Species Status Assessment (SSA) Report

for the

Northeastern Bulrush

(*Scirpus ancistrochaetus*)

Version 4

Scirpus ancistrochaetus (Photo credit: Bob Popp)

August 2019
U.S. Fish and Wildlife Service
Northeast Region
Hadley, Massachusetts

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for the northeastern bulrush (*Scirpus ancistrochaetus*). This report is intended to provide the biological support for the decision on whether the northeastern bulrush should remain listed as endangered, warrants downlisting to threatened status, or no longer meets the statutory definition of endangered or threatened and warrants removal from listed status under the Endangered Species Act (Act) of 1973, as amended. The process and this SSA report do not represent a decision by the U.S. Fish and Wildlife Service (Service) whether or not to retain endangered status, downlist, or delist the species under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the northeastern bulrush.

The northeastern bulrush is a member of the sedge family (*Cyperaceae*) native to the northeastern United States. It is a wetland obligate occurring in ephemeral wetlands and beaver-influenced wetlands in New Hampshire, Vermont, Massachusetts, New York, Pennsylvania, Maryland, Virginia, and West Virginia. The species' optimal habitat includes fluctuating water levels, little canopy cover, and acidic to circumneutral soils with high organic matter. Persistent shading, flood, and drought have been shown to cause populations to decline dramatically. The SSA identified fluctuating water levels, light availability, and regulatory protection as the primary factors influencing viability.

The Service listed the species as endangered under the Act in 1991. At that time, there were 13 known extant occurrences in 7 states. As of 2018, the northeastern bulrush is known to occur in 8 states, with at least 148 extant populations (figure 2-6). The populations can be loosely organized into northern and southern "regions" with a large gap in the distribution in southeastern New York. The species is listed as endangered in all states in which it occurs except West Virginia, which does not have endangered species legislation.

Our knowledge of the species' genetic makeup is based on a limited sample of genetic markers. Rangewide, the northeastern bulrush exhibits low genetic diversity but diversity varies geographically. The New England region shows very little diversity, while the southern states exhibit higher diversity along with some genetically unique populations. The species can reproduce sexually and clonally, but successful sexual reproduction and dispersal appears rare, resulting in clonal populations with clumped distributions and almost no genetic diversity. Additional genetic diversity may be present in undescribed markers.

We used the best available information, including peer-reviewed scientific literature; survey data provided by state agencies and academic institutions from New Hampshire, Vermont, Massachusetts, New York, Pennsylvania, Maryland, Virginia, and West Virginia; and first-hand accounts from state biologists and other species experts. We defined northeastern bulrush populations based on known occurrence locations. These locations include as few as one individual in one wetland or several individuals distributed in a closely spaced cluster of wetlands.

We considered the northeastern bulrush's ecological requirements and the factors that affect those requirements to assess current condition and predict future condition. We described the species' current and plausible future condition in terms of resiliency, redundancy, and representation – collectively known as the 3Rs.

We determined that fluctuating water levels, light availability, and regulatory protection are the primary factors affecting the species' viability. However, the available information on these factors lacked consistency across the species' range. Therefore, we evaluated resiliency at the population level using element occurrence (EO) rank, which incorporates population size, habitat condition, conditions over time, and probability of persistence. We used each population's EO rank to score each population as being in poor, fair, good, or excellent resiliency. The northeastern bulrush currently exhibits good resiliency rangewide, with approximately 60.8 percent of extant populations having good or excellent resiliency.

To evaluate representation, we considered the northeastern bulrush's genetics and environmental diversity. The available information on the species' genetics has limitations but generally indicates low genetic diversity, especially in New England, but there are substantial differences between the New England and Appalachian regions. The species demonstrates high environmental representation as it occurs in two habitat types–ephemeral wetlands and beaver-influenced wetlands—and four physiographic provinces.

The northeastern bulrush's redundancy is based on its 148 known extant occurrences distributed over a large geographic area including several distinct environmental settings. In addition, 60.8 percent of populations have excellent or good resiliency, and 89.2 percent have excellent to fair resiliency.

We modeled a single scenario to assess the potential future viability of the northeastern bulrush in the context of the 3Rs. We carried the scenario though year 2050, because we have information to reasonably assess risk from changes in climate within this timeframe. In the context of the northeastern bulrush, we generally anticipate higher water levels early in the growing season followed by hotter summers and a faster drying cycle. Changing climate will affect fluctuating water levels, climatic stochasticity, and light availability, and have neutral effects on beaver wetlands and negative effects on ephemeral wetlands. Consistent with current condition, we used EO rank to assess future resiliency condition.

The future scenario results in moderate negative effects on resiliency, a slight decline in representation and in redundancy, and extirpation of 13 populations from seasonal wetlands—2 in the New England region and 11 in the Appalachian region. Approximately 135 populations are predicted to remain in 2050, although this number would be higher if offset by discovery of new populations. The species likely will retain low genetic diversity, especially in the New England region, and over the long term, may have difficulty adapting to changing environmental conditions. Low genetic representation will continue to be mitigated by diversity of habitat type and physiographic provinces. The species is predicted to retain its redundancy driven by a wide geographic distribution and variety of environmental settings, although the species' apparent dispersal difficulty will limit its ability to shift its range in response to changing climate.

CHAPTER 1 - INTRODUCTION

Background

This report summarizes the results of a species status assessment (SSA) conducted for the northeastern bulrush (*Scirpus ancistrochaetus* Schuyler). The U.S. Fish and Wildlife Service (Service) listed the northeastern bulrush as endangered on June 6, 1991 (Service 1991, entire), under the Endangered Species Act of 1973, as amended (Act). At that time, there were 13 known extant occurrences and 9 historical occurrence in 7 states. As of 2018, the northeastern bulrush is known to occur in 8 states, with at least 148 known extant populations and 9 historical and extirpated populations. Because of the apparent substantial change in the rangewide status of the northeastern bulrush, the Service initiated a discretionary status review in April 2018 to compile and analyze the best available scientific and commercial data regarding the species' biology, factors influencing the species' viability, and current status.

Analytical Framework

The SSA report, the product of conducting an SSA, is intended to be a concise review of the species' biology and factors influencing the species, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA report to be easily updated as new information becomes available, and to support all functions of the Endangered Species Program. As such, the SSA report will be a living document upon which other documents such as recovery plans and 5-year reviews will be based if the species remains listed under the Act. The SSA report also will support future decisions about the northeastern bulrush's listing status and, eventually, a post-delisting monitoring plan.

This report is intended to provide the biological support for the decision to change or retain the endangered status of the species under the Act. The SSA process and this SSA report do not represent a decision by the Service regarding the species' status under the Act. Instead, this SSA report provides a review of the best available information strictly related to the biological status of and threats to the northeastern bulrush. Listing decisions will be made by the Service after reviewing this document and all relevant laws, regulations, and policies. The results of the listing decision will be explained in a 5-year review, and a decision to change the species' listing status would be announced in the Federal Register with opportunity for public comment.

Using the SSA framework (figure 1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (Service 2016, entire; Smith *et al*. 2018, entire). For the purpose of this assessment, we generally define viability as the ability of the northeastern bulrush to sustain populations in its natural habitat over time. Resiliency, redundancy, and representation are defined as follows:

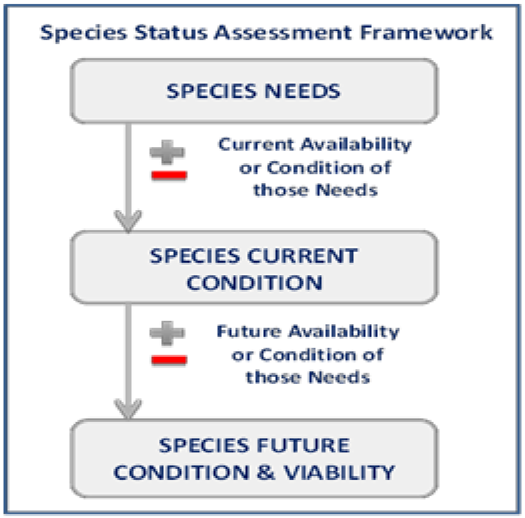

Figure 1-1. Species Status Assessment Framework

Resiliency means having sufficiently large populations for the species to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health—for example, population size and recruitment, if that information exists. Resilient populations are better able to withstand disturbances such as random fluctuations in recruitment (demographic stochasticity), variations in rainfall (environmental stochasticity), or the effects of human activities.

Redundancy means having a sufficient number of populations for the species to withstand catastrophic events (such as a rare destructive natural event or episode involving many populations). Redundancy is about spreading the risk and can be measured through the duplication and distribution of populations across the range of the species. Generally, the greater the number of populations a species has distributed over a larger landscape, the better it can withstand catastrophic events.

Representation means having the breadth of genetic makeup of the species to adapt to changing environmental conditions. Representation can be measured through the genetic diversity within and among populations and the ecological diversity (also called environmental variation or diversity) of populations across the species' range. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human-caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of the species' morphology, habitat characteristics within the geographical range, or both.

The decision whether to list, downlist, or delist a species is based not on a prediction of the most likely future for the species, but rather on an assessment of the species' risk of extinction. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future to account for the uncertainty of the species' future. We evaluate the current biological status of the northeastern bulrush by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of resiliency, redundancy, and representation (together, the

3Rs). We then evaluate the future biological status of the northeastern bulrush by describing the single plausible future scenario representing the plausible conditions for the primary factors affecting the species and forecasting the most likely future condition for that scenario in terms of the 3Rs. As a matter of practicality, the full range of potential future scenarios and the range of potential future conditions for each potential scenario are too large to individually describe and analyze. This scenario does not include all possible futures, but rather includes the single plausible scenario determined to be sufficiently likely as to make other scenarios implausible. This SSA report provides a thorough assessment of northeastern bulrush biology and natural history and assesses demographic factors and stressors in the context of determining the viability and risk of extinction for the species.

CHAPTER 2 - SPECIES INFORMATION

Taxonomy and Genetics

The northeastern bulrush is a member of the sedge family (*Cyperaceae*) native to the northeastern United States. It was first described as a new species by A.E. Schuyler in 1962 (Schuyler 1962, entire) and is 1 of 18 species in North America of a natural group of leafy bulrushes within the genus *Scirpus*. Based on the morphological and genetic evidence, as well as the botanical expertise of A.E. Schuyler with the genus *Scirpus*, the Service recognizes it as a species.

