at higher elevations, where slow melting snowpack can percolate into subsurface groundwater. However, on a local scale in GRTE and JODR, confirmed and likely fens were not concentrated in mountainous areas of the parks. Instead, confirmed and likely fens were concentrated at elevations below 2,150 m (7,054 ft) (Table 7), either in the glacial outwash surrounding Jackson Lake in GRTE or on the edge of the Yellowstone volcanic field in JODR. Of the 144 confirmed and likely fens, the majority (105 polygons or 73%) occurred below 2,150 m. The pattern was the same for both the number of fens and the acreage (Figure 9). At the other end of the elevation range, there were clusters of likely fens at higher elevations above 2,400 m (7,874 ft) (Figure 10). These were smaller in size and scattered in benches between the mountain peaks. Crews were unable to verify many high elevation polygons because they were far from roads and required multi-day trips. On one backpacking trip up Granite Creek, CNHP crews confirmed three peat-accumulating wetlands, but no fens with deeper organic soil. On another trip, NPS staff confirmed one fen below Hurricane Pass.

Table 7. Confirmed and likely fens mapped within GRTE and JODR by elevation bands.

	Confirmed and Likely Fens	
Elevation Range (m / ft)	**Count**	**Acres**
<2100 m / <6726 ft	68	718.0
2100–2150 m / 6726–7054 ft	37	143.7
2150–2200 m / 7054–7218 ft	8	78.3
2200–2250 m / 7218–7382 ft	1	0.6
2250–2300 m / 7382–7546 ft	4	6.4
2300–2350 m / 7546–7710 ft	2	12.6
2350–2400 m / 7710–7874 ft	3	4.8
>2400 m / 7874 ft	21	51.6
TOTAL	144	1016.0

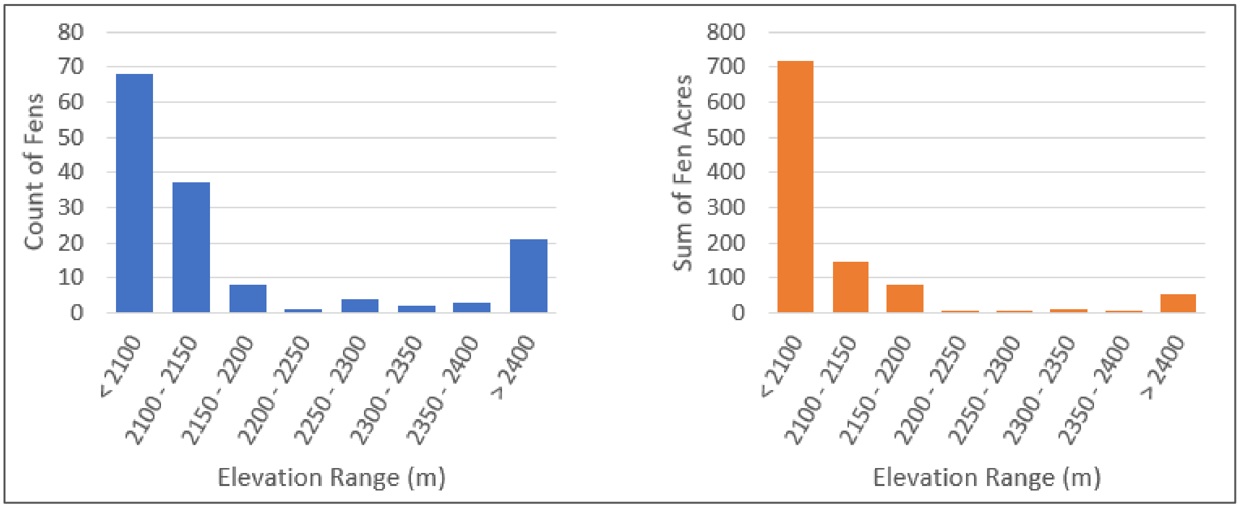

Figure 9. Histograms of confirmed and likely fens mapped within GRTE and JODR by elevation showing count (left) and acres (right).

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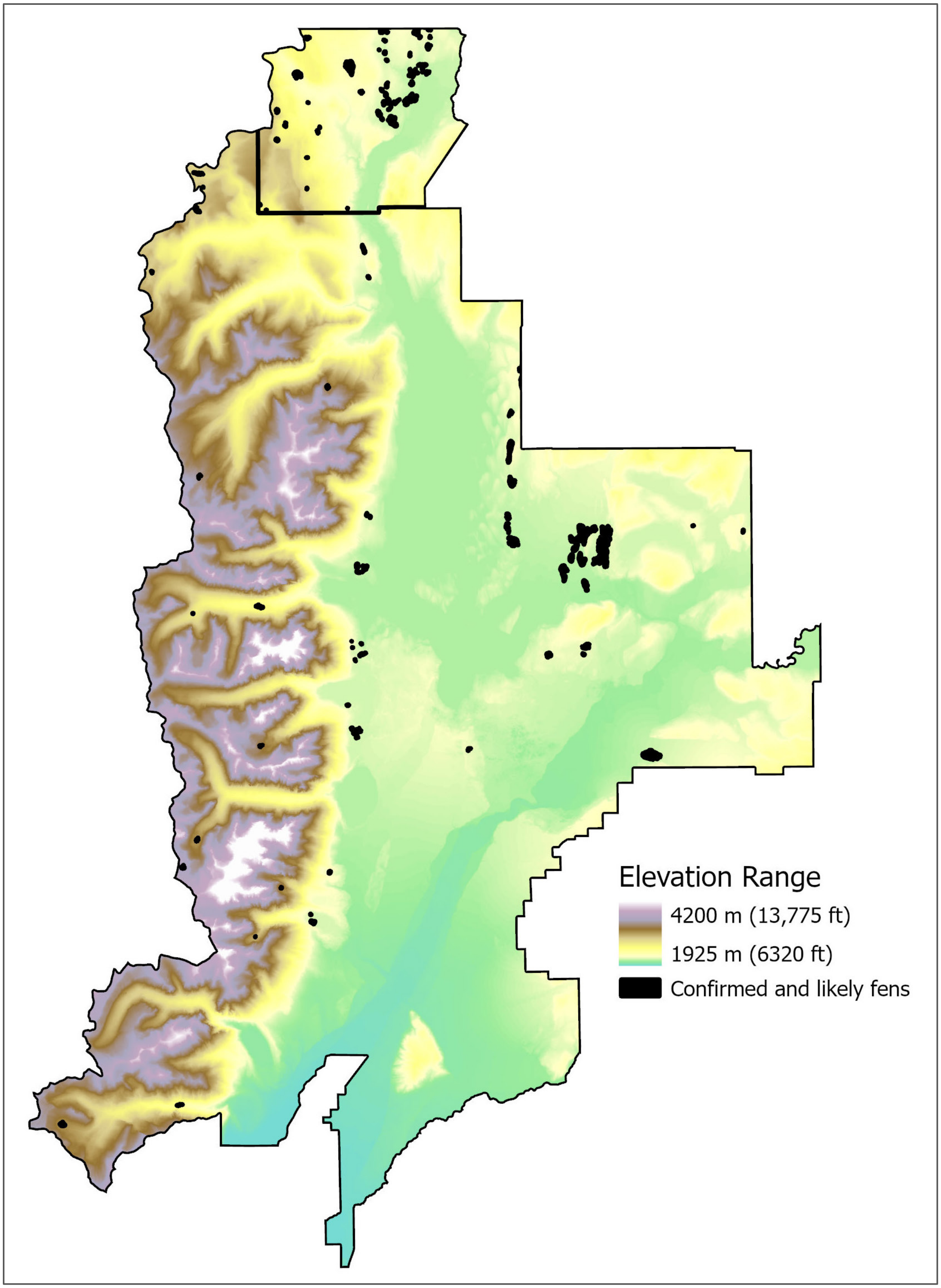

Figure 10. Confirmed and likely fens mapped within GRTE and JODR by elevation. Polygon boundaries exaggerated to visually highlight the locations.

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Geology

The most common geologic unit under confirmed and likely fens in both GRTE and JODR was Holocene age swamp deposits (Table 8). A geologic unit specific to wetland soils acknowledges the size and longevity of wetlands within the parks. This unit covers 2.0% of the park units but underlies 42% of confirmed and likely fens and 75% of the acreage. Many other common geologic units below confirmed and likely fens include units related to Pleistocene glaciation, specifically debris from the Jackson Lake moraine, debris from the Burned Ridge moraine, and glacial drift, as well as more recent alluvial floodplain deposits. Only a few of the confirmed and likely fens occurred on bedrock types of rhyolite, tuff, quartzite, or sandstone.

Table 8. Confirmed and likely fens mapped within GRTE and JODR by geologic unit.

Park Unit	Geologic Unit Code	Geologic Unit Name	Confirmed and Likely Fens	
			Count	**Acres**
GRTE	Qs	Swamp deposits (Holocene)	41	583.2
	Water	Water	11	27.2
	Qg4j	Debris of the Jackson Lake moraine (Pleistocene)	9	33.4
	Qg4	Drift (Pleistocene)	5	12.9
	Qa	Alluvium, gravel, and sand, and floodplain deposits (Holocene)	4	23.0
	Qf	Alluvial-fan deposits (Holocene and Pleistocene)	3	21.0
	QTgd	Glacial drift (Pleistocene and/or Pliocene)	2	0.9
	Xmo	Mount Owen Quartz Monzonite and associated pegmatite (early Proterozoic)	2	5.4
	Qg4b	Debris of the Burned Ridge moraine (Pleistocene)	1	0.8
	Thb	Huckleberry Ridge Tuff, Member B (Pliocene)	1	0.8
	Qtg	Terrace gravel (Pleistocene)	1	5.0
	Wgm	Layered gneiss and migmatite (late Archean)	1	3.0
	PNMta	Tensleep Sandstone and Amsden Formation (Pennsylvanian and Mississippian)	1	1.6
	Qt	Talus and related deposits (Holocene and Pleistocene)	1	0.3
	GRTE total	–	83	718.6
JODR	Qs	Swamp deposits (Holocene)	20	176.7
	Qag	Alluvium and glaciofluvial deposits (Holocene and Pleistocene)	15	60.1
	QTgd	Glacial drift (Pleistocene and/or Pliocene)	8	10.3
	Qg4j	Debris of the Jackson Lake moraine (Pleistocene)	6	19.0
	Qlc	Lewis Canyon Rhyolite (Pleistocene)	3	10.6
	Kf	Frontier Formation (Cretaceous)	2	3.2
	Water	Water	2	7.0
	Qls	Landslide debris (Holocene and Pleistocene)	2	3.7

Table 8 (continued). Confirmed and likely fens mapped within GRTE and JODR by geologic unit.

Park Unit	Geologic Unit Code	Geologic Unit Name	Confirmed and Likely Fens	
			Count	Acres
JODR (cont.)	Tha	Huckleberry Ridge Tuff, Member A (Pliocene)	1	0.9
	Qa	Alluvium, gravel, and sand, and floodplain deposits (Holocene)	1	5.1
	Thb	Huckleberry Ridge Tuff, Member B (Pliocene)	1	0.9
	JODR total	–	61	297.4
TOTAL	–	–	144	1,016.0

Vegetation Type

Confirmed and likely fens primarily fell within two vegetation types from the GRTE vegetation map: 'Flooded Wet Meadow Herbaceous Vegetation' and 'Willow Shrubland' (Table 9). Willow shrublands were much more common for fens in GRTE than JODR, where the fens were almost entirely herbaceous. Eleven confirmed and likely fens were mapped over the 'Lakes and Reservoirs' vegetation type. Many of those were floating mat fens within or surrounded by water. Other vegetation types contained five or fewer polygons. These wetlands were likely too small to be mapped separately in the vegetation map. Notably, four polygons were mapped in an area of 'Recently Burned Sparse Vegetation.' When observed in the 2023 field season, these wetlands maintained vigorous plant growth while the surrounding landscape was clearly impacted by past fire.

Table 9. Confirmed and likely fens mapped within GRTE and JODR by vegetation type.

Park Unit	General Vegetation Type	Vegetation Common Name	Confirmed and Likely Fens	
			Count	Acres
GRTE	Dwarf Shrubland	Arctic Willow Dwarf Shrubland	1	4.3
	Coniferous Woodland	Subalpine Fir - Engelmann Spruce Forest	3	1.2
	Coniferous Woodland	Douglas-fir Forest	1	15.4
	Coniferous Woodland	Lodgepole Pine Forest	2	0.7
	Upland Shrubland	Ceanothus Shrubland	1	0.5
	Upland Grassland	Mixed Grassland Herbaceous Vegetation	1	1.6
	Xeric Herbaceous Vegetation	Montane Xeric Forb Herbaceous Vegetation	1	0.3
	Riparian Shrubland	Willow Shrubland	21	313.8
	Mesic Herbaceous Vegetation	Alpine Mesic Meadows	1	3.0
	Mesic Herbaceous Vegetation	Subalpine Mixed Herbaceous Vegetation	5	17.6
	Mesic Herbaceous Vegetation	Montane Mesic Forb Herbaceous Vegetation	1	0.8

Table 9 (continued). Confirmed and likely fens mapped within GRTE and JODR by vegetation type.

Park Unit	General Vegetation Type	Vegetation Common Name	Confirmed and Likely Fens	
			Count	Acres
GRTE (cont.)	Mesic Herbaceous Vegetation	Flooded Wet Meadow Herbaceous Vegetation	34	331.5
	Unvegetated Surface	Lakes and Reservoirs	11	28.1
	GRTE total	–	83	718.6
JODR	Coniferous Woodland	Subalpine Fir - Engelmann Spruce Forest	2	53.8
	Upland Grassland	Mixed Grassland Herbaceous Vegetation	1	0.8
	Xeric Herbaceous Vegetation	Recently Burned Sparse Vegetation	4	10.1
	Riparian Shrubland	Willow Shrubland	1	0.4
	Mesic Herbaceous Vegetation	Flooded Wet Meadow Herbaceous Vegetation	52	230.7
	JODR total	–	61	297.4
TOTAL	–	–	144	1,016.0

Eighteen vegetation plots sampled in 2002 or 2003 for the GRTE vegetation mapping project overlapped with confirmed and likely fens. Those plots were classified by the vegetation mapping project into the following plant associations, each followed by the number of plots in parentheses:

- *Carex aquatilis* Herbaceous Vegetation (1)
- *Carex microptera* Herbaceous Vegetation (1)
- *Carex utriculata* Herbaceous Vegetation (5)
- *Dasiphora floribunda* / *Carex* spp. Shrubland (1)
- *Deschampsia caespitosa* Herbaceous Vegetation (2)
- *Menyanthes trifoliata* Herbaceous Vegetation (1)
- *Nuphar lutea* ssp. *polysepala* Herbaceous Vegetation (2)
- *Pinus contorta* / *Calamagrostis canadensis* Forest (1)
- *Salix boothii* / *Carex utriculata* Shrubland (1)
- *Salix drummondiana* / Mesic Forbs Shrubland (1)
- *Salix wolfii* / *Deschampsia caespitosa* Shrubland (1)
- *Salix wolfii* / Mesic Forbs Shrubland (1)

Notable Mapped Fens

The largest confirmed fen in GRTE was GRTE-00278-B, located in Willow Flats in the outwash of Pilgrim Creek, immediately west of Hwy 89, North Park Road (Figure 11). This 80-acre fen was embedded within a much larger wetland complex with several individual areas of fen, areas of shallow peat accumulation, and other wetland areas with mineral soil. The wetland was bisected to the west by the Willow Flats Trail, a historical road now used as a service road and trail. It is very likely that the original construction of this road impacted the hydrology of the fen, but the observed impact was relatively minor and localized given the size of the wetland. The largest confirmed fen in JODR was JODR-00046-A, located within Lewis Canyon rhyolite on the edge of the Yellowstone volcanic field (see Figure 4 above). This 50-acre site was downstream of South Boundary Lake along an unnamed tributary that flows into Glade Creek and was on the edge of a past fire scar. Both large sites were sampled with quantitative surveys.