The best available genetic information on the northeastern bulrush comes from Cipollini *et al*. (2013) and Cipollini *et al.* (2017). As the authors acknowledge, because the results of Cipollini *et al.* (2017) are based on analysis of only eight loci, there is some uncertainty in the conclusion drawn from these results. For example, analysis of other loci could reveal more diversity within the New England cluster than indicated by this study.

Cipollini *et al.* (2017, p. 68-71) explored genetic variation among populations of the northeastern bulrush across its range. They collected and analyzed leaf samples from 180 individuals in 96 wetlands at 71 sites across 7 states. The northeastern bulrush shows some genetic diversity across its range, although its nucleotide diversity is far lower than that of an outgroup, panicled bulrush (*Scirpus microcarpus*), determined from samples collected from Vermont and New York (Cipollini *et al.* 2017, p. 71). Populations do not appear to be well connected genetically and are clustered by geography and distance (Cipollini *et al.* 2013, pp. 692-693), resulting in Cipollini *et al.* (2017) identifying three genetic clusters: New England (Massachusetts, Vermont, and New Hampshire), Pennsylvania (Pennsylvania, Maryland, and northeastern West Virginia), and southern Appalachian (Virginia and westernmost site from West Virginia). The Pennsylvania and southern Appalachian clusters exhibit higher genetic diversity than New England (Cipollini *et al.* 2017, pp. 72, 74). This suggests either rare long-distance dispersal (e.g., seeds transported by migratory birds) and recruitment or a historically more widespread "parent" population with connectivity between the regions. The autosomal genotype found in the New England cluster is not represented in the other clusters. Genetic variation among populations within each cluster is low, especially in the New England states where populations are genetically identical to each other and differ from the other two clusters. Rangewide, there is almost no intrapopulation genetic diversity Cipollini et al. (2013, p. 693; 2017 pp. 71,74).

We are not aware of additional genetic studies that analyze northeastern bulrush population genetics in greater detail. The existing literature notes no morphological differences among populations.

Species Description

The northeastern bulrush is a tall (80 to 120 centimeter), leafy, perennial herb that produces stems and leaves from short, thick underground rhizomes (figure 2-1). It is distinguished from other *Scirpus* species by its drooping, clustered fruiting heads; dark, chocolate-brown florets;

achene bristles that are barbed to the base, and broad bracts (Schuyler 1962) (figures 2-2 and 2-3). Flowering occurs from mid-June to July, and fruit sets between July and September.

Figure 2-1. Thick underground rhizomes and leaves. Photo Credit: Terry Ettinger SUNY-ESF

Figure 2-2. Northeastern bulrush, Vermont. Photo Credit: Bob Popp

Figure 2-3. Dark, chocolate brown flowers of the northeastern bulrush, Vermont. Photo Credit: Bob Popp

Life History

The life history and reproductive biology of the northeastern bulrush are not fully understood, in part because the species is difficult to study—it is not easily identifiable when it is not fruiting or in flower; it occurs in widely scattered, isolated wetlands; and its presence or observability may be unpredictable from year to year.

The northeastern bulrush can reproduce both sexually and vegetatively. Sexual reproduction occurs in the form of flowering and/or fruiting stems. However, the primary means of recruitment appears to be vegetative reproduction by new plants developing from nodal and basal shoots. This appears to be supported by the observed clumping of stems (evidence of cloning). The parental stem dies by autumn, leaving the nodal shoots to root themselves as independent plants (as cited in Service 1993). Genetic information indicates frequent clonal reproduction and low success of sexual reproduction (Cipollini *et al.* 2013, pp. 691-695; 2017, p. 74), likely contributing to the species' low genetic interconnectedness and apparent difficulty dispersing.

Light availability and changes in hydrology can have substantial effects on the northeastern bulrush, and individuals likely respond to shifts in these habitat factors by altering reproductive strategy from sexual to asexual or vice versa. Lower water levels seem to promote sexual reproduction, but asexual reproduction also occurs under this condition (as cited in Service 1993; 2009).

Survey data from throughout the northeastern bulrush's range indicate there can be variable fluctuations in population size from year to year. In some cases, plants are absent above ground for several years before re-emerging. This is likely due to changes in environmental conditions, although the exact causal mechanisms are not well understood. When water levels and/or light availability are not favorable, the population becomes stressed, dwindles in size, and sometimes becomes completely absent above ground. When favorable habitat conditions return, the population may re-emerge. For example, a population in Pennsylvania had been declining for several years likely due to increased overstory canopy shading. Once canopy thinning occurred through active management of the site, the population gradually increased, though it is not yet at its maximum recorded numbers (Mary Ann Furedi, Pennsylvania Natural Heritage Program [PNHP], pers. comm. October 2018).

Habitat Needs

The northeastern bulrush is a wetland obligate plant occurring in acidic to almost neutral wetlands including sinkhole ponds, wet depressions, vernal pools (collectively, seasonal or ephemeral wetlands), beaver flowages, and other riparian areas found in hilly country (Schuyler 1962, p. 47). Optimal habitat includes abundant sunlight, higher organic matter (Lentz and Dunson 1999, p. 165), and seasonally and/or annually fluctuating water levels, although prolonged periods with too much or too little water may be detrimental. The northeastern bulrush may be found in a wide range of water depths from deep water to several feet away from the water's edge, depending on seasonal fluctuations in water levels (Thompson 1991, p. 5). Plants typically grow in open areas surrounded by forest. Light availability is known to influence plant growth, reproduction, and distribution (Boardman 1977, p. 372; Lentz and Cipollini 1998, p. 126). Shaded plants are often taller, but at the expense of the roots and other organs (Lentz and Cipollini 1998, pp. 127, 129), and the species usually is absent from the highly shaded perimeter of wetlands.

Wetland characteristics at occupied sites vary geographically—in the northern part of its range, the majority of known northeastern bulrush populations are in beaver flowages, whereas in the southern part of its range, known populations are almost exclusively found in ephemeral wetlands. Wetlands occupied by the species in the northern part of its range do not appear to have any obvious, unique habitat characteristics, and the species is absent from many seemingly suitable wetlands. Both wetland types supporting the northeastern bulrush are fed by surface water, although some wetlands also receive ground water inputs, which likely increase the stability of those wetlands (Lentz-Cipollini and Dunson 2006, p. 275). Populations in wetlands that fill solely from surface water may be more be sensitive to low rainfall years. The available information for most northeastern bulrush populations does not include whether groundwater influences water level.

Environmental Setting

The northeastern bulrush occurs in eight states: Vermont, New Hampshire, Massachusetts, New York, Pennsylvania, Maryland, Virginia, and West Virginia; and four physiographic provinces (New England, Blue Ridge, Valley and Ridge, and the Appalachian Plateaus [figure 2-4] [National Park Service (NPS) 2017 a-d]).

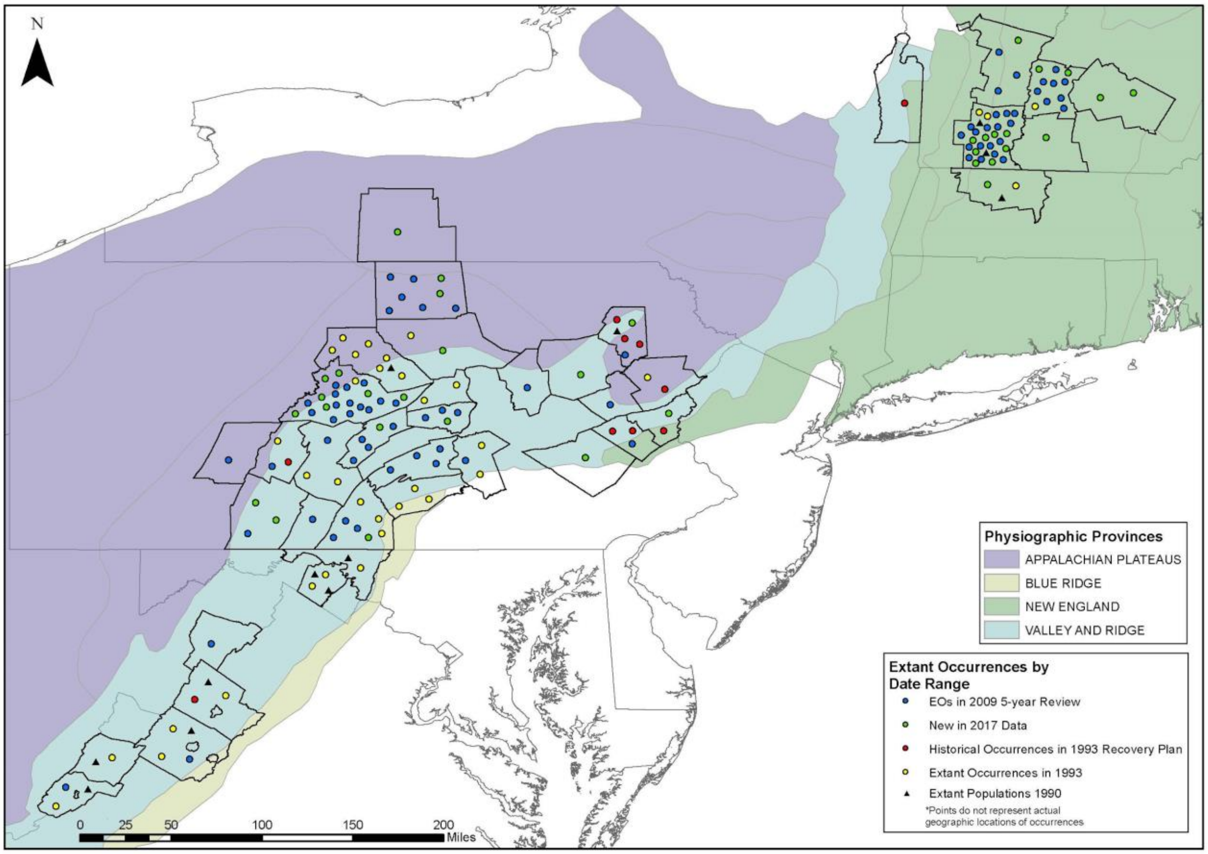

Figure 2-4. Northeastern bulrush range in eight states and four physiographic regions. Dots indicate the number, but not the exact location, of populations in a county and state.