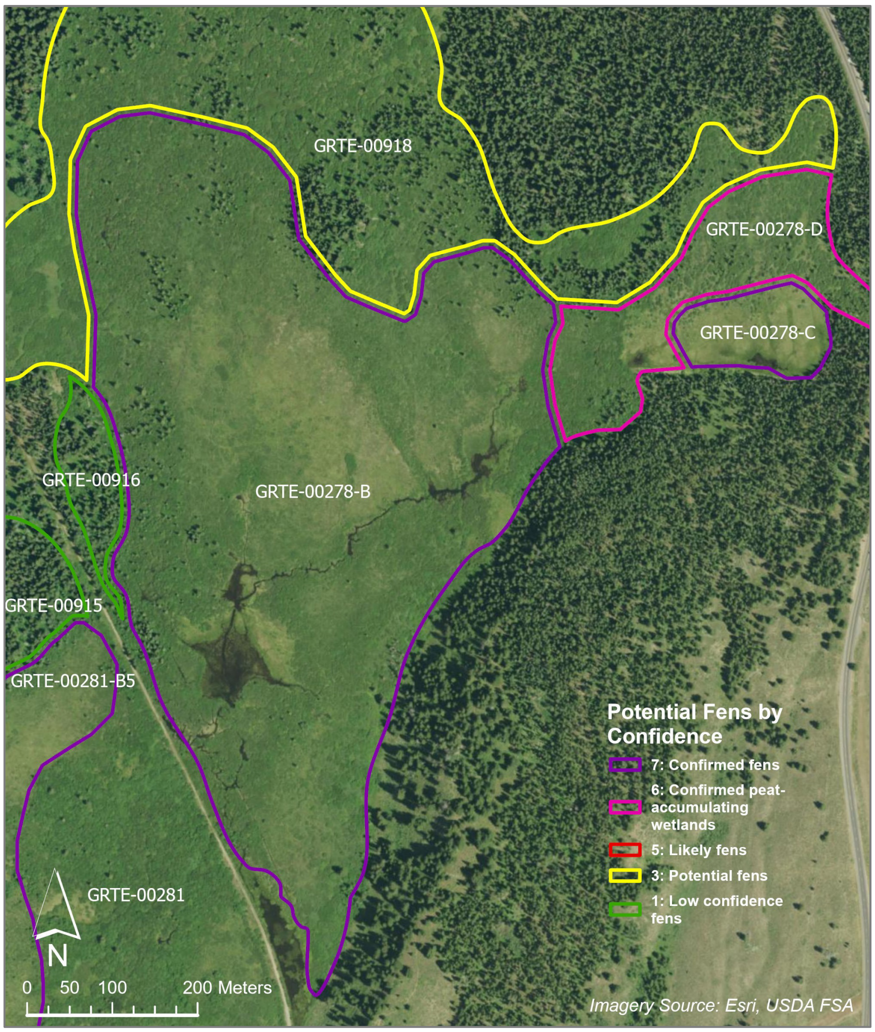

Figure 11. GRTE-00278-B. A large fen in Willow Flats bisected by a road.
NPS / CNHP

Several specific fen characteristics were noted by photo-interpreters (Table 10). Over 50 potential fens, mostly lower confidence sites, were identified as influenced by beaver. Beaver influence is a potentially confounding variable in fen mapping because longstanding beaver complexes can cause persistent saturation that appears like fen vegetation but often does not accumulate organic soil. However, beavers can build dams in fens, so areas influenced by beavers cannot be excluded from mapping.

Table 10. Confirmed and potential fens with distinctive characteristics mapped within GRTE and JODR.

	Confirmed and Potential Fens	
Characteristic	**Count**	**Acres**
Beaver influence	52	692.2
Floating mat	18	59.8
Potential rich fens	2	15.3
Spring	7	11.3

Floating mat fens are of particular interest for conservation. They are a unique kind of fen where at least 40 cm of peat forms above standing water, and they can support several vascular plant species considered rare in the Rocky Mountains. Several confirmed fens contained floating mats, most notably GRTE-00008 (Figure 12), located less than 250 m from the turn-off to Colter Bay Village. This large floating mat site was also sampled with a quantitative survey. In the full dataset, 18 potential fens of all confidence levels were mapped as potential floating mats.

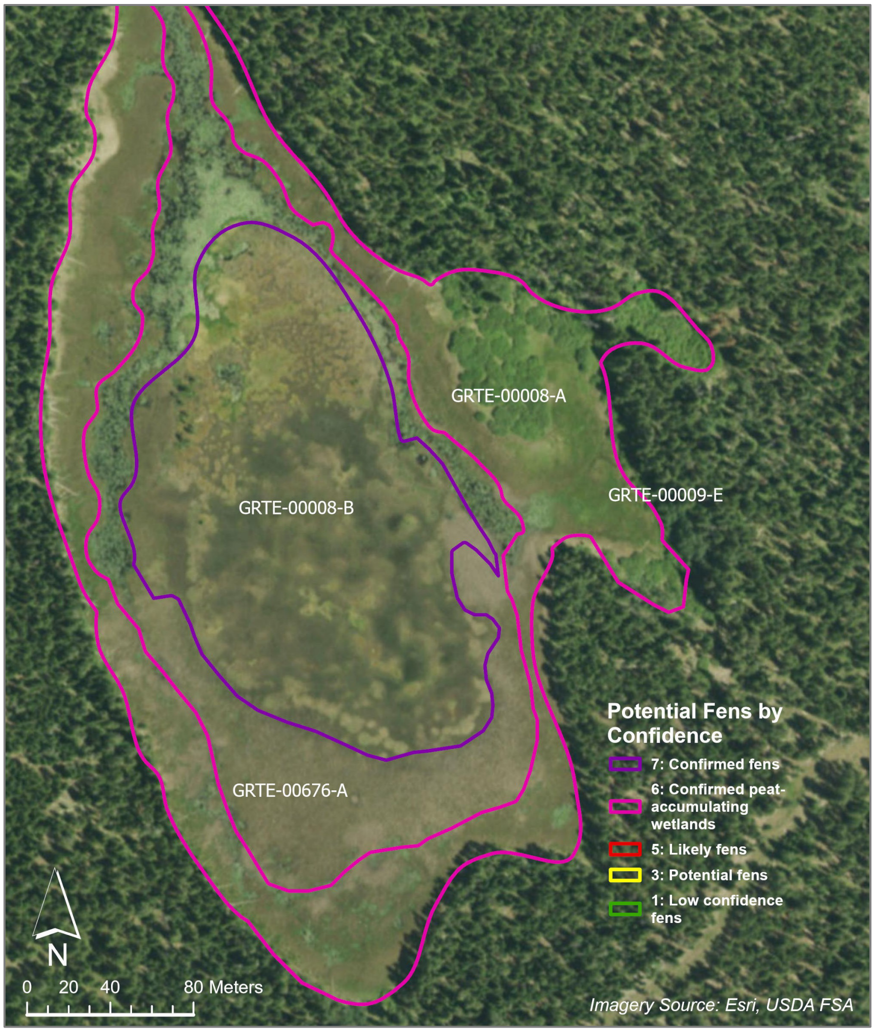

Figure 12. GRTE-00008. Large floating mat fen very close to Colter Bay Junction.
NPS / CNHP

At the outset of this project, NPS staff were particularly interested in identifying rich fens in GRTE or JODR. While most fens in the Rocky Mountains are rich fens from the international perspective (Wheeler & Proctor 2000; Malmer 1986), extreme rich fens are unique (Johnson & Steingraeber 2003; Cooper 1996). They are characterized by calcareous waters and often support rare calcium-adapted plant species. The water chemistry of extreme rich fens is influenced by surrounding sedimentary bedrock, such as limestone or dolomite, but can also be associated with glacial till (Lemly & Cooper 2011). During the mapping phase, we consulted the GRTE geologic map to identify potential fen polygons near the strongest sources of calcareous groundwater. Only two potential fens were identified in areas that might produce extreme rich fens. No confirmed fens contained species indicative of extreme rich fens; however, several fens matched the water chemistry profile of rich fens.

Springs and fens are both important types of groundwater-dependent ecosystems (GDEs). Discrete springs discharge points can be found within larger fen wetlands, but they can also occur independently with no organic soil accumulation. Springs were noted when observed on either the topographic map, aerial imagery, or if observed during field verification. Seven potential fens were observed in proximity to visible springs. This was not an exhaustive examination of springs within fens, as many springs are not visible from aerial imagery, though they can contribute to fen formation.

Rare Fen-Indicator Plant Species Observed

One hundred and twenty-seven populations of 23 rare fen-indicator plant species were observed either within or near confirmed fens or confirmed peat-accumulating wetlands (Table 11; Figure 13). We observed roughly one-third of the species on the target list (Appendix A). The species observed are all considered globally secure (G5) but rare within the state of Wyoming (S1, S2, or S3) based on conservation ranks assigned by NatureServe and WYNDD. Many fen-indicator plant species considered rare in the Rocky Mountains are common in northern latitudes but found in their far southern extent in Wyoming or Colorado. Fens in the southern Rocky Mountains serve as refuges for species that may have been more common at southern latitudes immediately following glaciation. All data on rare plant populations will be shared with WYNDD for entry in their database of known rare plant populations. Several populations were previously documented, but our data will update the last observation dates and provide more precise coordinates. Many populations were newly discovered, including three species not observed in GRTE or JODR.

Table 11. Rare fen-indicator plant species observed in and near confirmed fens.

Scientific Name	Common Name	# of Obs.	Wetland Status	C-Value	G Rank [A]	S Rank [A]
Botrychium multifidum	leathery grapefern	3	FAC	6	G5	S3
Carex buxbaumii	Buxbaum's sedge	13	OBL	8	G5	S3
Carex cusickii	Cusick's sedge	6	OBL	6	G5	S2
Carex diandra	lesser panicled sedge	4	OBL	8	G5	S2
Carex echinata	star sedge	8	OBL	8	G5	S2
Carex lasiocarpa	woollyfruit sedge	16	OBL	7	G5	S2
Carex limosa	mud sedge	2	OBL	8	G5	S3
Carex livida	livid sedge	4	OBL	8	G5	S3
Cicuta bulbifera	bulblet-bearing water hemlock	1	OBL	7	G5	S1
Comarum palustre	purple marshlocks	18	OBL	8	G5	S3
Drosera anglica	English sundew	7	OBL	9	G5	S3
Eriophorum angustifolium	tall cottongrass	5	OBL	8	G5	S3
Eriophorum chamissonis	Chamisso's cottongrass	4	OBL	8	G5	S3

[A] G and S Ranks indicate global and state rarity, as determined by the NatureServe Network and Wyoming Natural Diversity Database (WYNDD). Values updated February 12, 2025. More information is available at https://explorer.natureserve.org/AboutTheData/DataTypes/ConservationStatusCategories and https://www.uwyo.edu/wyndd/.

[B] Species is new record for GRTE or JODR.

Table 11 (continued). Rare fen-indicator plant species observed in and near confirmed fens.

Scientific Name	Common Name	# of Obs.	Wetland Status	C-Value	G Rank [A]	S Rank [A]
Eriophorum gracile	slender cottongrass	3	OBL	9	G5	S3
Eriophorum scheuchzeri [B]	white cottongrass	3	OBL	9	G5	S2
Juncus brevicaudatus [B]	narrowpanicle rush	7	OBL	7	G5	S3
Juncus filiformis	thread rush	1	FACW	7	G5	S2
Menyanthes trifoliata	buckbean	6	OBL	8	G5	S3
Potamogeton epihydrus	ribbonleaf pondweed	6	OBL	7	G5	S2
Scheuchzeria palustris	rannoch-rush	1	OBL	9	G5	S1
Sparganium natans	small bur-reed	4	OBL	6	G5	S3
Symphyotrichum boreale [B]	northern bog aster	1	OBL	7	G5	S3
Utricularia minor	lesser bladderwort	5	OBL	8	G5	S3

[A] G and S Ranks indicate global and state rarity, as determined by the NatureServe Network and Wyoming Natural Diversity Database (WYNDD). Values updated February 12, 2025. More information is available at https://explorer.natureserve.org/AboutTheData/DataTypes/ConservationStatusCategories and https://www.uwyo.edu/wyndd/.

[B] Species is new record for GRTE or JODR.

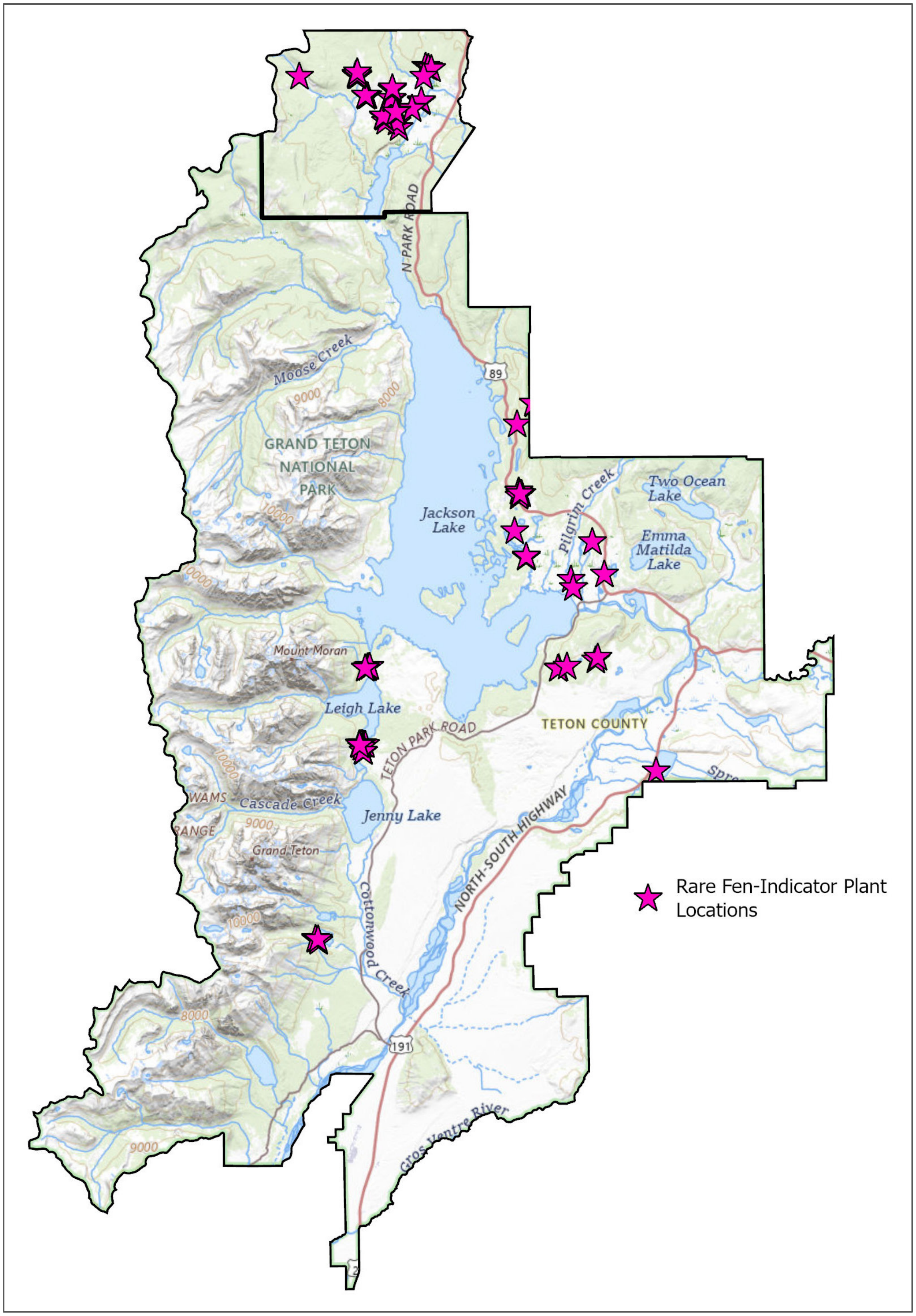

Figure 13. Locations of rare fen-indicator plant species observed in GRTE and JODR.
NPS / CNHP

Characteristics of Confirmed Fens Surveyed with Rapid Site Evaluations

Rapid site evaluations were conducted in 38 confirmed fens across GRTE and JODR (Figure 14; Table 12). The two confirmed fens not sampled were near other sampled sites and shared similar characteristics. Of the 38 sampled fens, 31 were considered basin fens, formed in a topographic low in the landscape that restricted water flow. Basin fens are more likely to form floating mats than other landform types, although not all basin fens contain a floating mat. Only seven fens were considered gently sloping fens, with unidirectional downslope flow of groundwater. Nearly all sampled fens were located between 2067–2173 m (6780–7130 ft) in elevation and located on Quaternary glacial, alluvial, or swamp deposits. One fen was sampled at 3048 m (10,000 ft) below Hurricane Pass on more ancient igneous rock. Peat depth at sampled sites was estimated to range from 40 cm (the minimum depth for a confirmed fen) to over 140 cm. True peat depth could not be determined from the methods in this study. Bryophyte abundance ranged from none to very abundant. Detailed data on all confirmed fens can be found on the NPS DataStore (https://irma.nps.gov/DataStore/Reference/Profile/2309743).

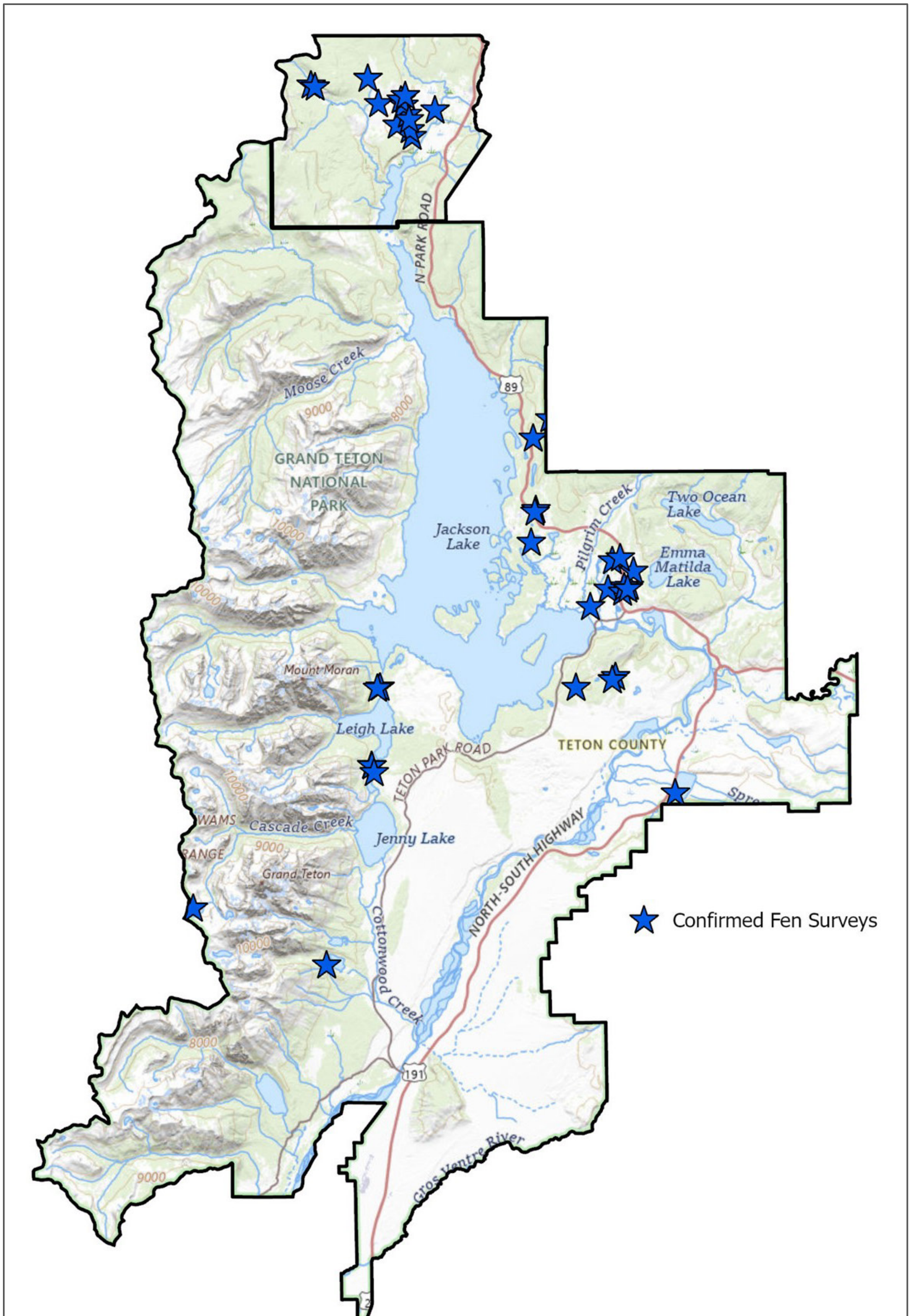

Figure 14. Confirmed fens surveyed with a rapid site evaluation in GRTE and JODR. Symbols are overlapping where multiple fens occur in the same vicinity.
NPS / CNHP

Table 12. Characteristics of confirmed fens.

Site ID	Elevation (m)	Landform	Geology [A]	Peat Depth (cm)	pH	Specific Conduct (µS)	Bryophyte abundance
GRTE-00001-A	2123	Basin	Qs	65.0	5.9	75	Minor
GRTE-00008-A	2093	Basin	Qa	143.3	6.3	24	Abundant
GRTE-00008-B	2096	Basin	Qa	NA	NA	NA	None
GRTE-00036-A	2099	Basin	Qs	65.7	NA	NA	Minor
GRTE-00091-A	2089	Basin	Qg4j	69.3	5.51	64	Minor
GRTE-00092-A	2092	Basin	Qg4j	70.2	7.53	31	Minor
GRTE-00095-A	2098	Basin	Qs	61.0	6.39	48	Common
GRTE-00099-A	2102	Basin	Qs	65.0	6.73	48	Common
GRTE-00104-A	2109	Gentle slope	Qs	49.4	7.29	111	Common
GRTE-00111-A	2099	Basin	Qs	42.5	6.37	30	Common
GRTE-00248-A	2095	Basin	Qs	45.0	4.66	33	None
GRTE-00278-A	2092	Gentle slope	Qs	42.5	6.73	210	Common
GRTE-00278-B	2096	Gentle slope	Qs	55.0	6.63	102	Common
GRTE-00279-A	2087	Gentle slope	Qs	86.7	NA	NA	Common
GRTE-00279-B	2079	Gentle slope	Qs	40.0	NA	NA	Minor
GRTE-00279-C	2099	Gentle slope	Qs	60.0	NA	NA	None
GRTE-00281-A	2077	Basin	Qs	68.7	7.23	1	Minor
GRTE-00287-A	2113	Basin	Qs	62.2	5.69	30	None
GRTE-00293-A	2113	Basin	Qg4j	61.0	5.79	55	None
GRTE-00294-A	2113	Basin	Qg4j	56.0	5.98	54	None
GRTE-00342-A	2089	Basin	Qs	58.3	7.67	276	Abundant
GRTE-00368-A	3048	Gentle slope	Xmo	NA	NA	NA	Common
GRTE-00420-A	2076	Basin	Qtg	100.0	8.38	260	Minor
GRTE-00421-A	2077	Basin	Qs	120.0	8.65	255	Minor
GRTE-00427-A	2067	Basin	Qs	60.0	NA	NA	Common
JODR-00046-A	2116	Basin	Qs	107.9	6.25	33	Abundant
JODR-00130-A	2173	Basin	Qag	50.0	6.14	40	Common
JODR-00131-A	2090	Basin	Qag	80.0	6.78	39	Minor
JODR-00184-A	2162	Basin	Qs	59.0	5.58	34	Common
JODR-00185-A	2122	Basin	Qag	95.0	NA	NA	Common
JODR-00186-A	2116	Basin	Qlc	77.5	NA	NA	Common
JODR-00187-A	2109	Basin	Qlc	106.3	6.5	38	Abundant

[A] Geologic symbols: Qa = Alluvial floodplain deposits (Holocene); Qag = Alluvium and glaciofluvial deposits (Holocene and Pleistocene); Qg4j = Glacial deposits of Jackson Lake moraine (Pleistocene); Qlc = Lewis Canyon Rhyolite (Pleistocene); Qs = Swamp deposits (Holocene); Qtg = Terrace gravel (Pleistocene); Xmo = Mount Owen Quartz Monzonite (early Proterozoic)

Table 12 (continued). Characteristics of confirmed fens.

Site ID	Elevation (m)	Landform	Geology [A]	Peat Depth (cm)	pH	Specific Conduct (µS)	Bryophyte abundance
JODR-00192-A	2101	Basin	Qag	51.7	5.86	31	Minor
JODR-00194-A	2103	Basin	Qag	55.0	5.95	35	Minor
JODR-00195-A	2102	Basin	Qs	95.0	NA	NA	Minor
JODR-00196-A	2099	Basin	Qs	97.3	5.93	57	None
JODR-00197-A	2101	Basin	Qs	66.3	6.57	59	None
JODR-00839-B	2091	Basin	Qs	105.2	6.16	727	None

[A] Geologic symbols: Qa = Alluvial floodplain deposits (Holocene); Qag = Alluvium and glaciofluvial deposits (Holocene and Pleistocene); Qg4j = Glacial deposits of Jackson Lake moraine (Pleistocene); Qlc = Lewis Canyon Rhyolite (Pleistocene); Qs = Swamp deposits (Holocene); Qtg = Terrace gravel (Pleistocene); Xmo = Mount Owen Quartz Monzonite (early Proterozoic)

Vegetation Cover and Composition of Confirmed Fens

The rapid site evaluation included a list of dominant species and associated cover classes. These surveys should not be considered exhaustive searches of all species present on the site but were reasonably comprehensive because of the experience and knowledge of the primary botanist. From the site species list, a series of vegetation indicators were calculated for each site (Table 13). Species richness ranged from 3 to 33 species, with a mean of 15.9 species. Targeted rare fen-indicator species were common within the sampled sites. On average, 2.6 rare species were observed in each site, with a range of 0–10 rare species per site. Floristic quality of samples sites was relatively high, with an average mean C-value of 5.86 and a range from 4.10 to 7.00.

Table 13. Mean, minimum, and maximum values for vegetation cover and composition metrics calculated for confirmed fens.

Metric Group	Metric	Mean	Minimum	Maximum
Richness	Total Species Richness	15.9	3	33
	Rare Species Richness	2.6	0	10
Floristic Quality	Mean C [A]	5.86	4.10	7.00
Composition (percent of the species list represented by a specific group of species)	Native Species	98.5%	84.6%	100.0%
	Hydrophytic Species [B]	86.6%	46.2%	100.0%
	Graminoids	42.5%	20.0%	100.0%
	Forbs	37.9%	0.0%	77.8%

[A] Mean C is calculated as the average C-value for all species observed within a site. C-values numerical ratings (0–10) applied to each species within a state's flora that indicate the species' fidelity to natural habitats and tolerance or intolerance to disturbance. C-values for Wyoming are from Washkoviak et al. (2017).

[B] Hydrophytic species are those rated OBL and FACW on the National Wetland Plant List for the Western Mountains region. OBL = obligate wetland species, found in wetlands 99% of the time; FACW = facultative wetland species, found in wetlands 67–99% of the time.

Table 13 (continued). Mean, minimum, and maximum values for vegetation cover and composition metrics calculated for confirmed fens.

Metric Group	Metric	Mean	Minimum	Maximum
Composition (percent of the species list represented by a specific group of species) (cont.)	Shrubs	16.8%	0.0%	46.7%
	Trees	2.7%	0.0%	11.1%
	Annuals	1.4%	0.0%	10.0%
	Perennials	98.6%	90.0%	100.0%
Relative cover (percent of the total cover represented by a specific group of species)	Native Species	98.4%	85.3%	100.0%
	Hydrophytic Species [B]	95.2%	79.7%	100.0%
	Graminoids	71.4%	46.9%	100.0%
	Forbs	11.8%	0.0%	50.2%
	Shrubs	15.5%	0.0%	44.4%
	Trees	1.0%	0.0%	7.8%
	Annuals	1.3%	0.0%	15.5%
	Perennials	98.7%	84.5%	100.0%

[A] Mean C is calculated as the average C-value for all species observed within a site. C-values numerical ratings (0–10) applied to each species within a state's flora that indicate the species' fidelity to natural habitats and tolerance or intolerance to disturbance. C-values for Wyoming are from Washkoviak et al. (2017).

[B] Hydrophytic species are those rated OBL and FACW on the National Wetland Plant List for the Western Mountains region. OBL = obligate wetland species, found in wetlands 99% of the time; FACW = facultative wetland species, found in wetlands 67–99% of the time.

Metrics for both cover and composition were calculated from the rapid species lists. Composition metrics refer to the percent of the species list represented by a specific group of species. For example, if 5 out of 20 species are forbs, then forbs represent 25% of the species list. Relative cover metrics represent the percent of total cover represented by a specific group of species. For confirmed fens in GRTE and JODR, cover and composition were similar for some metrics and different for others. On average, native species represented 98.5% of each species list and 98.4% of total cover, both very high numbers. Hydrophytic species represented 86.6% of each species list, on average, but 95.2% of total cover. This indicates that vegetation cover was overwhelmingly dominated by true wetland species and non-wetland plant species only occurred with low cover, which makes sense for permanently saturated wetlands. Graminoids were the most abundant lifeform for both composition and cover, representing 42.5% of species and 71.4% of cover. Forbs followed graminoids in terms of composition, with 37.9% of species, but only represented 11.8% of total cover. While many sites had high forb diversity, forbs often occurred with lower cover than the more dominant graminoid species. Shrubs were less common, with 16.8% of species and 15.5% of cover, on average. Some sites were dominated by shrubs, while many others lacked a woody component. Trees were also uncommon, with 2.7% of species and 1.0% of cover. Nearly all species (98.6%) and cover (98.7%) were perennials, with very few annual species observed in sampled sites.

Common Vascular Plant Species within Confirmed Fens

Across all 38 confirmed fens sampled with a rapid site evaluation, 136 unique taxa were identified, 116 to the species level. The least diverse sites were dominated by graminoid, most frequently by water sedge *(Carex aquatilis)* and Northwest Territory sedge *(Carex utriculata)*. The most diverse sites were sloping fens with a woody component and high spatial heterogeneity. The number of plant species identified also depended on the timing of the survey and the ability to fully access the site. Several confirmed fens were visited in early July. Due to an unusually wet spring and early summer, a few high confidence fen sites were not thoroughly sampled due to water deeper than chest waders.