The New England Province, in the northeastern United States, is a mountainous area of significant relief. The area is made up of highly deformed Precambrian and Paleozoic metamorphic rocks including gneisses, schists, slates, quartzite, and marble. The Precambrian rocks occur primarily to the west and south, with Paleozoic sedimentary and metasedimentary (metamorphosed sedimentary) rocks making up the rest of the region. In some areas, erosion has exposed large masses of coarsely crystalline Paleozoic granite. The Province was glaciated during the Pleistocene and shows both depositional and erosional effects of glacial ice. The Taconic, Green, and White Mountain Ranges are distinct features of the New England Province. The Taconic Mountains are a north-south trending mountain range along the western edge of the province, and are thought to be formed by erosion of an upper block of a large thrust fault. Also north-south trending, the Green Mountains exist primarily in Vermont and are made of Precambrian gneisses. The Green Mountains exhibit greater relief than the Taconic, with peaks exceeding 1.2 kilometers (4,000 feet). The White

Mountains are an exhumed mass of Paleozoic granite and include Mount Washington, the tallest in the region at 1,917 meters (6,288 feet).

The Valley and Ridge Province, in the Appalachian Mountain region, is a series of northeast-southwest trending synclines and anticlines composed of Early Paleozoic sedimentary rocks. Limestones and shales are more susceptible to erosion and make up much of the valleys, whereas more resistant sandstones and conglomerates form the ridges. This folded strata are the result of the compression associated with the assembly of the supercontinent Pangea and the various mountain building events that produced the Appalachian Mountains. Many of these folds are plunging, meaning that the axes (fold creases) are not horizontal but are tilted to the northeast or southwest. At the southernmost extent, the Valley and Ridge appears to plunge beneath the Coastal Plain Province. Erosion of this folded and tilted terrain has produced a trellis drainage pattern.

The Appalachian Plateaus Province is composed of sedimentary rocks including sandstones, conglomerates, and shales that exist largely as horizontal beds that have been cut by streams to form mountainous terrain. In the recent geologic past, the northern portion of the Appalachian Plateaus has been subject to the effects of glaciation (NPS 2017a).

The Blue Ridge Province is a mountainous belt stretching from Pennsylvania southwest to Georgia. The mountains are made of highly deformed metamorphic rocks of largely Precambrian ages. These include schists, gneisses, slates, and quartzites, and are extensively intruded by igneous bodies. The Blue Ridge Province includes several mountain ranges, including the Blue Ridge Range, which is a drainage divide between the Great Valley to the west and the Atlantic Ocean to the east, the Great Smoky Mountains along the Tennessee-North Carolina border, the Unaka and Cahutta Mountains, and the Black Mountains.

Prior to 2002, the species' known range in Virginia, West Virginia, Maryland, and Pennsylvania was limited to the Valley and Ridge Province. However, in 2002, a large population was found in Tioga County, Pennsylvania, in the Appalachian Plateaus Province, well outside the previously known range of the species. Since then, five additional populations have been found in the Appalachian Plateaus Province.

Range and Distribution

The Service's final rule to list the northeastern bulrush as endangered documented 13 populations in 6 states (Service 1991, entire) (figure 2-5); however, the species is now known from 148 extant populations in 8 states, including all states occupied in 1990 (figure 2-6). Increased survey effort since listing is likely the primary reason for the increase in the number of known populations. Recent survey results have been mixed. For example, 100 sites with seemingly suitable habitat in New Jersey were surveyed in 2016, with negative results (Gilbert 2017, entire). On the other hand, in 2017, thousands of plants were found in what could be the largest population in New Hampshire; and in July 2019, a new population[1] was discovered in Pennsylvania.

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[1] This population has not been officially surveyed and given an EO rank; therefore, it is not included in this SSA's analysis.

The populations can be loosely organized into northern and southern “regions” with a large gap in the distribution in southeastern New York (figure 2-6). These regions are consistent with the “evolutionarily significant units” recommended in Cipollini *et al.* (2017, p. 76) and provide an additional aspect, along with the rangewide distribution, with which to analyze the 3Rs. The northern or New England region includes extreme eastern New York and the New England states of Vermont, New Hampshire, and Massachusetts; and the southern or Appalachian region includes southwestern New York, Pennsylvania, Maryland, Virginia, and West Virginia. The vast majority of populations are in Pennsylvania (59.5 percent), Vermont, (20.9 percent), and New Hampshire (9.5 percent).

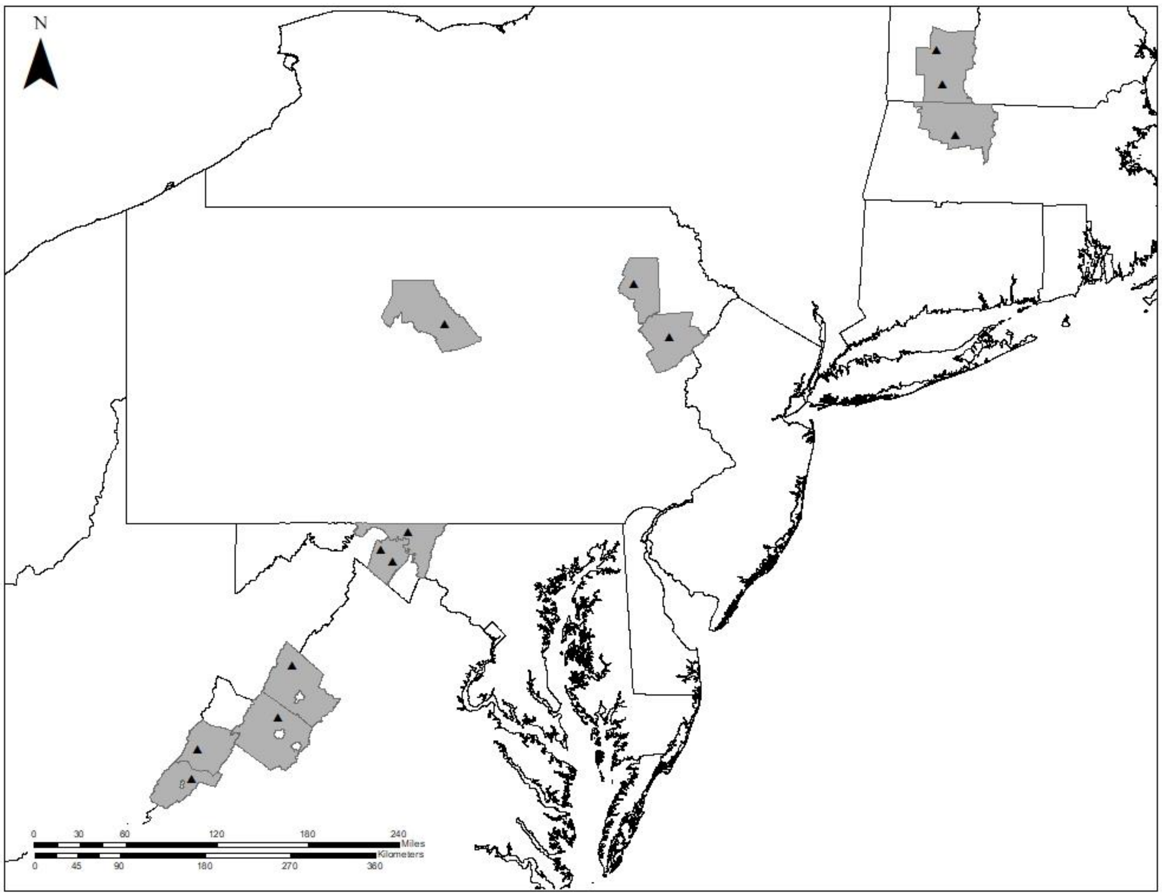

Figure 2-5. Extant populations in 1991.

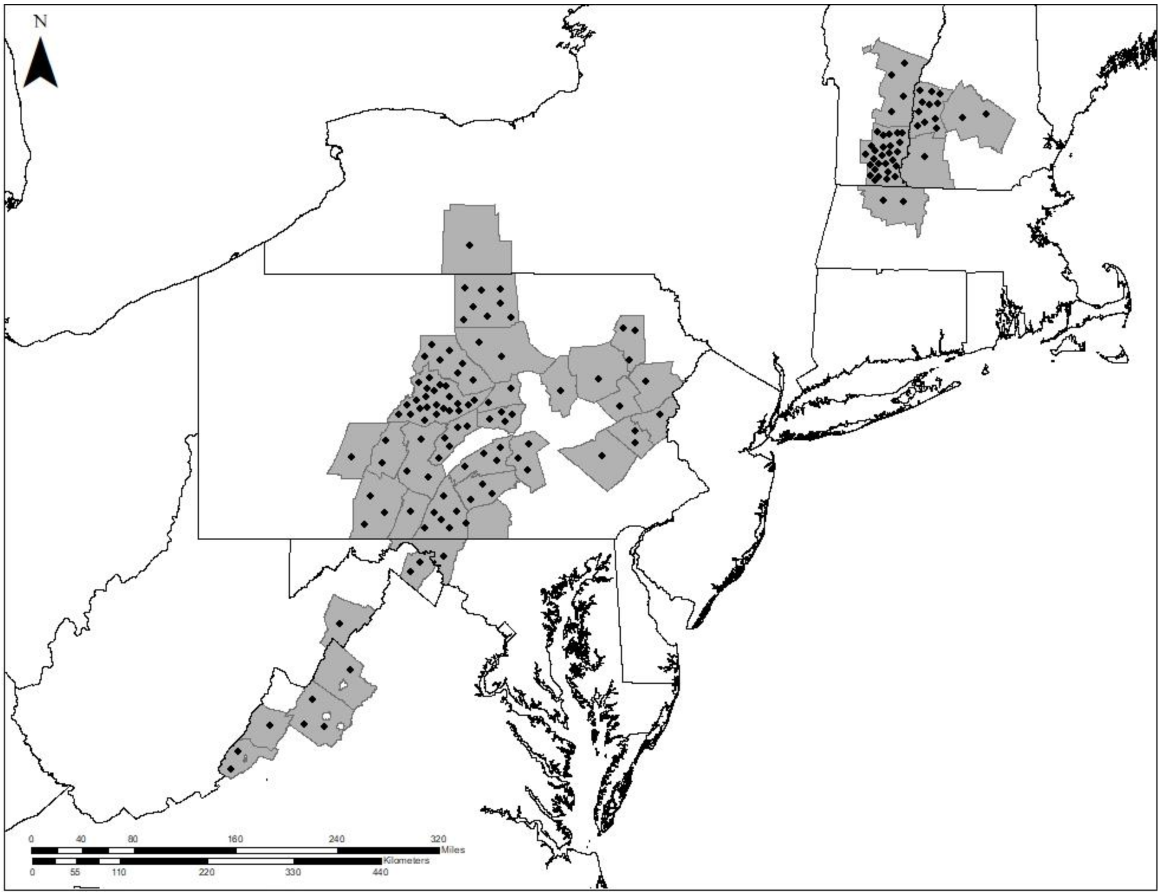

Figure 2-6. Extant populations in 2017.