The most common species (those recorded in 10 or more confirmed fens) were all native. Most of these common species were adapted to lower disturbance or relatively unaltered landscapes, as indicated by their coefficients of conservatism (C-values), which ranged from 4 to 8. The common species were also adapted to wetland environments. The list included ten true wetland obligates (OBL), five facultative wetland species (FACW), and one facultative species (FAC). Of all 116 species recorded, only six were listed as Facultative Upland (FACU) and four were listed as Not Rated (NR), which implies an upland obligate.

While no nonnative species were among our most commonly observed, three nonnative species were recorded within surveyed fens. Canada thistle *(Cirsium arvense)* was observed at five sites (2 west of String Lake, 1 at Christian Creek, 1 near Christian Pond, and 1 near Willow Flats), Kentucky bluegrass *(Poa pratensis)* was observed at three sites (Willow Flats, Christian Creek, JODR off Grassy Lake Road), and common tansy *(Tanacetum vulgare)* was observed at one site (Christian Creek). Canada thistle is listed as a noxious weed in Wyoming, but the other two nonnative species are not. All three nonnative species occurred with less than 2% cover.

The most common species observed had varying average cover. Of the species that were recorded in 10 or more confirmed fens, Northwest Territory sedge *(Carex utriculata)* and woollyfruit sedge *(Carex lasiocarpa)* had the highest average cover, 22.7% and 32.0% respectively. Where these species were found, they were most often found in abundance. Other species, like lodgepole pine *(Pinus contorta)* were found in several sites but often with only a few individuals. The list of common species also includes many ubiquitous forbs, such as elephanthead lousewort *(Pedicularis groenlandica)* (34% of sites, 1.2% average cover), marsh cinquefoil *(Comarum palustre)* (29% of sites, 3.8% average cover), and three-petal bedstraw *(Galium trifidum)* (29% of sites, <1% average cover). To focus on the species that best represent the sites surveyed, a unitless 'importance value' was calculated by adding relative frequency and relative abundance of each species.[2] The resulting twenty most important species best characterize the species composition of the confirmed fens within GRTE and the JODR. Together, these species comprised approximately 80% of the total plant cover recorded in all site visits.

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[2] Relative frequency for each species = number of times the species was observed / total number of species observations across all sites. Relative abundance for each species = sum of cover for that species wherever it occurred / sum of cover of all species across all sites.

The four species with the highest importance value were Northwest Territory sedge *(Carex utriculata)*, woollyfruit sedge *(Carex lasiocarpa)*, water sedge *(Carex aquatilis),* and Geyer's willow *(Salix geyeriana).* This list differed slightly from the most common species, with *Carex lasiocarpa* rising from 5th most common to 2nd most important. *Carex utriculata,* however, was the most common and most important species in the confirmed fens. It was also the only species to occur in nearly every confirmed fen. Of the top ten most important species in confirmed fens, six were sedges and four were wetland shrubs, the most characteristic wetland species groups. The list also includes non-sedge graminoids, such as bluejoint *(Calamagrostis canadensis),* tufted hairgrass *(Deschampsia cespitosa),* and swordleaf rush *(Juncus ensifolius).* Livid sedge *(Carex livida)* also made the important list. While livid sedge occurred in only three sites, it often occurred with higher cover. The only forbs on the list were Rocky Mountain pond lily *(Nuphar lutea* ssp. *polysepala)* and marsh cinquefoil *(Comarum palustre)*.

See Table 14 and Table 15 for a list of the most common species, those with the highest importance value, and their attributes.

Table 14. Vascular plant species observed in ten or more confirmed fens.

Scientific Name	Common Name	# of Obs.	Average Cover [A]	Wetland Status [B]	C-Value [C]	Native Status
Carex utriculata	Northwest Territory sedge	34	22.7	OBL	6	Native
Carex aquatilis	water sedge	25	11.7	OBL	6	Native
Salix geyeriana	Geyer's willow	16	7.5	FACW	5	Native
Pinus contorta	lodgepole Pine	15	1.8	FAC	5	Native
Carex lasiocarpa	woollyfruit sedge	14	32.0	OBL	7	Native
Salix boothii	Booth's willow	14	5.0	FACW	6	Native
Betula glandulosa	resin birch	13	6.9	OBL	8	Native
Pedicularis groenlandica	elephanthead lousewort	13	1.2	OBL	7	Native
Calamagrostis canadensis	Canada Bluejoint	12	3.1	FACW	5	Native
Comarum palustre	marsh cinquefoil	11	3.8	OBL	--	Native
Salix planifolia	diamondleaf willow	11	3.0	OBL	6	Native
Juncus ensifolius	swordleaf rush	11	2.9	FACW	7	Native
Galium trifidum	three-petal bedstraw	11	0.6	FACW	7	Native
Salix wolfii	Wolf's willow	10	14.1	OBL	7	Native
Carex buxbaumii	Buxbaum's sedge	10	11.1	OBL	8	Native
Nuphar lutea ssp. *polysepala*	Rocky Mountain pond lily	10	5.6	OBL	--	Native
Dasiphora fruticosa ssp. *floribunda*	shrubby cinquefoil	10	1.6	FAC	4	Native

[A] Average cover is derived by averaging the mid-points of each cover class assigned within the rapid vegetation survey and is not a precise measurement.

[B] Wetland Indicator Status is based on the National Wetland Plant List for the Western Mountains 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.

[C] C-value is a numerical rating (0–10) that indicates a species' fidelity to specific habitats and tolerance of disturbance. C-values for Wyoming are from Washkoviak et al. (2017).

Table 15. Twenty most important plant species observed in confirmed fens.

Scientific Name	Common Name	Importance Value [A]	# of Obs.	Average Cover	Wetland Status	C-Value	Native Status
Carex utriculata	Northwest Territory sedge	29.16	34	22.7	OBL	6	Native
Carex lasiocarpa	woollyfruit sedge	15.95	14	32.0	OBL	7	Native
Carex aquatilis	water sedge	13.13	25	11.7	OBL	6	Native
Salix geyeriana	Geyer's willow	6.40	16	7.5	FACW	5	Native
Salix wolfii	Wolf's willow	5.99	10	14.1	OBL	7	Native
Carex buxbaumii	Buxbaum's sedge	5.08	10	11.1	OBL	8	Native
Betula glandulosa	resin birch	4.96	13	6.9	OBL	8	Native
Carex simulata	analogue sedge	4.82	7	17.1	OBL	6	Native
Salix boothii	Booth's willow	4.54	14	5.0	FACW	6	Native
Carex vesicaria	blister sedge	4.09	6	16.8	OBL	6	Native
Pinus contorta	lodgepole pine	3.44	15	1.8	FAC	5	Native
Nuphar lutea ssp. *polysepala*	Rocky mountain pond lily	3.43	10	5.6	OBL	--	Native
Calamagrostis canadensis	Canada bluejoint	3.20	12	3.1	FACW	5	Native
Comarum palustre	marsh cinquefoil	3.16	11	3.8	OBL	--	Native
Salix planifolia	diamondleaf willow	2.89	11	3.0	OBL	6	Native
Deschampsia cespitosa	tufted hairgrass	2.88	9	4.8	FACW	5	Native
Juncus ensifolius	swordleaf rush	2.86	11	2.9	FACW	7	Native
Pedicularis groenlandica	elephanthead lousewort	2.73	13	1.2	OBL	7	Native
Carex livida	livid sedge	2.22	3	18.8	OBL	8	Native
Dasiphora fruticosa ssp. *floribunda*	shrubby cinquefoil	2.22	10	1.6	FAC	4	Native

[A] Importance value is a unitless number derived as the sum of relative frequency and relative cover across all species and all sites.

Water Chemistry of Confirmed Fens and Peat-accumulating Wetlands

Basic water chemistry measurements were taken in most confirmed fens and several peat-accumulating wetlands. In some sites, multiple measurements were taken, for a total of 49 measurements of pH, specific conductance, and temperature (Table 16). Mean pH was 6.56 and values ranged from 4.86 to 8.65. Mean specific conductance was 178 µS/cm, but the median was only 54 µS/cm because most values were < 400 µS/cm. The highest specific conductance values were measured in several peat-accumulating wetlands and one confirmed fen, all near Huckleberry Hot Springs in JODR (JODR-00066, 67, 68, and JODR-00838, 839) (Figure 15). The water chemistry of these sites was likely influenced by geothermal activity. These sites were also associated with high pH and the highest temperature measured, 51.0°C (124°F) at the hot spring itself. The highest pH values not associated with Huckleberry Hot Springs were located close to Christian Pond in the immediate vicinity of Jackson Lake Lodge (GRTE-00410-421). The lowest pH site (GRTE-00248) was a basin fen with low species diversity not far off the main park road upslope from Sargent's Bay.

Table 16. Mean, minimum, and maximum values for water chemistry parameters (pH, specific conductance, and temperature) measured in confirmed fens.

Parameter (n = 49)	Range	Mean	Median
pH	4.86–8.65	6.56	6.39
Specific conductance (µS/cm)	1–1105	178	54
Temperature (°C)	6.2–51.0	18.9	16.9

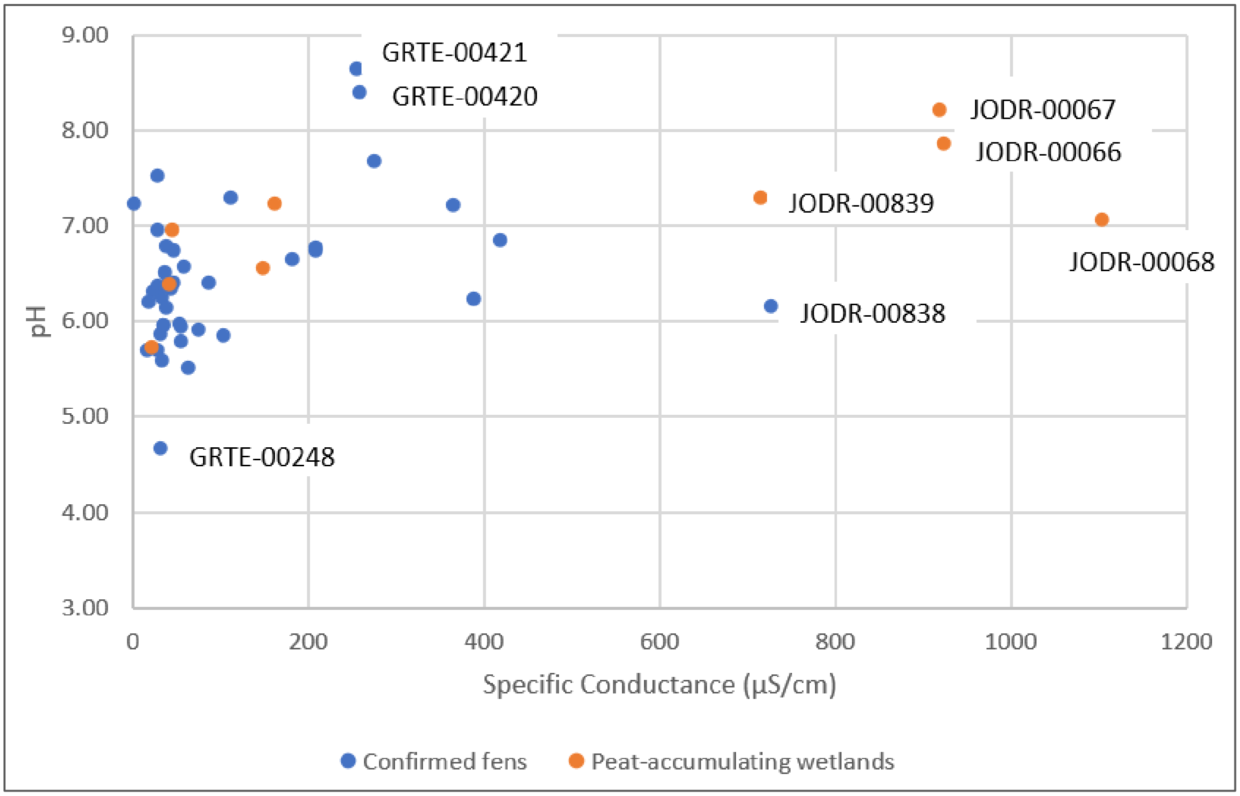

Figure 15. Scatter plot of pH vs. specific conductance measured in confirmed fens and confirmed peat-accumulating wetlands. Sites with specific conductance > 500 µS/cm, and/or pH < 5.00 or > 8.00 are labeled.
NPS / CNHP

Additional water quality parameters were analyzed in the five sites where quantitative vegetation data were collected (Table 17). One sample was collected at most sites, but two samples were collected at different dates in site GRTE-00008, one in the central floating mat (GRTE-00008-A) and one on the outer rim of the site (GRTE-00008-B). Of these five sites, GRTE-00008 had the lowest values for pH and electric conductivity (EC) and low values for cations and anions. This large floating mat site is the closest to the poor fen end of the water chemistry gradient. Sites GRTE-00278 (Willow Flats) and GRTE-00342 (String Lake) had the highest values for pH, EC, and ionic concentrations. These sites would be considered rich fens, though they did not contain species characteristic of extreme rich fens.

Table 17. Water quality parameters analyzed from collected water samples.

Parameter	Confirmed Fen Site					
	GRTE-00008-A, Colter Bay Junction	GRTE-00008-B, Colter Bay Junction	GRTE-00095-A, Spread Creek	GRTE-00278-A, Willow Flats	GRTE-00342-A, String Lake	JODR-00046-A, JODR
Field pH	5.70–6.30	5.70–6.30	6.35–6.39	6.73–6.77	6.84–7.67	6.25–6.37
Field spec conductance (µS/cm)	16.7–22.5	16.7–22.5	44–48	210–211	274–419	33–37
Lab pH	6.00	6.30	6.80	7.00	7.90	6.80
Electric conductivity (µS/cm)	30	30	50	200	290	30
Cation: Calcium (mg/L)	2.7	1.8	3.7	33.5	46.6	2.4
Cation: Magnesium (mg/L)	<1	<1	<1	6.0	9.0	<1
Cation: Sodium (mg/L)	2.0	2.0	5.0	6.0	8.0	2.0
Cation: Potassium (mg/L)	1.0	2.0	2.0	2.0	2.0	1.0
Anion: Carbonate (mg/L)	<1	<1.0	<1.0	<1	<1.0	<1.0
Anion: Bicarbonate (mg/L)	5.0	6.0	20.0	120.0	181.0	11.0
Anion: Sulfate (mg/L)	<1	<1	<1	2.0	2.0	<1
Anion: Chloride (mg/L)	2	2	2	2	2	2
Nitrate (mg/L)	1.32	0.89	0.89	1.32	0.89	0.89
Nitrate-Nitrogen (mg/L)	0.30	0.2	0.2	0.30	0.2	0.2
Nitrite (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite-Nitrogen (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Alkalinity as CaCO3	4.0	5	17.0	99.0	149.0	9.0
Total Hardness as CaCO3	12.00	9.00	14.0	108.00	155.0	9.0
Total Dissolved Solids	16.00	17.00	27.0	122.00	174.0	20.0
Phosphorus (mg/L)	0.02	0.01	0.01	0.06	<0.01	<0.01
Iron (mg/L)	0.12	0.03	0.02	0.02	0.05	0.17
Manganese (mg/L)	<0.01	<0.01	<0.01	0.06	<0.01	<0.01
Zinc (mg/L)	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Copper (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Boron (mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Patterns in Species Composition and Environmental Variables

Species composition in confirmed fens was related to environmental variables using an ordination. The final stress value for a three-dimension NMDS was 14.9 with a linear fit R^2 of 0.82, which indicates reasonable and interpretable representation of the data. For simplicity, we present and interpret the first two dimensions (Figure 16). Confirmed fen sites were grouped by bryophyte abundance, which displayed clear separation between sites with no bryophytes on the left and those where bryophytes were very abundant on the right. If grouped by landform, sloping fens also clustered on the right of the graph (not shown). Of the environmental variables included in the analysis, only pH was significantly related to the axes (p-value = 0.002, axis 1 = 0.317, axis 2 = -0.565) and pointed in the direction of sloping fens with abundant bryophytes. Seventeen species were also significantly related to the axes. Species on the left of the ordination space were adapted to high water levels or aquatic environments, including ribbonleaf pondweed *(Potamogeton epihydrus),* hemlock waterparsnip *(Sium suave),* blister sedge *(Carex vesicaria),* and Rocky Mountain pond lily *(Nuphar lutea* ssp. *polysepala)* in the upper left and Northwest Territory sedge *(Carex utriculata)* in the lower left. Several species occupied the right side of the ordination space, including shrubs and forbs. The first axis appears to reflect a gradient between basin fens with open water and no bryophytes and sloping fens with a woody component. Water levels were not recorded in each site but would likely be significantly related to axis 1. The second axis separates woollyfruit sedge *(Carex lasiocarpa)* at the top from water sedge *(Carex aquatilis)* at the bottom. This axis is also more strongly related to pH, perhaps reflecting a portion of the poor to rich gradient.