Prior to 2014, all of the known occurrences of the northeastern bulrush in New Hampshire were within 10 miles of the Connecticut River, in a 20-mile stretch from the town of Langdon in the south to Cornish in the north. However, in August 2014, a new population was found on private land in the Town of Canterbury, New Hampshire, in the Merrimack River watershed, a range expansion of roughly 40 miles to the east. This unexpected finding prompted *de novo* searches for additional locations in the area, resulting in discoveries of three other new sites, all within a mile of the original 2014 discovery location. In 2017, another new population in Canterbury was located on a site with split ownership—part of the population is on town-owned property and the other part is on private property. In what could be the largest population in New Hampshire, thousands of plants could be observed in the wetlands adjacent to town-owned land, but could not be surveyed, because the property is privately owned.

In New York prior to 2010, there was only one historical extirpated population, located in northeastern New York near the Vermont border. In 2010, a second New York population was found in the Appalachian region, adjacent to north-central Pennsylvania. There is a third population in New York, where the Wetland Trust and the Upper Susquehanna Coalition implemented a pilot program to propagate and transplant the northeastern bulrush. The effort has been moderately successful to date, with a population that appears to be self-sustaining; however, because (1) this population was only recently established; (2) data is limited for the population as it has not been surveyed under the same protocols as other populations; and (3) the population has not been given an initial element occurrence rank; we did not include it in our analysis of northeastern bulrush viability. In Massachusetts, where there was only one previously known population, a second population was found in 2011.

CHAPTER 3 –FACTORS INFLUENCING VIABILITY

Based on the northeastern bulrush's life history and habitat needs, we identified potential negative and positive influences, and the contributing sources of those influences, likely to have meaningful effects on the species' viability.

Fluctuating Water Levels

The northeastern bulrush is an emergent sedge found in forest vernal pools and other ephemeral wetlands as well as beaver-influenced ponds and marshes. A common characteristic of all wetlands where the northeastern bulrush is found is water levels that fluctuate seasonally and/or annually, providing adequate surface water to fill wetlands and then allow a gradual drawdown of water levels. Ephemeral wetlands typically experience inundation in late winter and spring and falling water levels in summer and fall to the point that surface water may be absent but the soil is still saturated (Service 1993). Fluctuations can vary greatly within a given season due to variable temperature and precipitation patterns acting on surface water along with increased evapotranspiration rates from surrounding vegetation. There is evidence that water level differences as small as 2 inches can trigger changes in initial growth pattern, leaf life span, and root-to-shoot ratio (Lentz and Dunson 1998, p. 216). Water levels in beaver wetlands can fluctuate on seasonal timescales but also shift on longer-term cycles of beaver occupation, disuse, and reoccupation of an area. The species' adaptation for dormancy above ground is beneficial as it allows for survival during unfavorable habitat conditions; however, too much or too little water is detrimental.

Although the northeastern bulrush has adapted to fluctuating water levels, populations may decline if hydrology is altered to the point that water remains too high or low. Stochastic climatic events can create these conditions through drought or flood. Typically, climatic events are not dramatic enough and persistent enough to extirpate a population, although flood and drought likely reduce population resiliency. However, large differences (4+ inches) in annual rainfall, and/or successive years of flood or drought, can cause substantial population effects in a single season (Lentz-Cipollini and Dunson 2006, p. 275). Beavers can create flood conditions by increasing water depth by constructing or adding to a dam and raising the water level in a wetland occupied by the northeastern bulrush. Consistently low water could make individuals less competitive against other species, and water levels that remain too high decrease the lifespan of the northeastern bulrush (Lentz and Dunson 1998, p. 217). Water levels that remain too low create conditions less favorable to the northeastern bulrush and more favorable to other vegetation, which can result in the dominance of other species over the northeastern bulrush. While it is clear that extremes in water level fluctuation can have substantial consequences for northeastern bulrush populations, currently there is little information about the frequency, magnitude, and duration in water level fluctuation a population can tolerate before it begins to decline or is extirpated.

Light Availability

The northeastern bulrush is typically found in wetland openings surrounded by forests. The species performs well under higher light conditions and is generally found in the sunniest portions of a wetland. Overarching trees edging the perimeter of wetlands create a shaded environment that can become even more light limited as forest succession and maturation proceeds. Increased canopy shading over time can reduce light quality at a site, which in turn can have a negative effect on individual plant health, population size, and population persistence at a site. Lentz and Cipollini (1998, p. 129) found that light levels strongly affected growth and biomass allocation of the northeastern bulrush. Shaded plants were often taller to maximize light exposure but at the expense of shoot and root mass. These results indicate that increases in shading, which can result from forest canopy closure, can contribute to the reduction or loss of northeastern bulrush populations at a site. Northeastern bulrush population decline has been attributed to increased canopy shading for some sites in Pennsylvania (Cipollini and Cipollini 2011, p. 281; M. Furedi, PNHP, pers. comm. 2018).

Forest succession and maturation typically cause canopy closure and reduced light availability. Conversely, tree canopy gaps are created naturally through various mechanisms, such as wind throw, flooded soils weakening trees, and beaver activity. Beavers have a positive effect habitat quality by harvesting trees and other woody vegetation for food and shelter, thereby creating open canopy and increasing light availability. Land managers in Pennsylvania and West Virginia have used active vegetation management (physical cutting of trees, girdling, and chemical applications) to partially open the canopy at a few sites where bulrush populations have diminished in size (as cited in Cipollini and Cipollini 2011, p. 284; M. Furedi, PNHP, pers. comm. 2018). Post treatment monitoring data indicate a positive population response to increased light levels at these sites.

For larger wetlands, the shading effect is probably minimal and limited to the wetlands' edge, but for smaller wetlands, like vernal pools, overarching canopy shading can significantly reduce light availability at a site over time. In a comparative study of northeastern bulrush sites followed over 14 years, Cipollini and Cipollini (2011, p. 284) found a general increase in canopy cover by approximately 25 percent overall. In the absence of canopy disturbance (whether it be natural or human-caused), it is likely that light availability at these sites will continue to decline. A northeastern bulrush population will respond negatively to persistent shading and, without canopy relief, could be extirpated. Shading could be a threat to the species' viability in the southern portion of the range, because most northeastern bulrush sites in that area are found in ephemeral wetlands. However, most ephemeral wetland populations persist without active maintenance, even if at smaller population sizes, than they would with active maintenance, because shading can be naturally alleviated by wind throw, flooded soils weakening trees, and beaver activity. Therefore, while shading likely reduces population resiliency, it does not appear to be a sole or common factor in population loss.

Regulatory protection

Regulatory mechanisms, including listing under the Act, benefit the northeastern bulrush by raising the species' public profile and protecting, or at least minimizing impacts to, the species and its habitat. The Act has facilitated surveys and habitat management by raising awareness and urgency of the northeastern bulrush as a listed species among non-Federal land managers (M. Furedi, PNHP, pers. comm. 2018). However, in assessing the status of a listed species, the Service assumes the species is not listed under the Act; therefore, we do not consider protections, funding, or other benefits of the Act in assessing risks to the northeastern bulrush in the future. Furthermore, to the extent that Federal regulatory mechanisms other than the Act, as well as state and local regulatory mechanisms, are providing benefits to the northeastern bulrush solely as a consequence of its listing under the Act, the future benefits of these other regulatory mechanisms also would not be considered in assessing the status of the species.

The species is designated as state endangered throughout its range except for West Virginia, which does not have a State endangered species law. The states that currently protect the northeastern bulrush under an endangered species law or otherwise, generally, at a minimum, require project proponents to coordinate with state resource agencies to develop minimization measures. These states do so independently of the species' Federal designation, even if protecting the species originally was triggered by a Federal listing action. Removing state protections would occur after independent state review and not compulsorily with a change in Federal status.

The wetland habitats in which the northeastern bulrush occurs are ostensibly protected by Federal and state statutes and regulations (e.g., Clean Water Act), although they typically include a permitting process that allows direct impacts to wetlands. Some states have statutes and/or regulations that afford greater protection to the northeastern bulrush than the Act does. For example, Vermont, New York, and Massachusetts require protection of upland buffers and permits to work within wetlands; however, state protection of upland areas around the wetlands is inconsistent, and disturbance such as roads or other development near wetlands can cause indirect effects such as sedimentation, altered hydrology, and introduction of invasive species. Conversely, roads occasionally cause ponding with suitable hydrological fluctuation for the northeastern bulrush.

Following is a summary, taken from the 5-year review (Service 2009) and verified for this SSA, of current laws and regulations regarding wetlands and buffers in states in which the northeastern bulrush occurs:

> ***Maryland***. Under Maryland's endangered species regulations, *Scirpus ancistrochaetus* is listed as endangered, independent of its status under the Act. Protection is afforded only to the habitat, not the plants. Under the State's Wetland Protection Act, about 200 wetlands identified as Wetlands of Special State Concern (WSSC) are legally protected. If State or federally listed species are present, a wetland must be designated a WSSC. All WSSC are regulated by Maryland's Department of the Environment and are protected by a 100-foot buffer. Although this buffer prevents most development impacts, there may be some allowances for "unavoidable" impacts such as placement of stormwater devices. Under the Critical Area Law, all known locations of State and federally listed species are considered to be Habitat Protection Areas (HPAs). These HPAs are given various forms of protection as circumstances differ (nature of activity, underlying zoning, local ordinances, etc.), and buffers are not delineated in advance.
>
> ***Massachusetts***. Under the Massachusetts Endangered Species Act (MESA; chapter 131A), S*cirpus ancistrochaetus* is listed as State endangered, independent of its status under the Act. It is protected from take unless a permit has been issued by the Director of

Fisheries and Wildlife. MESA offers protection to all State-listed endangered, threatened, and special concern species, whether or not they occur on public or private lands.