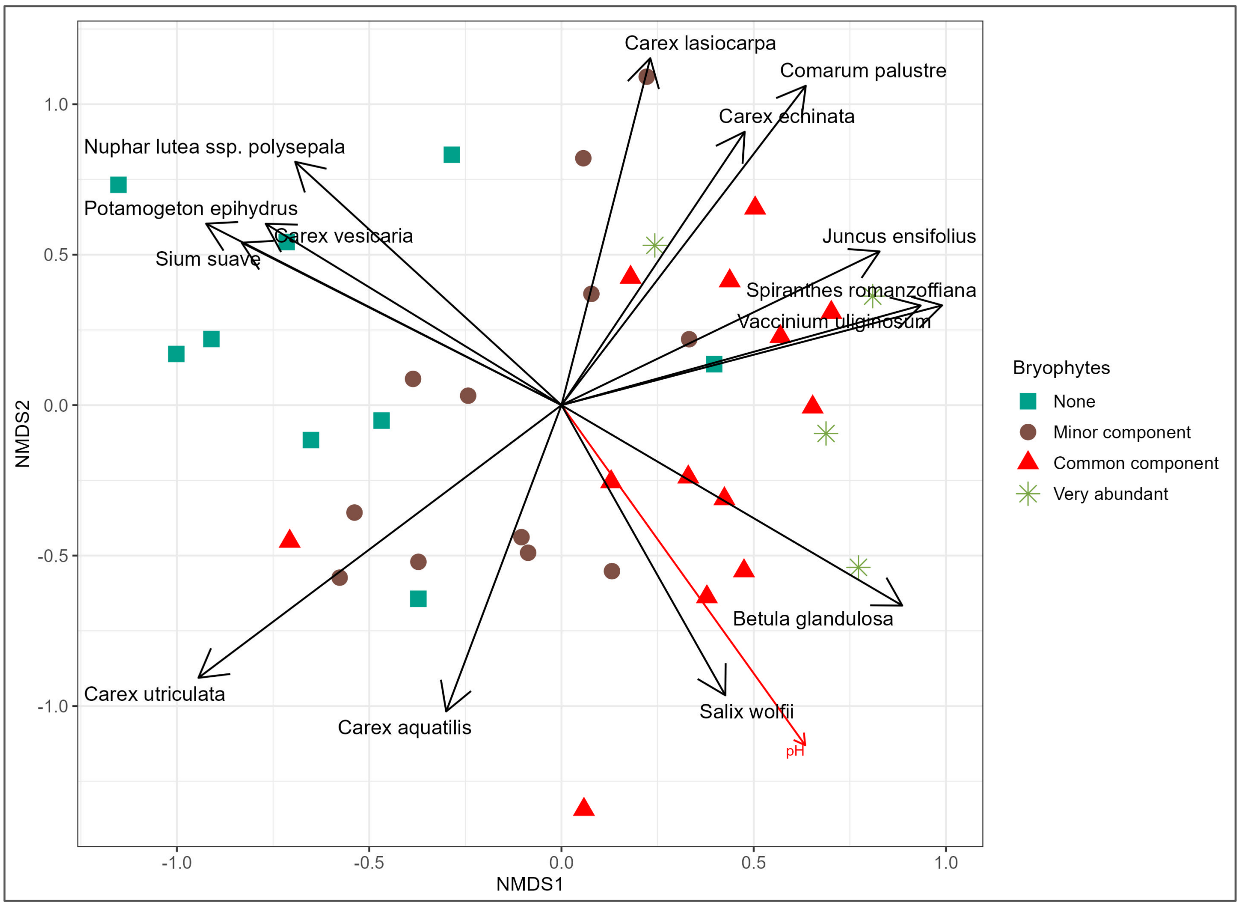

Figure 16. Ordination of vegetation composition related to environmental variables and vegetation metrics for confirmed fens grouped by bryophyte abundance. Of the environmental variables included in the analysis, only pH was significantly related to the axes. Species on the left of the ordination space were adapted to high water levels or aquatic environments.
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Quantitative Vegetation Surveys

Quantitative vegetation surveys were carried out in five large, confirmed fens. See Figure 6 for a map of the five sites and Figures 17–21 for aerial photographs and example transects and quadrats of each site. Quantitative surveys provided a more precise measurement of vegetation cover and ground surfaces within the five sites, including cover of all vascular plants, native species, hydrophytic species, cover by life form, and cover of annuals and perennials (Table 18). In addition, the cover of each species observed within the quadrats was calculated (Table 19). Patterns in the quantitative data were similar to the rapid site evaluations. All species recorded in the quadrats were both native and perennials, and the majority of vascular plant cover was from hydrophytic species. Cover by life form varied by site. GRTE-00008-A, the floating mat near Colter Bay Junction, had very low cover of vascular plants in general, and the cover was split between graminoids and forbs. The ground surface of this site was overwhelmingly covered in water, with litter or dead plant materials in roughly 40% of quadrat corners. GRTE-00095-A was dominated by graminoids, with no forbs and low cover of woody shrubs and trees. This site was similarly wet like GRTE-00008-A, but with less litter and a minor amount of woody debris. GRTE-00278-A had the highest cover of vascular plants, including over 30% cover of shrubs. This site had lower water covers, high litter and bryophyte cover. GRTE-00342-A was the driest site, with very low water cover. This site had 15% cover of shrubs and 12.7% cover of graminoids, but very high bryophyte covers over 70% of quadrat corners. The only quantitative survey in JODR was JODR-00046-A. This site was dominated by graminoids, with few forbs and no woody cover. The site had moderate cover of litter, bryophytes, and water.

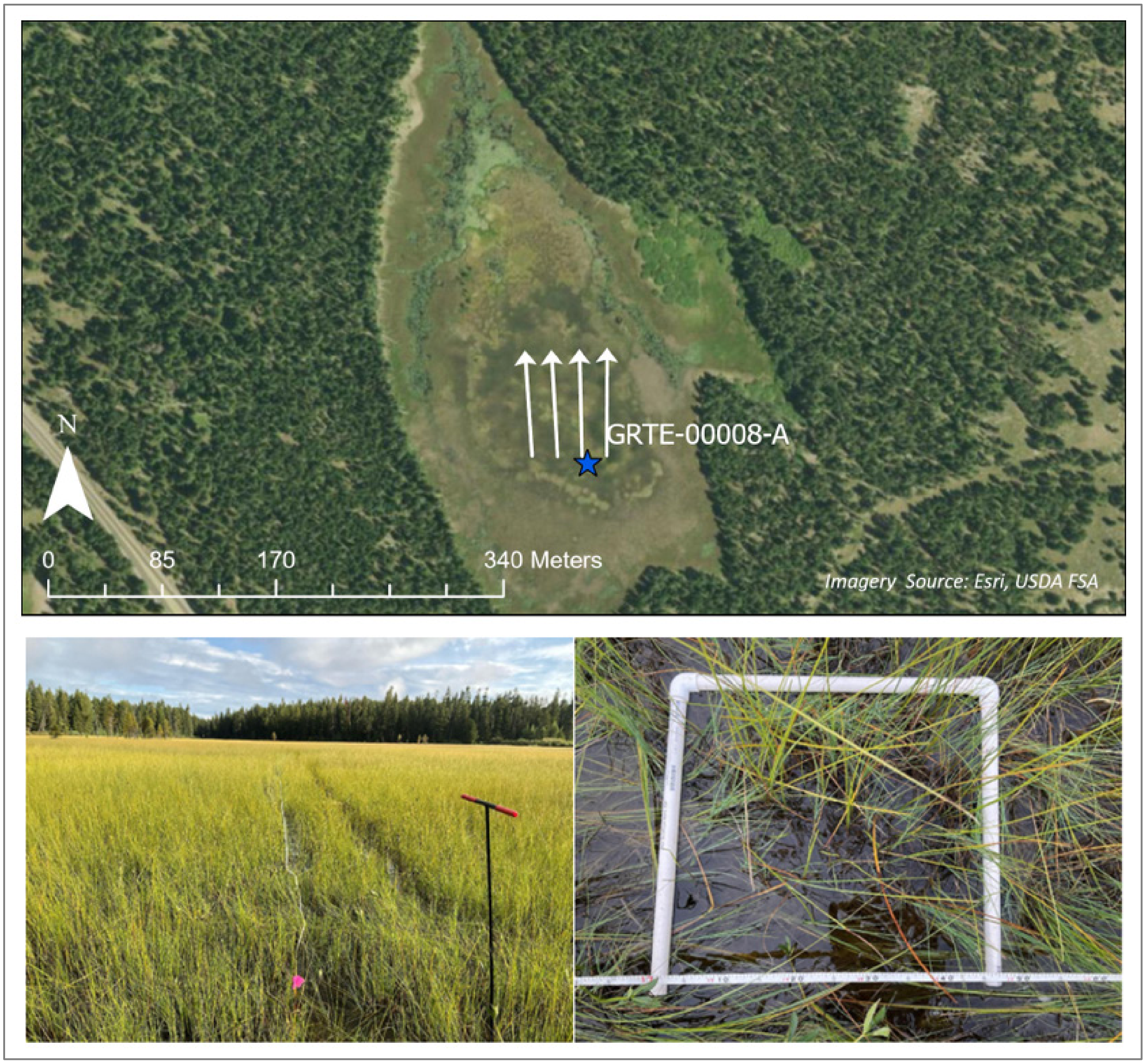

Figure 17. GRTE-00008-A. Large floating mat fen very close to Colter Bay Junction. Top image is an aerial photograph. White arrows are vegetation transects for the quantitative vegetation survey. Bottom left is a transect start. Bottom right is an example 0.5 × 0.5 m quadrat.

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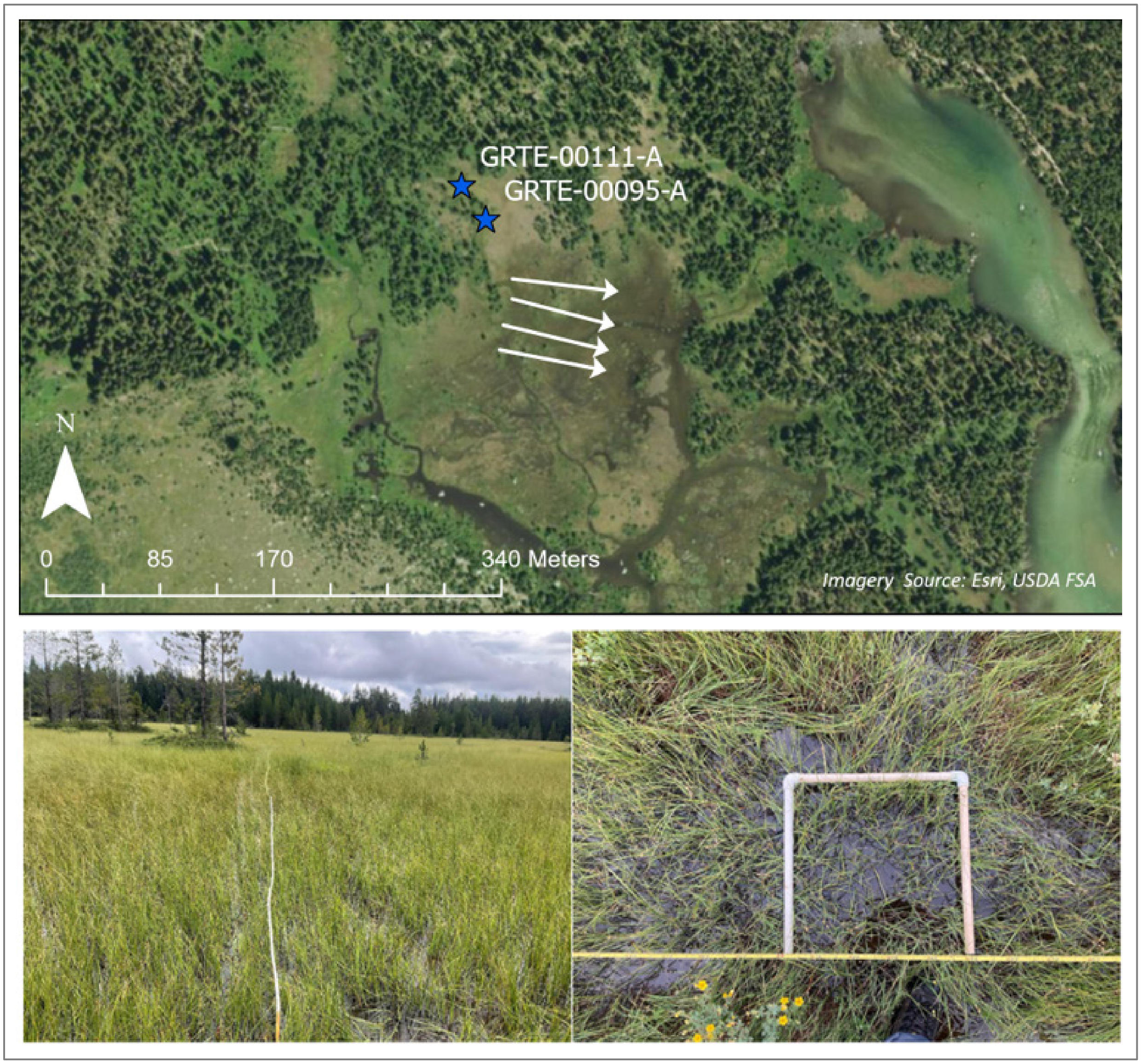

Figure 18. GRTE-00095-A. Large fen near String Lake. Top image is an aerial photograph. White arrows are vegetation transects for the quantitative vegetation survey. Bottom left is a transect start. Bottom right is an example 0.5 × 0.5 m quadrat.