Buffer zones are defined as 100 feet, and projects proposed within this area must be reviewed; however, this does not mean that work cannot occur, because individual town bylaws vary with regard to the limits of "Do Not Disturb" restrictions within the 100-foot buffer area. In addition, plants are not necessarily protected by the State's Wetland Protection Act. Currently, wetland plant species, including *Scirpus ancistrochaetus*, are given a 200-foot buffer around their "species habitat polygons" (i.e., 200 feet are added to what is interpreted as the "species habitat polygon"). This establishes the "Species Regulatory Polygon" used to trigger environmental review under current regulations. Most agricultural practices, including crop production and mowing, are not reviewed by regulatory agencies. Other exemptions also exist. Only larger timber removal projects are reviewed against the Species Regulatory Polygons.

New Hampshire. Independent of its status under the Act, the northeastern bulrush is listed as endangered under the New Hampshire Native Plant Protection Act of 1987. The New Hampshire Department of Environmental Services requires review of all wetlands applications for the presence of threatened or endangered species and makes recommendations to avoid or minimize impacts. However, the presence of a threatened or endangered plant does not limit a landowner's ability to proceed with a project. Only proposed activities in designated "prime wetlands" are required to have an upland buffer. Currently, there are not any northeastern bulrush populations within designated prime wetlands.

In general, nonregulated activities in New Hampshire that might occur in northeastern bulrush wetlands include (1) repair or reconstruction of certain existing legal structures; (2) mowing or cutting of vegetation in some wetlands, subject to conditions to minimize surface disturbance; (3) culvert installation in limited flow situations; and (4) removal of beaver dams, subject to certain conditions.

New York. In New York, the northeastern bulrush is listed as State endangered, independent of its status under the Act. Wetlands containing threatened and endangered species are ranked as "Class 1" wetlands, which receive more stringent standards for permits. New York also regulates a 100-foot upland buffer around all wetlands (with or without threatened and endangered species).

Regulated activities in New York include (1) filling, including filling for agricultural purposes; (2) draining and altering water levels, except as part of an agricultural activity; (3) removing or breaching beaver dams; (4) clear-cutting trees and other wetland vegetation; (5) grading, dredging, or mining; constructing roads; (6) drilling a water well to serve an individual residence; (7) installing docks, piers, or wharfs; (8) constructing bulkheads, dikes, or dams; (9) constructing a residence or related structures or facilities; (10) constructing commercial or industrial facilities, public buildings, or related structures; installing utility services; and (11) applying pesticides.

Pennsylvania. In Pennsylvania, the northeastern bulrush is listed as State endangered under the Wild Resources Conservation Act (25 Pa. Code, Chapter 82), independent of its status under the Act. Permits are required to collect, remove, or transplant wild plants classified as threatened or endangered; however, private landowners are exempt from these requirements.

Wetlands supporting threatened and endangered species are considered "exceptional value" wetlands under the State's wetland permitting regulations. As such, there are more stringent requirements to receive a permit to encroach into the wetland. Only encroachments for safety purposes would be considered for permitting. No upland buffers around any wetlands are regulated or protected at the State level.

Additionally, in Pennsylvania, most agricultural (crop production, tilling) and timber harvest practices are not reviewed under State wetland regulations, unless fill in the wetland is proposed (e.g., for a road crossing) and a permit is sought. Upland activities that do not involve a wetland encroachment, including residential and commercial development, are typically not reviewed or regulated under State wetland laws, although some type of stormwater permit and/or earth disturbance permit may be necessary, in addition to complying with local municipal zoning requirements. Consequently, a review for endangered and threatened species is typically not done for these upland activities.

Vermont. Independent of its status under the Act, the northeastern bulrush is listed as endangered under Vermont's Endangered Species Law. Under this law, a permit is required to take, possess, or transport wildlife or plants that are members of an endangered or threatened species. If the listed plant occurs in a significant wetland, no additional protection is mandated. However, if the listed plant were to occur in a wetland not previously designated as significant, the presence of the plant would raise that wetland's status to significant. If a wetland is deemed significant, only certain allowed uses may occur in that wetland; all other uses would require a conditional use permit. Wetlands in Vermont receive a 50-foot buffer if they contain endangered or threatened species, and are considered significant.

Allowed uses that are exempt from review and conditional use permits, even in significant wetlands, include (1) silvicultural activities that comply with a plan approved by the Commissioner of Forest and Parks; (2) agricultural activities if threatened or endangered species are protected; (3) routine repair and maintenance of existing structures; (4) recreational activities; (5) fish and wildlife management, including removal of beaver dams which pose a hazard to public safety, or public or private property; (6) operation of existing hydroelectric facilities which many involve dredging, draining or altering flow; routine repair and maintenance of utility poles; (7) emergency repair of structures and facilities, including roads, docks, piers, buildings, etc.; (8) routine maintenance of manmade ponds (less than 2 acres), including dredging, temporary draining, altering the flow of water; (9) control of nonnative nuisance plants by hand pulling; and (10) the operation of dams, provided there is no undue adverse effect on protected wetland functions (this use may involve draining or altering the flow of water).

These allowed uses may occur only if the configuration of the wetland's outlet, or the flow of water into or out of the wetlands, is not altered, and no draining, dredging, filling, or grading occurs.

Virginia. In Virginia, the northeastern bulrush is listed as State endangered, independent of its status under the Act; however, no additional protection (e.g., buffers) is afforded to wetlands supporting the species. No upland buffers are regulated or protected around any wetlands in the State. The northeastern bulrush is protected under the Endangered Plant and Insect Species Act of 1979, which prohibits take without a permit, but individual landowners are exempt from these permitting requirements.

West Virginia. The northeastern bulrush has no official State government status in West Virginia, and this State does not have an endangered species law. Therefore, no protections similar to those provided by the Federal Endangered Species Act would apply in the absence of the Act. No upland buffers are regulated or protected around any wetlands in the State.

Other Factors Considered

In addition to the influences described above, other factors may affect the northeastern bulrush, but are of such low likelihood as to be discountable or such low magnitude as to be insignificant. We considered the factors below but did not carry them forward for further analysis.

<u>Disturbance (human-caused) - Development</u>
Anthropogenic disturbance can affect northeastern bulrush populations directly by damaging or killing individuals or indirectly by destroying vernal pools or wetlands, introducing pollutants and sediment, and altering the hydrology of a site. The Service's listing rule indicated development was a direct and indirect threat to the northeastern bulrush and described known habitat loss, habitat degradation, and loss of populations from development and modification of wetland hydrology. Development activities that have affected the species include residential and commercial development, road construction/maintenance, pipeline and power line construction/maintenance (Service 1993, pp. 34-36), and agriculture. The listing rule documented populations in Virginia, West Virginia, and Pennsylvania that had been disturbed/destroyed, or were threatened, by development.

Although development was an important threat at the time of listing, the threat largely seems to have abated, with only one population lost to development since listing. The development activities listed above are still possible future threats to northeastern bulrush populations. At this time, oil and gas development in Pennsylvania is perhaps the most likely arena for this threat to manifest; however, no available information indicates any populations are under imminent threat from development. Therefore, while anthropogenic activities can adversely affect the northeastern bulrush, extirpation of a population due to development is unlikely.

<u>Land Ownership</u>
Approximately 60 percent of northeastern bulrush populations occur on publicly owned land subject to multiple uses that may include some combination of forestry, oil and gas leasing, road

construction and maintenance, and recreation. Populations on privately owned land generally face similar activities, but also could be impacted by residential and commercial development and agricultural activities. However, as stated above, although at the time of listing we considered development to be an important threat, at this time we consider it to be a discountable or insignificant threat. Lastly, although statutes and regulations can treat populations differently depending on land ownership, protections vary state to state, and some lax state protections are superseded by Federal protections (e.g., the Clean Water Act). For these reasons, we did not find a clear distinction in negative or positive effects on the species based on land ownership.

Fire

Fire is an uncommon stressor on northeastern bulrush populations, because natural fires occur infrequently in the northeastern United States, and to impact the northeastern bulrush, an ignition source has to coincide with a wetland that is dry enough to burn. However, when these conditions align, fire can have severe impacts on a population. When fire is used as a management tool, it is usually done in the early spring when vernal pools are at full capacity so even if the fire burns at high temperature, it tends to be limited to the edges, and if vegetation is present at such an early time in the season, it may be mostly submerged in the water-filled pool/wetland. For these reasons, we consider fire to be an insignificant threat.

Disturbance (non-human-caused)

Animal-mediated disturbance is the primary non-human disturbance mechanism affecting the northeastern bulrush. White-tailed deer (*Odocoileus viginianus*) are known to browse and trample individual northeastern bulrush plants. Browsing and trampling adversely affects plant fitness, especially if other factors such as limited light availability are also affecting the individual (Lentz and Cipollini 1998, p. 129). While they typically operate at the individual level, browsing and trampling can have population-level impacts in very small populations. Browsing and trampling are unlikely to have long-term impacts on a population, because they usually do not kill plant roots and individual plants can resprout in subsequent seasons. Responses from the states to our 2017 request for data for this SSA included reports of 9 populations (6.1 percent of 148), all in Pennsylvania, exhibiting signs of deer browsing. Other observers reported higher levels of deer browse at northeastern bulrush sites. Cipollini and Cipollini (2011, p. 282) reported deer trampling and browsing at 22 (38 percent) of 57 sites visited in Pennsylvania, Maryland, West Virginia, and Virginia.

Black bears (*Ursus americanus*) also contribute to the trampling of plants as they move through northeastern bulrush sites; however, the wallows they form are more damaging. Bears excavate wallows near the edge of wetlands, which affects above- and below-ground parts of northeastern bulrush individuals. The wallows can be big enough and used consistently enough to destroy an entire population if the population is very small. The information we received after our SSA data call indicated 9 populations were affected by bear wallowing, while Cipollini and Cipollini (2011, p. 282) reported 10 (17 percent) of 57 sites affected, and 1 population possibly extirpated, by wallowing. On the other hand, wallows can be beneficial. Cipollini and Cipollini (2011, p. 286) reported that wallows help create open water, which is important during dry periods, and that bears may be dispersers of northeastern bulrush seeds.