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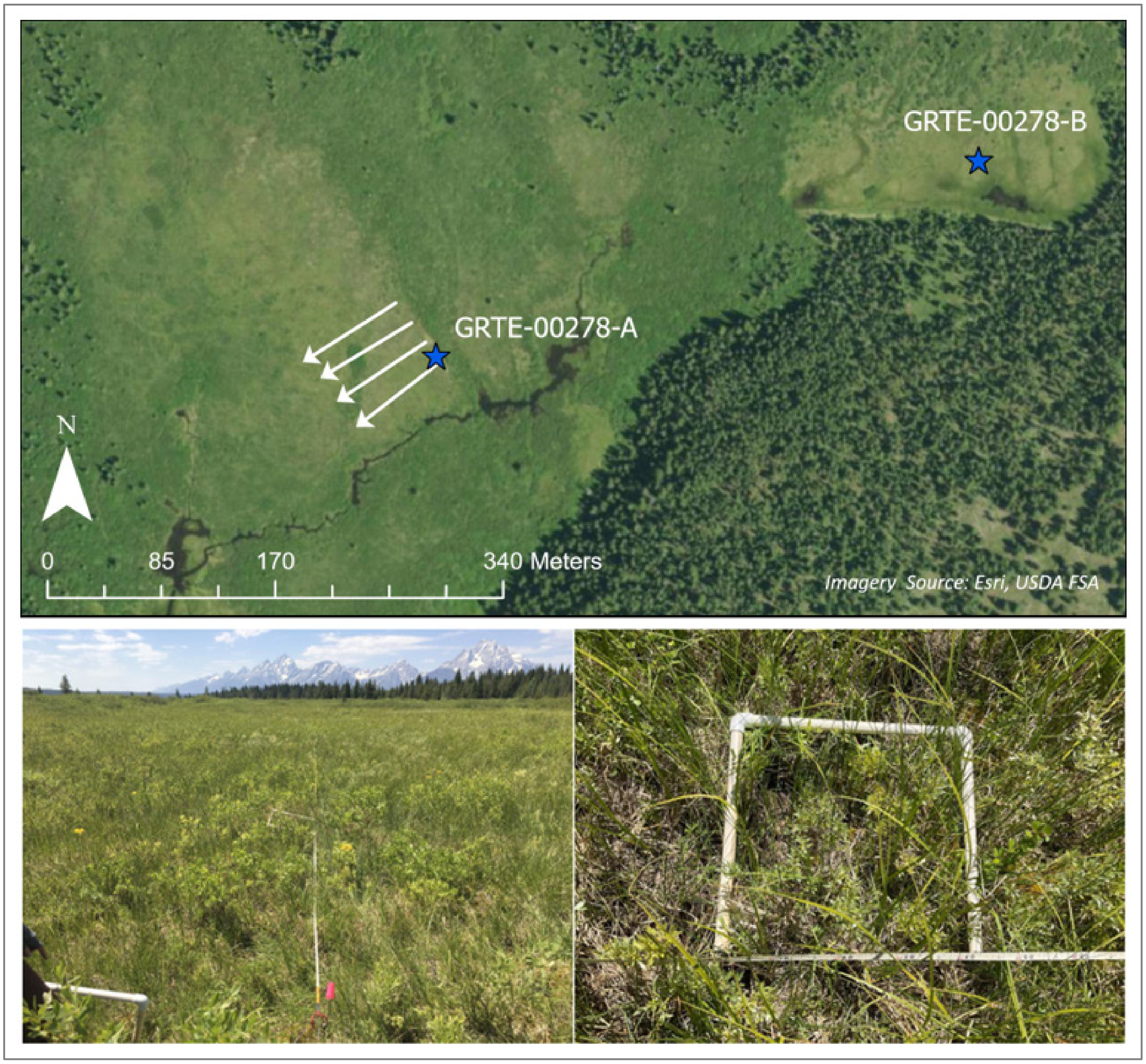

Figure 19. GRTE-00278-A. A large fen in Willow Flats. Top image is an aerial photograph. White arrows are vegetation transects for the quantitative vegetation survey. Bottom left is a transect start. Bottom right is an example 0.5 × 0.5 m quadrat.

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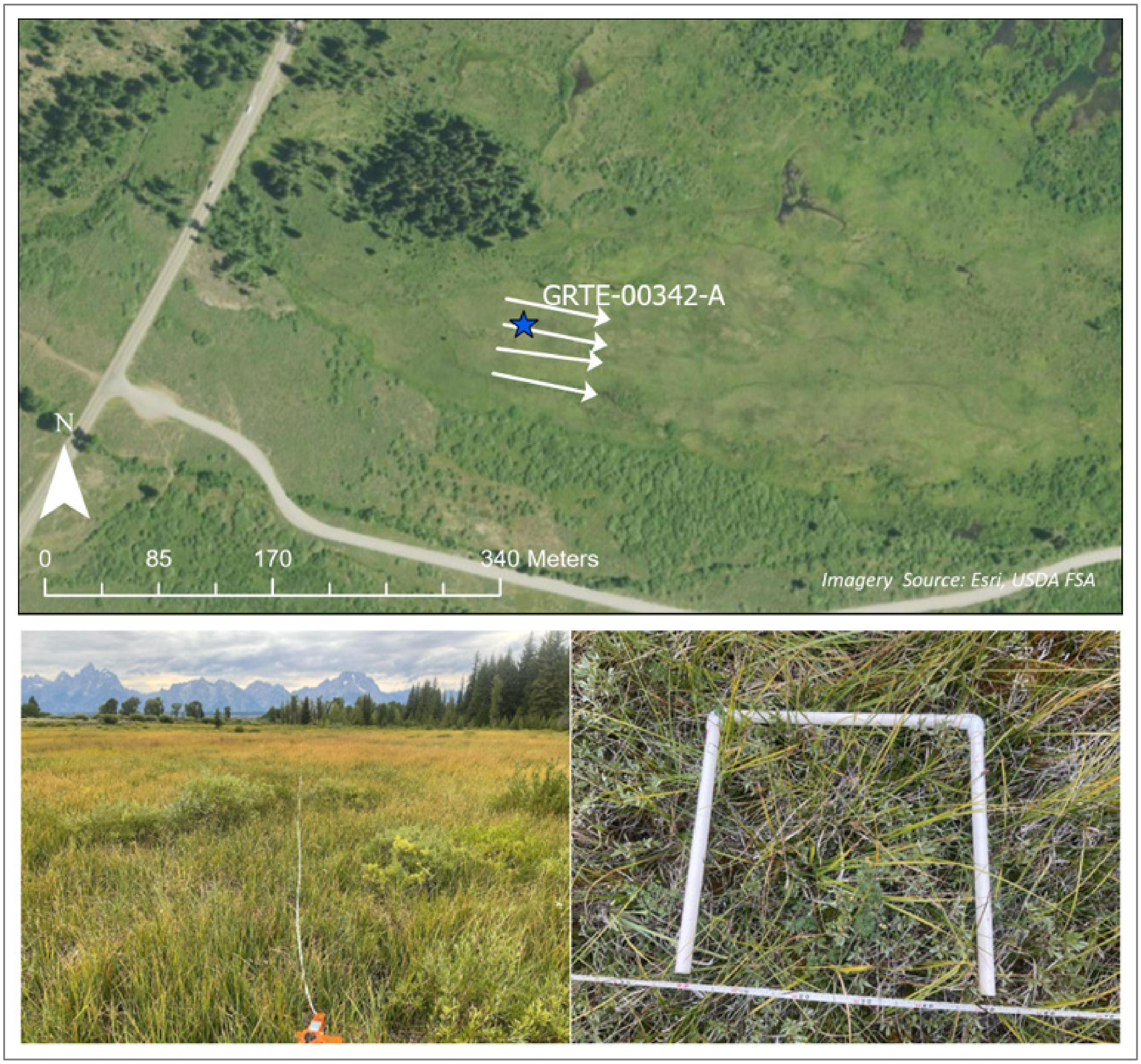

Figure 20. GRTE-00342-A. Large fen along Spread Creek. Top image is an aerial photograph. White arrows are vegetation transects for the quantitative vegetation survey. Bottom left is a transect start. Bottom right is an example 0.5 × 0.5 m quadrat.

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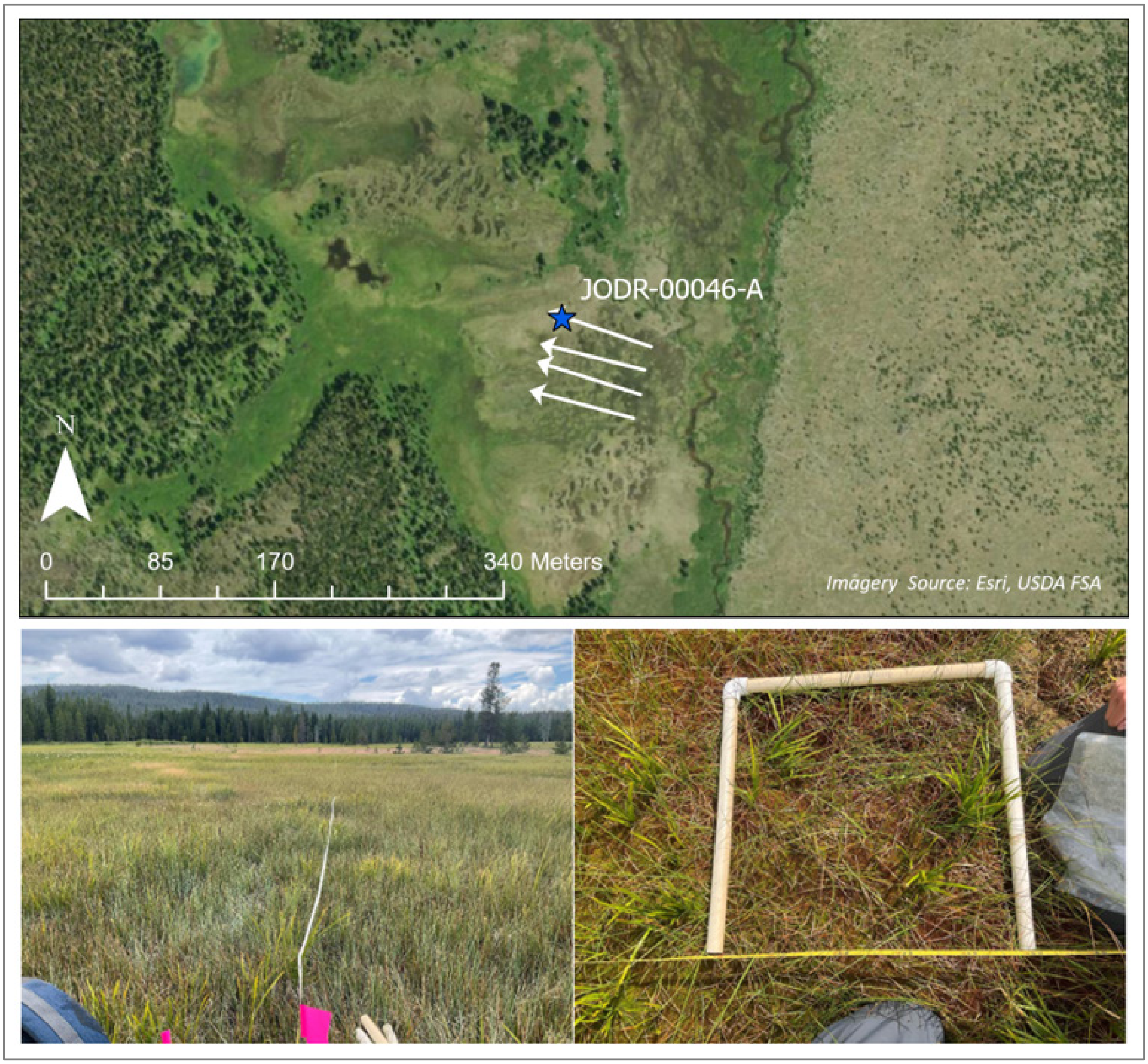

Figure 21. JODR-00046-A. Large fen along Grassy Lake Road in JODR. Top image is an aerial photograph. White arrows are vegetation transects for the quantitative vegetation survey. Bottom left is a transect start. Bottom right is an example 0.5 × 0.5 m quadrat.

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Table 18. Vegetation metrics calculated from quantitative vegetation surveys. Cover metrics are percent absolute cover plus or minus one standard deviation. Ground surface metrics are the mean proportion of quadrat corners (out of 4 per quadrat) where the ground cover attribute was observed, plus or minus one standard deviation.

	Confirmed Fen Site				
Parameter	**GRTE-00008-A**	**GRTE-00095-A**	**GRTE-00278-A**	**GRTE-00342-A**	**JODR-00046-A**
Cover vascular plants	10.5% ± 0.1	21.1% ± 0.6	50.9% ± 0.4	29.3% ± 0.3	31.7% ± 0.4
Cover native species	10.5% ± 0.1	21.1% ± 0.6	50.9% ± 0.4	29.3% ± 0.3	31.7% ± 0.4
Cover hydrophytic species	10.4% ± 0.1	19.0% ± 0.5	50.0% ± 0.4	25.7% ± 0.3	26.4% ± 0.4
Cover graminoids	5.5% ± 0.1	17.8% ± 0.5	16.2% ± 0.3	12.7% ± 0.2	27.8% ± 0.4
Cover forbs	4.2% ± 0.1	–	2.8% ± 0.1	1.5% ± 0.0	3.9% ± 0.2
Cover shrubs	0.8% ± 0.0	1.3% (n=1)	31.9% ± 0.5	15.0% ± 0.4	–
Cover trees	–	2.1% ± 1.4	–	–	–
Cover annuals	–	–	–	–	–
Cover perennials	10.5% ± 0.1	21.1% ± 0.6	50.9% ± 0.4	29.3% ± 0.3	31.7% ± 0.4
Basal vegetation	15.6% ± 20.6	38.5% ± 25.5	28.1% ± 23.7	20.8% ± 26.2	59.4% ± 30.2
Bare soil	–	–	–	–	4.2% ± 15.9
Litter	38.5% ± 39.7	18.8% ± 24.7	82.3% ± 21.5	54.2% ± 24.1	43.8% ± 43.1
Bryophytes	5.2% ± 20.8	1.0% ± 5.1	50.0% ± 35.4	71.9% ± 28.8	26.0% ± 36.5
Water	91.7% ± 28.2	95.8% ± 20.4	20.8% ± 29.2	1.0% ± 5.1	46.9% ± 44.4
Wood	–	3.1% ± 15.3	3.1% ± 8.4	–	–

Table 19. Count of quadrats, mean cover, and standard deviation for all species observed by site within quantitative vegetation surveys.

Fen Site	**Species Scientific Name**	**Count of Quadrats**	**Mean Cover**	**Stand Dev**
GRTE-00008-A	*Carex lasiocarpa*	24	2.88%	0.09
	Carex limosa	21	2.38%	0.08
	Scheuchzeria palustris	16	1.21%	0.07
	Utricularia minor	16	1.17%	0.06
	Menyanthes trifoliata	13	1.04%	0.09
	Kalmia microphylla	2	0.83%	0.05
	Drosera anglica	2	0.63%	0.00
	Lycopus uniflorus	1	0.08%	0.15
	Carex livida	1	0.04%	NA
	Carex species	1	0.04%	NA
	Perennial Graminoid Generic	1	0.04%	NA

Table 19 (continued). Count of quadrats, mean cover, and standard deviation for all species observed by site within quantitative vegetation surveys.

Fen Site	Species Scientific Name	Count of Quadrats	Mean Cover	Stand Dev
GRTE-00008-A (cont.)	*Carex utriculata*	1	0.04%	NA
	Calamagrostis canadensis	1	0.04%	NA
	Comarum palustre	1	0.04%	NA
GRTE-00095-A	*Carex lasiocarpa*	21	8.21%	0.56
	Carex buxbaumii	12	8.04%	0.55
	Pinus contorta	1	2.08%	NA
	Vaccinium uliginosum	1	1.25%	NA
	Juncus brevicaudatus	8	1.13%	0.28
	Carex utriculata	8	0.38%	0.01
	Picea engelmannii	1	0.04%	NA
GRTE-00278-A	*Salix wolfii*	15	11.17%	0.57
	Betula glandulosa	19	8.75%	0.41
	Carex utriculata	17	8.12%	0.39
	Salix boothii	10	7.58%	0.51
	Carex aquatilis	15	3.50%	0.20
	Carex diandra	7	2.83%	0.42
	Salix geyeriana	3	2.50%	0.72
	Juncus arcticus ssp. *littoralis*	11	1.75%	0.15
	Salix planifolia	4	1.46%	0.31
	Polemonium occidentale	17	1.29%	0.05
	Senecio sphaerocephalus	5	1.00%	0.20
	Dasiphora fruticosa ssp. *floribunda*	2	0.46%	0.27
	Equisetum arvense	3	0.29%	0.10
	Parnassia species	2	0.08%	0.00
	Stellaria crassifolia	1	0.04%	NA
	Epilobium species	1	0.04%	NA
	Galium trifidum ssp. *subbiflorum*	1	0.04%	NA
GRTE-00342-A	*Salix wolfii*	13	7.63%	0.52
	Carex nebrascensis	14	5.13%	0.28
	Carex utriculata	16	2.96%	0.16
	Carex simulata	10	2.17%	0.17
	Juncus arcticus ssp. *littoralis*	18	2.04%	0.10

Table 19 (continued). Count of quadrats, mean cover, and standard deviation for all species observed by site within quantitative vegetation surveys.

Fen Site	Species Scientific Name	Count of Quadrats	Mean Cover	Stand Dev
GRTE-00342-A (cont.)	*Dasiphora fruticosa* ssp. *floribunda*	13	2.71%	0.22
	Salix planifolia	6	1.46%	0.24
	Betula glandulosa	4	1.33%	0.38
	Salix boothii	5	1.17%	0.34
	Arctostaphylos uva-ursi	4	0.63%	0.17
	Polemonium occidentale	9	0.42%	0.01
	Carex interior	7	0.33%	0.02
	Parnassia palustris	5	0.29%	0.04
	Symphyotrichum boreale	3	0.25%	0.07
	Equisetum laevigatum	4	0.17%	0.00
	Swertia perennis	3	0.17%	0.02
	Antennaria pulcherrima	3	0.13%	0.00
	Salix geyeriana	2	0.13%	0.03
	Pedicularis groenlandica	2	0.08%	0.00
	Perennial Graminoid Generic	1	0.04%	0.52
	Perennial Forb Generic	1	0.04%	0.28
JODR-00046-A	*Carex livida*	20	11.71%	0.66
	Eleocharis quinqueflora	16	7.00%	0.35
	Agrostis scabra	11	3.71%	0.39
	Carex utriculata	13	1.50%	0.12
	Juncus arcticus ssp. *littoralis*	3	1.46%	0.32
	Drosera anglica	4	1.33%	0.34
	Carex lasiocarpa	5	1.13%	0.34
	Packera species	1	0.83%	NA
	Triantha occidentalis	6	0.75%	0.11
	Symphyotrichum species	4	0.71%	0.18
	Carex echinata	5	0.46%	0.07
	Carex limosa	3	0.42%	0.06
	Eriophorum chamissonis	4	0.21%	0.02
	Pedicularis groenlandica	3	0.17%	0.02
	Carex aquatilis	2	0.13%	0.03
	Triantha occidentalis	1	0.08%	NA
	Poa species	1	0.04%	NA
	Spiranthes romanzoffiana	1	0.04%	NA

Discussion

Extent and Condition of GRTE and JODR Fens

Based on mapping from this study, GRTE and JODR contain nearly 3,500 acres of potential fens. Of this area, 1,016 acres are confirmed or considered highly likely to be fens, which represents far less than 1% of the landscape within the parks. The density of fens was greater in JODR, a small park unit on the edge of the Yellowstone Plateau with gentle topography that is conducive to fen formation. In GRTE, fens were rare in the steep topography at high elevation, but far more common in the glaciated valley of Lower Jackson Lake. Both park units contained large and complex fen sites. The largest fen polygon within GRTE was over 80 acres and located in Willow Flats, and the largest fen in JODR was 50 acres. Both sites and many other fens across the parks are truly exceptional.

Of particular importance, fens in GRTE and JODR are in excellent condition. Very little evidence of disturbance was observed in the surveyed sites. Only three non-native species were recorded, none occurred at more than a few sites, and all occurred with less than 2% cover. Floristic quality, as measured by the mean coefficient of conservatism (mean C-value), was considered high. The average mean C-value for sampled sites was 5.86 and the highest mean C-value was 7.0, indicating plant fidelity to natural habitats and adaptation to lower disturbance or relatively unaltered landscapes. There was little evidence of trampling within fens sites, including those located near roads and trails. The site with the most observed impacts was the drier edge of Willow Flats. Disturbance in this area looked historic, including old wood and barbed wire, and may have predated the development of the park.

Biodiversity Significance of GRTE and JODR Fens

Rocky Mountains fens are highly important for protecting regional biodiversity, storing soil carbon, and maintaining watershed hydrology. Previous studies from across the Rocky Mountains have shown that fens host numerous rare species and deserve greater conservation attention (Cooper 1996; Cooper et al. 2002; Johnson & Stiengraeber 2003; Heidel & Jones 2006; Lemly et al. 2007; Chimner et al. 2010; Lemly & Cooper 2011; Heidel 2011; Heidel et al. 2013; Heidel et al. 2017; Heidel 2019). Many of the rare species found in Rocky Mountain fens are disjunct from their population centers in far northern latitudes of Alaska and Canada, and represent remnants of cooler, moist environments more common thousands of years ago. Within the present-day Rocky Mountains, where summers are warm and dry, these rare species find refuge only within fen habitats. Rocky Mountain fens are considered irreplaceable "old growth" wetlands because their deep organic soils formed in relatively stable environments over thousands of years since the last glacial retreat.

Like other studies of Rocky Mountain fens, results from this study confirm that GRTE and JODR fens support rare species. One hundred and twenty-seven populations of 23 rare fen-indicator plant species were observed either within or near confirmed fens or confirmed peat-accumulating wetlands in GRTE and JODR. The species observed are considered globally secure but rare within the state of Wyoming, meaning these sites are refuges at the edge of the species' range. The rarest species observed, bulblet-bearing water hemlock *(Cicuta bulbifera)* and rannoch-rush *(Scheuchzeria palustris),* are both considered S1 or critically imperiled in the state of Wyoming and were both observed only once. Several other species considered S2 or imperiled in the state of Wyoming were found in multiple populations. Of particular note, S2 species woollyfruit sedge (Carex lasiocarpa) was one of the most common species found in the study and occurred in high cover where observed. Conservation and rarity ranks can be updated following intensive study like this that reveal species are more common than previously thought. However, the conservation ranks incorporate potential threats facing the species as well as the number of known populations.

Characteristics of GRTE and JODR Fens

GRTE and JODR fens share similar characteristics to fens in surrounding mountain ranges but are also notable in their own right. Most confirmed fens in GRTE and JODR were graminoid-dominated basin fens. Basin fens, also called topogenous fens, form in depressions that are fully or partially filled with peat soil. Water flow in basin fens is relatively slow, which limits the transfer of cations and anions and produces a chemical environment similar to poor fens. Basin fens can include floating mats of thick peat layers that extend out from the vegetated margin over open water or mats that rest entirely on open water. Several sites in GRTE contained floating mats. The most notable was GRTE-00008, an extensive fully floating mat located less than 250 m from Colter Bay Junction. The central floating mat was inaccessible in early July due to high water in the moat surrounding the mat but could be accessed during a second visit in late August. The floating mat at GRTE-00008 supported mounds of *Sphagnum* moss and a large population of English sundew *(Drosera anglica)*, a carnivorous plant that only grows on peat soil (Figure 22). This site also hosted the only observed population of rannoch-rush *(Scheuchzeria palustris).* Similar basin fens and floating mats were observed in Yellowstone National Park (YELL) (Lemly 2007), particularly the southern Bechler region of YELL, as well as the Bridger-Teton and Caribou-Targhee National Forests (Heidel 2019), and in the Beartooth Mountains (Heidel et al 2017).

Figure 22. Mounds of *Sphagnum* moss on the floating mat of GRTE-00008 (right) and a close-up of English sundew (right).
NPS / CNHP

Seven of the 38 confirmed fens were gently sloping sites. Also called soligenous fens, these sites occur on gentle slopes along valley margins or at the base of alluvial fans where groundwater expresses to the surface. Water flows through sloping fens at a higher rate than basin fens, oxygenating the water and allowing for a higher rate of ionic exchange. Sloping fens in GRTE were more likely to support low shrubs and a higher diversity of plant species (Figure 23), although shrubs were found on the margins of some basin fens. In the mountains of Colorado, sloping fens are more common than basin fens (Chimner et al. 2010), but the highly glaciated landscape of GRTE and JODR creates the perfect template for basin fen formation.

Figure 23. Low shrubs in a sloping fen in Willow Park.
NPS / CNHP

Gradients Driving the Vegetation of GRET and JODR Fens

Peatland vegetation is known to respond to multiple different gradients at regional to local scales (Bridgham et al. 1996; Wheeler and Proctor 2000; Rydin and Jeglum 2006). On a regional scale, climate, elevation, and bedrock geology influence species composition (Sjörs 1950; Økland 1990). Climate and elevation affect the timing and volume of water, and bedrock geology contributes to the chemical content of groundwater (Cooper and Andrus 1994; Bedford and Godwin 2003; Chimner et al. 2010; Cooper et al. 2010). The resulting water chemistry, specifically pH, electroconductivity, and ionic concentrations, creates the poor to extreme-rich gradient of fen vegetation (Figure 24) (Sjörs 1950; Malmer 1986). Within peatlands, soil water pH and EC are often closely linked. Precipitation driven bogs and poor fens have low pH, low electroconductivity, and low ionic concentrations. This can be because the surrounding bedrock is relatively low in available ions, or because a high volume of precipitation or snowmelt dilutes the ions. Rich fens (sometimes called intermediate rich fens) have higher pH, moderate electroconductivity, and moderate ionic concentrations. Extreme rich fens are often located in watershed with sedimentary layers, such as limestone or dolomite, and have the highest pH, much higher electroconductivity, and often high calcium concentrations (Johnson &

Steingraeber 2003). At a local scale within sites, landforms, differences in water table depth and soil aeration, and the peatland margin – peatland expanse gradient influence species distribution (Andrus 1986; Malmer 1986; Økland 1990).

In neighboring YELL, fen vegetation was strongly influenced by bedrock geology (Lemly 2007). The water chemistry in YELL fens spanned the poor to extreme-rich gradient (2.89–7.98). Some sites were poor fens with pH = 4.0–5.0, most sites were rich fens with pH = 5.0–7.0, and some sites were extreme rich fens with pH >7.0 influenced by glacial till containing sedimentary material. A handful of YELL fens were influenced by geothermal activity, which produced highly acidic groundwater (<4.0) with high electroconductivity. These sites did not fit within the poor to rich gradient but were similar to iron-rich acidic fens in Colorado (Cooper et al. 2002). In other neighboring regions, water chemistry measurements from fens in the Beartooth mountains were also mostly categorized as rich fens with pH from 5.1 to 7.6 (Heidel at al. 2017), though some measurements in previous studies were lower. Fens in the Wind River Range had an even tighter range with pH from 5.9 to 6.8 and had low cation concentrations.

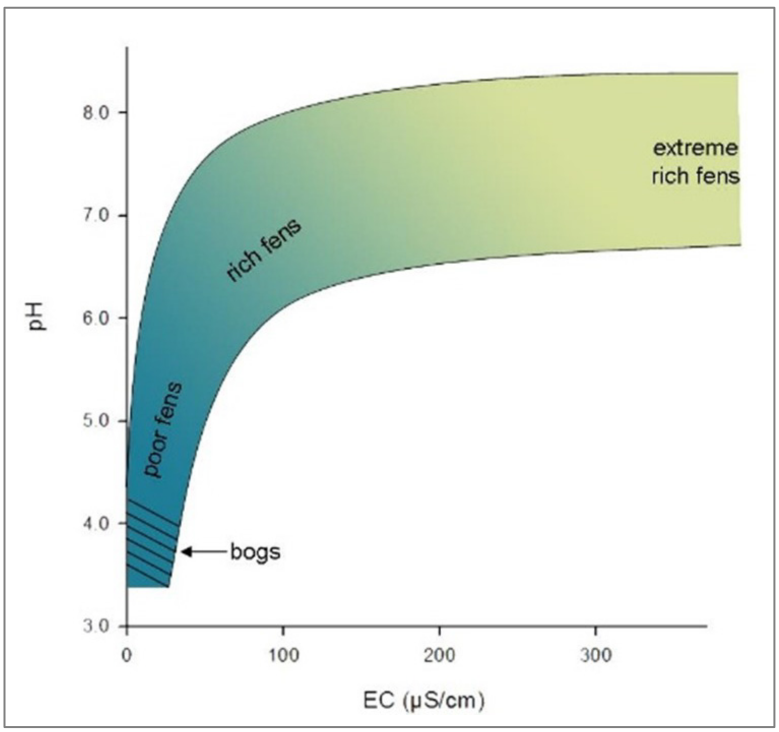

Figure 24. Range of soil water pH and electroconductivity (EC) along the poor–rich gradient in peatlands. Adapted from Malmer (1986).
NPS / CNHP

The range of water chemistry values in GRTE and JODR was similar to YELL, though values at both ends of the gradient were less common. Water pH in this study ranged from 4.86 to 8.65 with a mean of 6.56. Specific conductance (EC relativized at 25°C) ranged from 1–1105 µS/cm with a mean of 178 and a median of 54. Most pH values were between 5.0 and 7.0 and most specific conductance values were below 200, the typical range for intermediate rich fens. The highest pH and EC values were associated with geothermal activity at Huckleberry Hot Spring in JODR or in the vicinity of Jackson Lake Lodge. Detailed water chemistry from five sites in GRTE and JODR showed a range of ionic concentrations varied by location in the park and were highest in Willow Park and near String Lake. The surficial geology mapped below most fens in GRTE and JODR were Quaternary glacial and alluvial deposits, or even swamp deposits, which indicate the longevity of wetland sites in the parks. There was no clear signal related to geology in this study because the geologic template is relatively similar across the areas of parks where fens occurred. The steepness of the Teton Range precludes fen formation at higher elevations where bedrock geology might place a more significant role.

Ordination of fen vegetation in GRTE and JODR showed strong patterns related to landform, water depth, and pH. Sloping fens with willow-dominated shrub communities were clearly separated from basin with standing water and Rocky Mountain pond lily *(Nuphar lutea ssp. polysepala).* Floating mats with dense stands of woollyfruit sedge *(Carex lasiocarpa)* marsh cinquefoil *(Comarum palustre)* occupied another area of the ordination space. Both sloping fens and basin fens with floating mats had high cover of bryophytes. This study did not identify moss to the species level, but based on previous studies, bryophytes in the sloping fens were likely brown mosses *(Aulacomnium palustre, Tomentypnum nitens,* and members of the *Drepanocladus* group) (Figure 25), while bryophytes on floating mats were likely *Sphagnum* spp.