In summary, browsing, trampling, and wallowing can have mixed, yet substantial, impacts on northeastern bulrush populations. However, these factors potentially affect only a small number of populations, are highly unlikely to cause population extirpation, and may produce a net benefit to some populations.

Proximity to roads/trails

Other anthropogenic activities affecting the northeastern bulrush include off-road vehicle activities, logging/forest road construction and maintenance, and modification of beaver activity to reduce road flooding (Bob Popp, Vermont Fish and Wildlife Department, pers. comm. August 2019). In response to our data call for the SSA, we received reports of old vehicle tracks through wetlands and a spectrum of road effects. Roads near bulrush habitat range from seldom used forest roads/trails to logging roads. Effects similarly ranged from negative impacts of runoff to neutral effects of roads used primarily for hunting to positive effects when a road caused ponding that actually improved northeastern bulrush habitat. An example of negative impacts occurs in Pennsylvania where drainage on some forestry roads is diverted away from the roads and into vernal pools. This has the potential of altering the hydrology of the pool through increased surface water contributions (M. Furedi, PNHP, pers. comm. 2018). Some populations in Pennsylvania where this has occurred have declined over time, but the decline may be a combination of changes in hydrology and increased shading of these sites (M. Furedi, PNHP, pers. comm. 2018). This practice also can result in increased sedimentation to the site and potential changes to water chemistry as influenced by road materials.

Northeastern bulrush populations regularly occur near roads, although the available information suggests that roads have minor, population-level impacts. Twenty-four (16.2 percent) of 148 site/population descriptions mention that roads are either in or near the wetland occupied by the northeastern bulrush. However, only five (3.4 percent) of those records describe an adverse effect from the road(s) (including sedimentation), while many of the roads are described neutrally as “seldom-used,” “only used for hunting,” or other low-impact uses. The surveyors also occasionally report that roads benefited the northeastern bulrush by causing ponding.

Sedimentation

The available information suggests roads are the primary source of excessive sediment in northeastern bulrush habitat; however, as mentioned above, roads rarely appear to have adverse effects on populations.

Plant competition

Northeastern bulrush populations can be subject to competitive effects from native and nonnative species, especially invasive species. The Service (2018) defines nonnative, invasive species as “...an exotic species whose introduction into an ecosystem in which the species is not native causes or is likely to cause environmental or economic harm or harm to human health.” These species can outcompete, predate, or otherwise cause substantial direct or indirect negative impacts to one or more native species and/or their habitats. The northeastern bulrush is affected at some sites by the nonnative Japanese stiltgrass (*Microstegium vimineum*) and glossy buckthorn (*Frangula alnus*). Reed canarygrass (*Phalaris arundinacea*), which is described as both native and nonnative (Forest Service 2018), is, at least, an effective competitor of the northeastern bulrush and may have extirpated the species at one site (Cipollini and Cipollini 2011, p. 281).

Besides nonnative, invasive species, the northeastern bulrush may face competitive threats from native plants under certain environmental/climatic conditions. The northeastern bulrush has adapted to fluctuating water levels, but changes in hydrological regime, especially if it persists over many years, may alter competitive advantage in favor of another species to the detriment of the northeastern bulrush. If the wetlands in which the northeastern bulrush exist dry out earlier in the growing season due to low water levels or increased temperatures, other species may outcompete it over time (Lentz and Dunson 1998, p. 218).

Still, the available information indicates the viability of few northeastern bulrush populations is currently affected by competing plant species, and we have no information to indicate that this factor may become a significant threat in the future.

<u>Conservation measures</u>

There are conservation measures in progress that benefit northeastern bulrush viability:

1. Since listing, every state in the species' range has conducted ongoing surveys of known occupied and suitable habitat, which resulted in a dramatic increase in the number of known populations and the species' known occupied range.
2. In Pennsylvania, there is a long-term monitoring effort being conducted in an attempt to understand population dynamics and environmental control mechanisms, and how they can be applied to successful management strategies.
3. Some targeted habitat management is occurring. For example, a population in Pennsylvania had been declining for several years likely due to increased overstory canopy shading. Once canopy thinning occurred through active management of the site, the population gradually increased, though it is not yet at its maximum recorded numbers (M. Furedi, PNHP, pers. comm. October 2018).
4. In New York, the Wetland Trust and the Upper Susquehanna Coalition have implemented a pilot program for the propagation and transplantation of the northeastern bulrush. The effort has been at least moderately successful to date, with a 40 percent plant survival rate after 2 years and a population that appears to be self-sustaining. However, because the success of the recent propagation is uncertain, and the population has not been surveyed and evaluated under the same protocols as other populations (e.g., it does not have an EO rank), we did not consider this population as contributing to the species viability.
5. In Vermont, the Service is implementing measures to control glossy buckthorn affecting a population in Putney.

CHAPTER 4 – CURRENT CONDITION

Methodology

To assess the biological status of the northeastern bulrush across its range, we used the best available information, including peer-reviewed scientific literature, survey data provided by state agencies, unpublished information from species experts, and information in our files. We defined northeastern bulrush populations using known occurrence locations reported by the states. According to the SSA framework, we assessed the species' current condition in the context of the 3Rs—resiliency, redundancy, and representation. We determined resiliency for each population and then evaluated resiliency, redundancy, and representation at the rangewide scale.

Ideally, we would use quantitative metrics of the four primary factors influencing the species viability to describe the species' current condition; however, the types of data and information available to us varied from one northeastern bulrush population to the next and from state to state. This occurred due to nonstandardized survey frequency, survey rigor, terminology, and data collection. Examples include: some populations were surveyed more frequently than others, different individuals surveyed the same population, and some surveyors counted or estimated the number of northeastern bulrush individuals, while others used qualitative descriptions. The resulting data set precluded us from confidently applying a standardized description of population resiliency using typical habitat and demographic metrics (e.g., number of individuals, recruitment rate). Therefore, we used surrogate parameters of demographic and habitat condition to describe population resiliency.

Element Occurrence Rank

We used EO rank to assess and describe the current resiliency of northeastern bulrush populations. Element occurrence rankings (Hammerson *et al*. 2008; NatureServe 2018) document the status and quality of plant population occurrences and assess the probability of an occurrence persisting. Surveyors of the northeastern bulrush report an EO rank each time a population is surveyed, and depending on their observations, the rankings may change from one survey effort to the next. For the purposes of this analysis, we used the EO rank that was assigned to each population during the most recent survey.[2]

<u>Summary titles for NatureServe EO ranks, not all of which were reported in northeastern bulrush survey data:</u>

A - Excellent estimated viability/ecological integrity
A? - Possibly excellent estimated viability/ecological integrity
AB - Excellent or good estimated viability/ecological integrity
AC - Excellent, good, or fair estimated viability/ecological integrity

[2] The 2008 5-year review for the northeastern bulrush (Service 2009) reported general EO rank definitions, as well as quantitative and qualitative rank definitions developed specifically for the northeastern bulrush (appendix 1). We were unable to identify the origin of these definitions, so we are using the general EO rank definitions listed in Hammerson *et al*. (2008).

B - Good estimated viability/ecological integrity
B? - Possibly good estimated viability/ecological integrity
BC - Good or fair estimated viability/ecological integrity
BD - Good, fair, or poor estimated viability/ecological integrity
C - Fair estimated viability/ecological integrity
C? - Possibly fair estimated viability/ecological integrity
CD - Fair or poor estimated viability/ecological integrity
D - Poor estimated viability/ecological integrity
D? - Possibly poor estimated viability/ecological integrity
E - Verified extant (viability/ecological integrity not assessed)
F - Failed to find
F? - Possibly failed to find
H - Historical
H? - Possibly historical
X - Extirpated
X? - Possibly extirpated
U - Unrankable
NR - Not ranked

We consider the EO rank to be the most meaningful way to describe a population's status, as it requires an in-person observation and combines multiple components of a population's condition into a single metric. EO ranks are assigned by a surveyor based on observations beyond just population size, but also habitat conditions at the site at the time of the survey, conditions over time since its last observation, and probability of persistence.

We scored each EO rank rating for each population to develop a current condition resiliency score for each population. We considered populations with EO ranks of A, AB, or AC "excellent;" populations with EO ranks of B, BC, or BD "good;" populations with EO ranks of C or CD "fair;" and populations with an EO rank of D or E "poor." We summarized the range of scores for each rating in table 4-1. We did not score occurrences with an EO rank of F (Failed Occurrence), H (Historical Occurrence), or X (Extirpated Occurrence), as we considered these populations extirpated.

Table 4-1. EO rank ratings and score used to describe current condition.

EO Rank Rating	Score
A, AB, AC	Excellent
B, BC, BD	Good
C, CD	Fair
D, E	Poor

Uncertainty
There is uncertainty in our interpretation of EO rank:

1. Survey effort is not uniform, and some populations were last surveyed many years ago. However, trying to modify our method to account for time since the last survey would have introduced additional uncertainty and potential error. Therefore, we consistently applied our methodology to the available information.
2. At least one other, more rigorous ranking method (e.g., Cipollini and Cipollini 2011) exists. This method likely has advantages over the EO rank method we used; however, the EO ranks we used are consistent across all states in the species' range, and the Cipollini and Cipollini (2011) method was applied only once to a subset of populations.
3. When an EO rank rating includes a pair of letters (e.g., AC), it indicates the population is rated somewhere along the spectrum of the two letters. So an "AC" population is somewhere from Excellent to Fair. We chose to use the high side of these rankings; therefore, an AC population scored as excellent rather than good or fair. This method errs on the side of higher viability.

Current Condition – 3Rs

Appendix 2 includes resiliency scores for all 148 extant populations (and lists 9 extirpated populations) and provides the basis for our analyses of the species' current status using the 3Rs. The EO rank/population score is a measure of each population's resiliency, and these scores form a comparative foundation for our analyses of the species' redundancy (among the various populations) and representation (across its environmental settings). Table 4-2 summarizes the number of populations categorized under each rank (poor, fair, good, excellent).