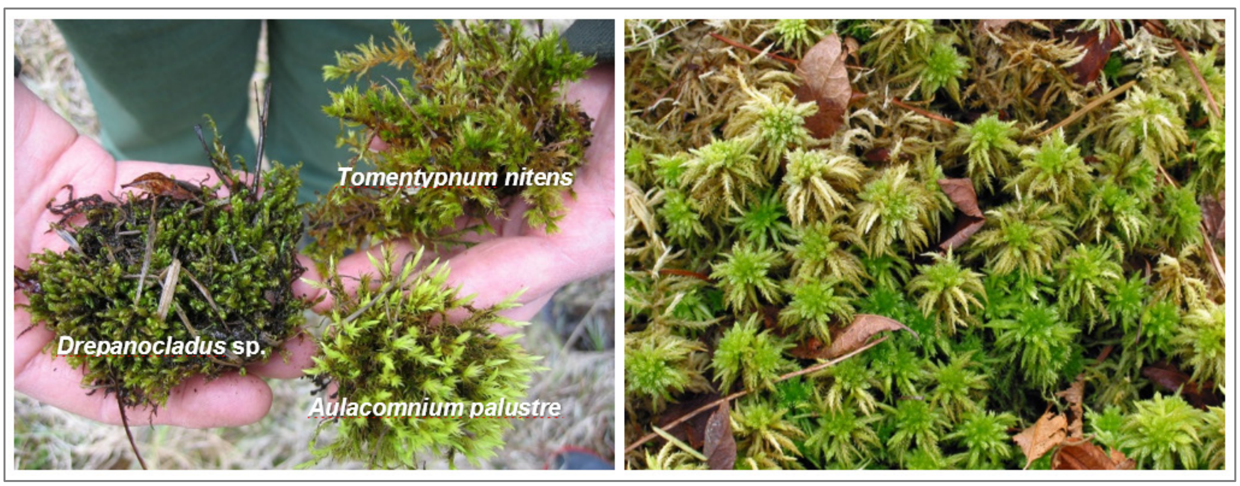

Figure 25. Common mosses of Rocky Mountains fens. Brown mosses (left) and *Sphagnum* moss (right). *NPS / CNHP*

Opportunities for Additional Research

This study provided a rich dataset on the location and characteristics of fens and rare fen species in GRTE and JODR that could be expanded with additional research. Most of the vegetation data in this study was collected through rapid, plotless inventories. Additional unrecorded species would likely be observed if more thorough inventories were conducted. In particular, record snowfall in 2023 lead to high standing water in early July and prevented a thorough inventory of potential fens in the

Cygnet Lake area. Additional survey effort in this area could locate new rare species populations. Likewise, potential fens farther from the road and trail network were not visited during this study and additional populations of rare species may occur in unvisited sites.

In the rapid species inventories, cover values were estimated in broad classes across large sites. To provide a more precise estimate of species cover, quantitative surveys were carried out in five sites. These transects could be repeated in future years to monitor vegetation change. Individual species cover values for the quantitative surveys were often lower than the cover classes estimated during the rapid inventory. Looking directly down at the vegetation in a small quadrat produced a more accurate and precise estimate of cover than estimating cover at an oblique angle. Figure 17 from GRTE-00008 clearly shows this phenomenon. Looking across the site from an oblique angle, the site looked well vegetated, but looking down at the quadrat revealed sparse vegetation and high water cover. This should be considered when comparing the quantitative transects to the rapid surveys. High water levels in 2023 should also be considered if the transects are repeated. Two of the five sites had high cover of water in 2023 that may have been related to the relatively high precipitation.

Soil samples were not collected in this study. Analysis of soil carbon content and more accurate measurements of organic soil depth would provide an estimate of carbon sequestration within the parks' fens. Carbon dynamics, including net primary productivity and CO_2 emissions, could be monitored in select fens to determine if the systems are continuing to accumulate carbon under current climatic conditions or becoming a net source of carbon (*sensu* Chimner 2000). Additionally, water chemistry samples were only collected in five sites during this study. More detailed analysis of water chemistry with the parks' fens could identify clearer relationships between water chemistry parameters and species distribution. Furthermore, this study did not include surveys of birds, wildlife or invertebrate species, many of which utilize wetland habitats. Focused study on the animal and invertebrate use of fens would likely reinforce their importance for biodiversity.

Conclusion

In conclusion, GRTE and JODR fens are exceptional resources that support regional biodiversity by hosting numerous rare species on the edge of their range. Fens in the parks are currently in excellent condition. Management plans for the park units should protect and avoid impacting these special habitats and their species so they remain intact into the future.

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Appendix A: Rare Fen-Indicator Species List

Table 20 includes the rare fen-indicator species list used during this inventory.

Table 20. Rare fen-indicator species list. Nomenclature follows Wyoming Natural Diversity Database standards, downloaded February 12, 2025.

Scientific Name	Common Name	WYNDD Tracked [A]	G Rank [B]	S Rank [B]	USFS Status [C]	Fen Affinity [D]	GRTE [E]	YELL [E]	Nearby USFS [E]
Amerorchis rotundifolia	round-leaved orchid	Y	G5	S1	Sens R2	OBL	–	–	X
Arctous rubra (Arctostaphylos rubra)	red fruit bearberry	Y	G5	S1	–	OBL	–	–	X
Botrypus virginianus (Botrychium virginianum)	rattlesnake fern	N	G5	S3	–	FAC	X	X	X
Carex buxbaumii	Buxbaum's sedge	N	G5	S3	–	OBL?	X	X	X
Carex capillaris	hair-like sedge	N	G5	S3	–	OBL?	X	–	X
Carex concinna	low northern sedge	Y	G5	S1	–	OBL?	–	–	X
Carex cusickii	Cusick's sedge	N	G5	S2	–	OBL?	X	X	–
Carex diandra	lesser panicled sedge	Y	G5	S2	Sens R2	FAC?	X	X	X
Carex echinata (C. muricata)	star sedge	N	G5	S2	–	FAC?	X	X	–
Carex flava	yellow sedge	Y	G5	S1	–	OBL?	–	X	–
Carex gynocrates (C. dioica var. *gynocrates)*	northern bog sedge	N	G5	S2S3	–	FAC	–	–	X

[A] WYNDD Tracked species are those considered species of concern by the Wyoming Natural Diversity Database (WYNDD). 'Watch' means the species is on the watch list and is a species of potential concern.

[B] G and S Ranks indicate global and state rarity, as determined by the NatureServe Network and WYNDD. Values updated February 12, 2025. More information is available at https://explorer.natureserve.org/ and https://www.uwyo.edu/wyndd/.

[C] USFS Status indicates species considered sensitive by the United States Forest Service (USFS) Region 2 and/or Region 4.

[D] Fen Affinity was determined by best professional judgment of Bonnie Heidel, for WYNDD Botanist. 'OBL' means obligate fen species, one that nearly always occurs in a fen. 'FAC' means facultative fen species, one that can occur both in fens and other habitats.

[E] GRTE, YELL, and Nearby USFS indicate previously known populations in Grand Teton National Park, Yellowstone National Park, or nearby USFS lands.

Table 20 (continued). Rare fen-indicator species list. Nomenclature follows Wyoming Natural Diversity Database standards, downloaded February 12, 2025.

Scientific Name	Common Name	WYNDD Tracked [A]	G Rank [B]	S Rank [B]	USFS Status [C]	Fen Affinity [D]	GRTE [E]	YELL [E]	Nearby USFS [E]
Carex hallii *(C. parryana* var. *unica)*	deer sedge	Y	G4?	S2	–	FAC?	–	–	–
Carex laeviculmis	smoothstem sedge	Y	G5	S1	–	FAC?	X	–	–
Carex lasiocarpa	woollyfruit sedge	N	G5	S2	–	OBL	X	X	X
Carex leptalea	bristlystalk sedge	N	G5	S3	–	OBL	X	X	X
Carex limosa	mud sedge	N	G5	S3	–	OBL	X	X	X
Carex livida	livid sedge	Watch	G5	S3	Sens R2	OBL	X	X	X
Carex luzulina var. *atropurpurea*	woodrush sedge	Y	G5T4	S2	–	FAC	X	–	X
Carex magellanica	boreal bog sedge	N	G5	S2	–	FAC	–	–	–
Carex magellanica var. *irrigua* *(C. paupercula)*	boreal bog sedge	N	G5T5	S2	–	FAC	–	–	–
Carex microglochin	fewseeded bog sedge	Y	G5	S2	–	OBL	–	X	X
Carex scirpodes var. *scirpiformis*	Canadian single-spike sedge	Y	G5T4Q	S1	–	OBL	X	–	X
Cicuta bulbifera	bulblet-bearing water hemlock	Y	G5	S1	–	FAC	X	–	X

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Comarum palustre (Potentilla palustris)	purple marshlocks	N	G5	S3	–	OBL	X	X	X
Cypripedium parviflorum var. *pubescens*	greater yellow lady's slipper	Y	G5T5	S2	Sens R2, R4	FAC	–	–	X
Drosera anglica	English sundew	Watch	G5	S3	Sens R2	OBL	X	X	X
Dulichium arundinaceum	three-way sedge	Y	G5	S1	–	FAC?	–	X	–
Epilobium oregonense	Oregon willowherb	N	G5	S2S3	–	FAC	–	–	–
Epilobium palustre	swamp willowherb	N	G5	S2	–	FAC	–	X	X
Epipactis gigantea	giant helleborine	Y	G4	S1	Sens R2	FAC	X	X	–
Equisetum fluviatile	water horsetail	Y	G5	S1	–	FAC	X	X	X
Eriophorum callitrix	arctic cottongrass	Y	G5	S1	–	OBL?	–	–	X
Eriophorum chamissonis	Chamisso's cottongrass	Watch	G5	S3	Sens R2	OBL	X	X	X
Eriophorum gracile	slender cottongrass	Watch	G5	S3	Sens R2	OBL	X	X	X
Eriophorum scheuzeri (E. altaicum)	white cottongrass	Y	G5	S2	–	OBL	–	–	X
Eriophrum viridicarinatum	thinleaf cottonsedge	Y	G5	S2	–	OBL	X	X	X
Gentianopsis simplex	oneflower fringed gentian	Y	G5	S1	–	OBL?	X	X	–

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Juncus brevicaudatus (J. tweedyi misappl.)	narrowpanicle rush	N	G5	S3	–	FAC	–	X	–
Juncus filiformis	thread rush	N	G5	S2	–	FAC	X	X	X
Kobresia simpliciuscula	simple bod sedge	Y	G5	S1	Sens R2	OBL	–	–	X
Lomatogonium rotatum	marsh felwort	Y	G5	S2	–	FAC	–	–	–
Lonicera caerulea	bluefly honeysuckle	N	G5	S2	–	FAC	–	X	X
Lycopodiella inundata	inundated clubmoss	Y	G5	S1	–	OBL	–	–	X
Lycopus uniflorus	northern bugleweed	N	G5	S3	–	FAC	–	–	X
Menyanthes trifoliata	bog buckbean	N	G5	S3	–	FAC	X	X	X
Muhlenbergia glomerata	marsh muhly	N	G5	S2	–	FAC	–	X	X
Packera indecora	elegant groundsel	N	G5	S2	–	FAC	–	–	X
Petasites frigidus var. *sagittatus*	arrowleaf sweet coltsfoot	N	G5T5	S3	–	FAC	–	X	X
Potamogeton amplifolius	largeleaf pondweed	Y	G5	S1S2	–	FAC?	–	–	X
Potamogeton epihydrus	ribbonleaf pondweed	N	G5	S2	–	FAC?	X	–	–
Potamogeton illinoiensis	Illinois pondweed	Y	G5	S1	–	FAC?	–	–	X
Potamogeton praelongus	whitestem pondweed	N	G5	S2	–	FAC	–	–	X

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[B] G and S Ranks indicate global and state rarity, as determined by the NatureServe Network and WYNDD. Values updated February 12, 2025. More information is available at https://explorer.natureserve.org/ and https://www.uwyo.edu/wyndd/.

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Potamogeton robbinsii	Robbins' pondweed	N	G5	S2	–	FAC?	–	X	X
Potamogeton zosteriformis	flatstem pondweed	Y	G5	S1S2	–	FAC?	X	–	–
Primula egaliksensis	Greenland primrose	Y	G4G5	S1	Sens R2, R4	OBL	–	–	X
Salix barrattiana	Barratt's willow	Y	G5	S1	Sens R2	OBL?	–	–	X
Salix candida	sageleaf willow	Y	G5	S2S3	Sens R2	OBL	–	X	X
Salix farriae	Farr's willow	N	G4G5	S3	Sens R4	Fac	–	X	X
Salix myrtillifolia	myrtleleaf willow	Y	G5	S1	Sens R2	OBL	–	–	X
Salix serrisima	autumn willow	Y	G4	S1	Sens R2	OBL	–	–	–
Botrychium multifidum (Sceptridium multifidum)	leathery grapefern	N	G5	S3	–	FAC	X	–	X
Scheuchzeria palustris	rannoch-rush	Y	G5	S1	–	OBL?	X	X	X
Schoenoplectus subterminalis	swaying bulrush	Y	G5	S1	–	OBL	–	X	–
Selaginella selaginoides	club spikemoss	Y	G5	S1	Sens R2	FAC?	–	X	X
Sparganium natans (Sparganium minimum)	small bur-reed	N	G5	S3	–	OBL?	X	X	X

[A] WYNDD Tracked species are those considered species of concern by the Wyoming Natural Diversity Database (WYNDD). 'Watch' means the species is on the watch list and is a species of potential concern.

[B] G and S Ranks indicate global and state rarity, as determined by the NatureServe Network and WYNDD. Values updated February 12, 2025. More information is available at https://explorer.natureserve.org/ and https://www.uwyo.edu/wyndd/.

[C] USFS Status indicates species considered sensitive by the United States Forest Service (USFS) Region 2 and/or Region 4.

[D] Fen Affinity was determined by best professional judgment of Bonnie Heidel, for WYNDD Botanist. 'OBL' means obligate fen species, one that nearly always occurs in a fen. 'FAC' means facultative fen species, one that can occur both in fens and other habitats.

[E] GRTE, YELL, and Nearby USFS indicate previously known populations in Grand Teton National Park, Yellowstone National Park, or nearby USFS lands.

Table 20 (continued). Rare fen-indicator species list. Nomenclature follows Wyoming Natural Diversity Database standards, downloaded February 12, 2025.

Scientific Name	Common Name	WYNDD Tracked [A]	G Rank [B]	S Rank [B]	USFS Status [C]	Fen Affinity [D]	GRTE [E]	YELL [E]	Nearby USFS [E]
Symphyotrichum boreale (Aster borealis, Aster junciformis)	northern bog aster	N	G5	S3	–	FAC	–	X	X
Thalictrum alpinum	alpine meadow-rue	N	G5	S2	–	FAC?	–	–	X
Trichophorum pumilum (Scirpus pumilus)	Rolland's bulrush	Y	G5	S2	–	OBL	–	–	X
Utricularia intermedia	flatleaf bladderwort	Y	G5	S1	–	OBL	–	–	X
Utricularia minor	lesser bladderwort	Watch	G5	S3	Sens R2	OBL	X	X	X
Utricularia ochroleuca	northern bladderwort	Y	G4G5	S2	–	OBL	–	X	–

[A] WYNDD Tracked species are those considered species of concern by the Wyoming Natural Diversity Database (WYNDD). 'Watch' means the species is on the watch list and is a species of potential concern.

[B] G and S Ranks indicate global and state rarity, as determined by the NatureServe Network and WYNDD. Values updated February 12, 2025. More information is available at https://explorer.natureserve.org/ and https://www.uwyo.edu/wyndd/.

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