Resiliency

Resiliency describes the ability of a population to withstand environmental or demographic stochastic disturbance. We used EO rank to assess northeastern bulrush population resiliency and ranked populations as having poor, fair, good, or excellent resiliency. Extirpated populations did not receive a resiliency score.

<u>Rangewide Resiliency</u>

Table 4-2. Summary of current northeastern bulrush resiliency rangewide.

Resiliency	EO Rank Group	Current Condition: # of Populations	% of 148 Extant Populations	% of 157 Populations Including Extirpated
Extirpated	N/A	9	N/A	5.7
Poor	D/E	16	10.8	10.2
Fair	C	42	28.4	26.8
Good	B	66	44.6	42.0
Excellent	A	24	16.2	15.3

The northeastern bulrush currently exhibits good resiliency rangewide. Ninety populations (60.8 percent of extant populations) currently have good or excellent resiliency, and 88.5 percent of extant populations scored fair or better. All occupied states except Maryland, which has only one extant population, have at least one population with good or excellent resiliency. Element occurrence ranks in A and B groups indicate populations that occur in favorable or better habitat and are likely to persist for at least the next 20 to 30 years (Hammerson *et al*. 2008).

Forty-two populations have fair resiliency (EO rank of C or CD), indicating small and declining populations and/or those that occur in less-than-ideal or relatively low-quality habitat. However, these populations still are likely to persist into the future (at least 20 to 30 years) if they are protected and appropriately managed (Hammerson *et al*. 2008).

Sixteen populations (10.8 percent of extant populations) have "poor" resiliency and have a high probability of being extirpated. These populations occur in low-quality habitat and/or experience various complications from very small population size.

To interpret these results with respect to the species' needs and other factors influencing resiliency for which our parameters are surrogates, northeastern bulrush populations with excellent and good resiliency tend to have stable populations in high-quality habitat (i.e., fluctuating water levels, suitable soil pH, adequate light), more individuals per population, and lower risk of disturbance. In the context of resiliency, these populations are more likely to recover from stochastic disturbance because the habitat is superior and a stable population, regularly expressing above ground, can reproduce more often than an inconsistent population. In addition, as high resiliency populations are in lower risk environments, perhaps they are less likely to experience stochastic disturbance.

Regional Resiliency

Table 4-3. Summary of northeastern bulrush regional resiliency – extant populations

Resiliency	EO Rank Group	Number of New England[3] Populations	% New England Populations	Number of Appalachian[4] Populations	% Appalachian Populations
Poor	D/E	4	8.3	12	12.0
Fair	C	13	27.1	29	29.0
Good	B	23	47.9	43	43
Excellent	A	8	16.7	16	16

We explored whether the species' current resiliency condition varied geographically (table 4-3), and found the two regions exhibit similar resiliency. The largest differences were in the poor and good categories, but both by less than 5 percentage points. Given that we are using an index to determine resiliency, and the index is not strictly consistent between populations (see

[3] Includes New Hampshire, Vermont, Massachusetts, and eastern New York.
[4] Includes southwestern New York, Pennsylvania, Maryland, Virginia, and West Virginia.

“Uncertainty” subsection above), the geographic variation in resiliency is too small to say with confidence that the differences between the regions are substantial.

<u>Resiliency by Habitat</u>
Rangewide, most populations (78 percent) occur in seasonal wetlands, but the distribution is geographically disparate. In the New England region, 60.4 percent of populations (29 of 48) occur in beaver wetlands, while in the Appalachian region, 97 percent of populations (97 of 100) occur in ephemeral wetlands.

Excellent and good resiliency populations occur in both beaver-influenced and ephemeral wetlands; however, there may be differences in the probability that good and excellent populations would occur in each habitat type. When we pooled the two habitat types, 60.8 percent of 148 extant populations ranked good or excellent. However, a larger percentage of populations in beaver-influenced wetlands scored good and excellent than those in seasonal wetlands—75 percent versus 57 percent, respectively. Beaver-influenced wetlands may support higher resiliency populations, because (1) they are larger, on average, than ephemeral wetlands, allowing larger northeastern bulrush populations; (2) water fluctuations are present but tempered by upstream water inputs and damming compared to faster wetting/drying cycles in ephemeral wetlands; (3) they typically have less canopy cover (i.e., greater light availability) than ephemeral wetlands; and (4) suitable habitat conditions are available more often from year to year, prompting northeastern bulrush populations to express above ground and reproduce/recruit more often.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions over time and is characterized by the breadth of genetic and environmental diversity within and among populations. We evaluated two facets of the northeastern bulrush’s adaptive capacity: genetics and environmental diversity.

<u>Genetics</u>
The available information indicates the northeastern bulrush generally demonstrates low genetic diversity across its range, especially in the New England region. Threats from low genetic diversity include genetic drift and inbreeding depression, and lower genetic diversity reduces the species’ adaptive capacity (i.e., representation). The effects of low diversity on reproduction and viability have not been studied; therefore, there is no evidence of any symptoms of low genetic diversity.

As described in Chapter 2, based on regional genetic differences and predominant habitat types (beaver-influenced wetlands versus ephemeral wetlands), Cipollini *et al*. (2017, p. 76) recommended recognition of two “important evolutionarily significant units,” New England and Pennsylvania/southern Appalachians (Appalachian). They combined the Pennsylvania and southern Appalachian clusters into one unit because of relatively weak support for the southern Appalachian genetic cluster, habitat similarity (nearly all Appalachian populations occur in ephemeral wetlands), and geographic proximity (Cipollini *et al*. 2017, p. 72).

The Appalachian unit contains higher genetic diversity, signifying the importance of protecting allelic diversity within this group, especially in light of the species' limited overall genetic diversity (Cipollini *et al*. 2017, pp. 71-76).

The New England populations contain little variation, but Cipollini *et al*. (2017, p. 76) pointed to the potential adaptive importance of the species' occupation of different habitats (beaver wetlands and ephemeral wetlands). They also suggest that developing new markers may show diversity within the New England region not identified in the suite of loci used in their study (Cipollini *et al*. 2017, pp. 67, 75).

Although the northeastern bulrush exhibits some genetic diversity, especially in the Appalachian region, the species has a low sexual reproduction, and populations are genetically isolated and have poor dispersal success rate (Cipollini *et al.* 2013, pp. 692-693; 2017, pp. 73-74), which functionally isolates populations. In addition, populations often reproduce clonally. These factors reduce the species' ability to adapt to changing environmental conditions.

<u>Environmental Diversity</u>
Habitat Diversity – As discussed above, the northeastern bulrush occurs in two habitat types—ephemeral wetlands and beaver-influenced wetlands. Both habitat types occur rangewide, although a much higher percentage of populations in the New England region occur in beaver wetlands than in the Appalachian region—60.4 percent versus 3 percent, respectively. While the two habitat types appear equally suitable for the species at this time, we reason that the two habitats have differences that diversify the species' potential adaptive response. For example, the two habitat types likely have different cycles of canopy cover succession, short- and long-term hydroperiod(s), and frequency at which the species' needs are available such that the species can present above ground and reproduce. The two habitats may exert different selective pressures on bulrush populations, possibly increasing the species' ability to respond to changing environmental conditions.

On the other hand, few (3) populations in the Appalachian region occur in beaver wetlands, which reduces its representation with regard to habitat type. The New England region has a more balanced habitat type distribution, and therefore has a higher representation with regard to habitat type.

Physiographic Provinces – There are extant populations of the northeastern bulrush in four physiographic provinces (figure 2-4): New England, Valley and Ridge, Appalachian, and Blue Ridge. There are dozens of populations in the New England and Valley and Ridge Provinces, with fewer in the Appalachian Plateau, and at least one in the Blue Ridge. Each physiographic province provides different geology, topography, climatic variability, soils, and other characteristics that drive biotic and abiotic environmental diversity and adaptive pressures, and the species' persistence in these areas demonstrates increased adaptive capacity.

Redundancy

Redundancy describes the ability of a species to withstand catastrophic events by maintaining multiple, resilient populations distributed within the species' ecological settings and across the species' range. The northeastern bulrush's redundancy is based on its 148 known extant occurrences distributed over a large geographic area, including several distinct environmental settings (i.e., physiographic provinces and habitat types). In addition, 60.8 percent of populations have excellent or good resiliency, and 89.2 percent have excellent to fair resiliency.

The northeastern bulrush is now known from a large geographic area stretching approximately 600 miles from the northernmost populations in Merrimack County, New Hampshire, to the southernmost populations in Alleghany County, Virginia. This area comprises four physiographic provinces (figure 2-4), and the species' redundancy continues to grow as more populations are discovered. Since listing, the number of known extant northeastern bulrush populations increased from 13 to 148, with only 9 populations considered extirpated. Excellent- and/or good-resiliency populations occur in every occupied state, and occurrences persist in every state in which the species has been observed. The species' distribution and physiographic diversity suggest it should be able to withstand large-scale climatic events or other disturbance.

The geographic distribution and habitat diversity suggest the species also should be resistant to events such as drought, flood, and disease. For example, impacts of large-scale drought on ephemeral wetlands could be moderated by persistent habitat availability in beaver wetlands due to impounded water. Because the Appalachian region has relatively few beaver wetlands, it could experience greater disruption from drought; however, it is possible drought would not affect populations in multiple physiographic provinces equally. As another example, if disease had a large-scale impact on beaver populations, habitat for the northeastern bulrush would remain in ephemeral wetlands, even in New England where a much larger percentage of populations occur in beaver wetlands. Lastly, the absence of the species in southeastern New York and Connecticut creates a gap in the species' distribution. In the context of representation and genetic exchange, this gap could be interpreted as a liability; however, in the context of a catastrophic mechanism like disease, a disjunct distribution could be an asset that prevents or slows transmission and increases redundancy at the rangewide scale.

Summary of Current Condition

We are aware of 148 extant populations of the northeastern bulrush, and 89.2 percent of these demonstrate excellent, good, or fair resiliency. Genetic diversity is limited, especially in New England, but there are substantial differences between the New England and Appalachian regions. Representation is reduced by low genetic diversity rangewide and limited dispersal ability. The species' redundancy is driven by its wide geographic distribution of excellent- and good-resiliency populations, and variety of environmental settings (four physiographic provinces and two habitat types) in which the species occurs.

CHAPTER 5 – FUTURE CONDITION

Methodology

We modeled a single scenario to assess the potential future viability of the northeastern bulrush in the context of the factors influencing species viability and the 3Rs. We carried the scenario though year 2050, because we have information to reasonably predict changes in climate within this timeframe. While there are other possible future scenarios, we determined that the likelihood of the modeled scenario is sufficiently high as to make other scenarios implausible.

Just as for current condition, we do not have adequate data on the factors influencing the species' viability—fluctuating water levels, climatic stochasticity, light availability, and regulatory protection—to directly use these factors to anticipate future condition of the northeastern bulrush. Therefore, consistent with current condition, we used EO rank to assess future resiliency condition.

We explored plausible changes in the factors considered in an EO ranking—population size, biotic factors, abiotic factors, and landscape context (Hammerson *et al*. 2008)—to anticipate future changes in EO rank at each population. We were unable to explicitly predict changes in population size; however, we were able to use existing climate models to qualitatively anticipate effects of changing climate on biotic and abiotic factors (i.e., habitat type and quality). We used the same population resiliency scoring model for future condition that we used for current condition. Accordingly, to describe plausible future viability, we model future resiliency at the population level and likely trends in redundancy and representation at the rangewide scale.

Future Scenario

Here we describe the plausible future scenario based on information we have about how the primary factors influencing viability may change into the future and expressed in terms of the 3Rs. In this scenario, we expect climatic conditions to change between now and 2050 and affect fluctuating water levels, climatic stochasticity, and light availability. This results in extirpation of the 13 "most vulnerable" populations, which currently have poor resiliency and occur in seasonal wetlands. Surveys may discover new populations; therefore, we estimate a net decrease in approximately 10 populations, most of which occur in the Appalachian region.[5] Our scenario considers an absence of protection under the Act. We predict that this scenario will result in moderate negative effects on resiliency, a slight decline in representation, and a slight decline in redundancy. Table 5-1 summarizes expected changes in each of the condition parameters.

[5] The northeastern bulrush population recently propagated in New York by the Wetland Trust and the Upper Susquehanna Coalition may ultimately contribute to the species' viability. However, uncertainty about the success of the outplanting, and the lack of survey and element occurrence rank protocols applied to all other populations, led us to exclude this population from contributing to the species' future viability.

Table 5-1. Projected trend for future condition.

	Future Condition
Resiliency	Moderate decline
Representation	Slight decline
Redundancy	Slight decline

<u>Regulatory Protection</u>
In our future scenario, regulatory protection continues to act on the northeastern bulrush in a similar manner as in current condition. Although we do not consider protections under the Act in this status review, the protections afforded the species and its habitat by the Clean Water Act and state statutes and regulations are implemented to avoid or minimize impacts on the species. All but one state—West Virginia—protects the species or its habitat to some extent independently of the species' Federal status, and West Virginia contains only three populations of the northeastern bulrush. For these reasons, our future scenario anticipates regulatory protection similar to that of the current condition. However, as a nonlisted species, the northeastern bulrush may receive less of the funding and attention that spurred surveys for the species and discovery of so many previously unknown populations.

<u>Changing Climatic Conditions</u>
We discuss what the future condition of the northeastern bulrush may look like by considering how changes in climate may impact the surrogate factors that describe the future condition of the northeastern bulrush. We used climate change projections found in Representative Concentration Pathway (RCP) 8.5. For detailed descriptions of this scenario, see Hayhoe *et al*. (2017, pp. 135-149), and refer to Brown and Caldeira (2017, p. 47) for updated (and increased) temperature projections.

We use RCP 8.5 based on data on current trends in global emissions (Jackson *et al.* 2017, entire) and the long-lasting influence of greenhouse gases already in the atmosphere (Collins *et al.* 2013, pp. 1102-1105). The U.S. Global Change Research Program stated with very high confidence that the observed increase in global carbon emissions over the past 15 to 20 years has been consistent with higher scenarios such as RCP 8.5 (Wuebbles *et al.* 2017, p. 31). Therefore, it is reasonable to conclude that changes from now through mid-century will also be closest to RCP 8.5 rather than a lower-emission scenario.

According to Vose (2017, p. 197), "Daily extreme temperatures are projected to increase substantially in the contiguous United States, particularly under the higher scenario (RCP 8.5). For instance, the coldest and warmest daily temperatures of the year are expected to increase at least 5°F (2.8°C) in most areas by mid-century, rising to 10°F (5.5°C) or more by late-century. In general, there will be larger increases in the coldest temperatures of the year, especially in the northern half of the Nation, whereas the warmest temperatures will exhibit somewhat more uniform changes…"

Under RCP 8.5, average annual temperatures are projected to increase across all states within the northeastern bulrush's range. For the northeastern states, the average increase is projected at 2.83°C (5.09°F) by mid-century (2036-2065) (Vose *et al*. 2017, pp. 196, 197).

A study of the impact of climate change on northern New Hampshire (Wake *et al*. 2014, entire) mirrors Vose's projections. The authors conclude that for northern New Hampshire, the frequency of extreme heat days is projected to increase dramatically, and the hottest days will be hotter. Moreover, extreme cold temperatures are projected to occur less frequently, and extreme cold days will be warmer than in the past (Wake *et al*. 2014 entire). For example, the Town of Plymouth, New Hampshire (approximately 35 miles north of the closest northeast bulrush population) is anticipated to experience an annual increase in the minimum temperature of 1.0 to 1.1°C (1.8 to 2.0°F) (low emission scenario to high emission scenario) by 2039, an annual increase in temperature of 1.6 to 2.8°C (2.9 to 5.1°F) by 2069, an annual increase in maximum temperature of 1.0°C (1.8°F) by 2039, and an annual increase in temperature of 1.7 to 2.7°C (3.1 to 4.9°F) by 2069 (Wake *et al*. 2014, p. 64).

The frequency of extreme precipitation events is expected to increase across the northeastern bulrush's range (Janssen *et al*. 2014, pp. 110-111; Kunkel *et al*. 2017, relevant state summaries). The seasonality of these events has been projected to change from the base period 1901 to 2005 to the projected period of 2006 to 2100 (Janssen *et al*. 2016, pp. 5387-5388). Broadly speaking, the fraction projected to occur in the winter, spring, and fall will increase and the fraction projected to occur in summer will decrease (Janssen *et al*. 2016, pp. 5387-5391).

By mid-century, winter precipitation in New York, New Hampshire, and Vermont were projected to increase by greater than 15 percent, with most as rain rather than snow (Frankson *et al*. 2017a, p. 5; Runkle *et al*. 2017a, p. 4; Runkle *et al*. 2017b, p. 4; Runkle *et al*. 2017c, p. 4). For Pennsylvania, the projection is for a 10- to 15-percent increase in winter precipitation, but the summary does not state whether there will be more rain than snow (Frankson *et al*. 2017b, p. 4).

Spring precipitation in the northern states is projected to increase by 10 to 15 percent (Kunkel *et al*. 2017; relevant state summaries). An earlier spring snowmelt (Horton *et al*. 2014, p. 374) with higher winter and spring rain is predicted to cause greater winter/spring flooding.

In the Northeast, the increased summer temperatures will lead to greater evaporation such that there will be heavier rain events interspersed with periods of summer drought (Horton *et al*. 2014, p. 374).

Uncertainty

We acknowledge that even the narrowest of these analyses and predictions apply to regions that encompass multiple northeastern bulrush populations. Climate changes and effects on weather will vary interannually and geographically, and actual localized impact on northeastern bulrush populations will not be uniform across the species' range. However, in the absence of higher resolution models, this is the best information available to anticipate climate change impacts on the northeastern bulrush.

Resiliency

In our future scenario, we predict that resiliency will decrease (see table 5-2) because populations in seasonal wetlands (78.4 percent of all populations) will experience reduced habitat quality.

Table 5-2. Current and future resiliency comparison not including a few new populations discovered under the future scenario.

Resiliency	EO Rank	Current Condition: # of Populations	% of 148 Extant Populations	Future Condition: # of Populations	% of 135 Extant Populations
Extirpated	N/A	9	N/A	22	N/A
Poor	D/E	16	10.8	16	11.9
Fair	C	42	28.4	49	36.3
Good	B	66	44.6	52	38.5
Excellent	A	24	16.2	18	13.3

While annual variations in precipitation and temperature are normal, climate change projections indicate that, across the range of the northeastern bulrush, average temperatures will rise, winter and spring precipitation will increase, summer precipitation will be similar or slightly increase, and the frequency of extreme precipitation events will increase. Interpreted in the context of the northeastern bulrush, we generally anticipate higher water levels early in the growing season followed by hotter summers and a faster drying cycle.

Seasonal wetlands will experience greater change in habitat conditions than beaver wetlands. Increased precipitation during the early growing season likely will result in more frequent flood conditions early in the growing season. Hotter summers without a corresponding increase in precipitation likely will result in more frequent drought conditions. Generally, longer growing seasons may result in increased canopy cover and reduced sunlight availability, although it is also possible that flood and drought could stress and/or kill trees and result in less canopy cover. Northeastern bulrush populations respond negatively to flood, drought, and shaded conditions. These changes in habitat condition also could create favorable conditions for competing vegetation, which could establish and encroach on northeastern bulrush habitat. Unfortunately, the available information did not consistently contain data that would allow a site-specific consideration of future resiliency. For these reasons, the future scenario generally anticipates lower habitat value in seasonal wetlands. To simulate this effect on the future condition of northeastern bulrush resiliency, we dropped EO ranks for all seasonal wetlands by one level. For example, a population with a current condition EO rank of "A" dropped to "AB," "BC" dropped to "C," and so on. Appendix 2 shows current and future resiliency for all populations.

The northeastern bulrush is able to implement protective measures during unfavorable habitat conditions and conserve energy by not displaying above ground. This allows plants to survive during 1 or more years of drought, high water conditions, etc., and resurface when conditions are favorable, although there also is a stored resource cost to this strategy that can reduce fitness. Many years of consistently unfavorable habitat conditions may be required to extirpate a population. However, 16 populations currently have poor resiliency, and of those, 13 occur in seasonal wetlands. These populations appear most vulnerable to extirpation due to additional stress from increased canopy cover and more frequent flood and drought conditions anticipated in the future scenario, and we expect they will not be able to respond to the additional stresses of changing climate. Therefore, our future scenario predicts these 13 populations will be extirpated (figure 5-1).

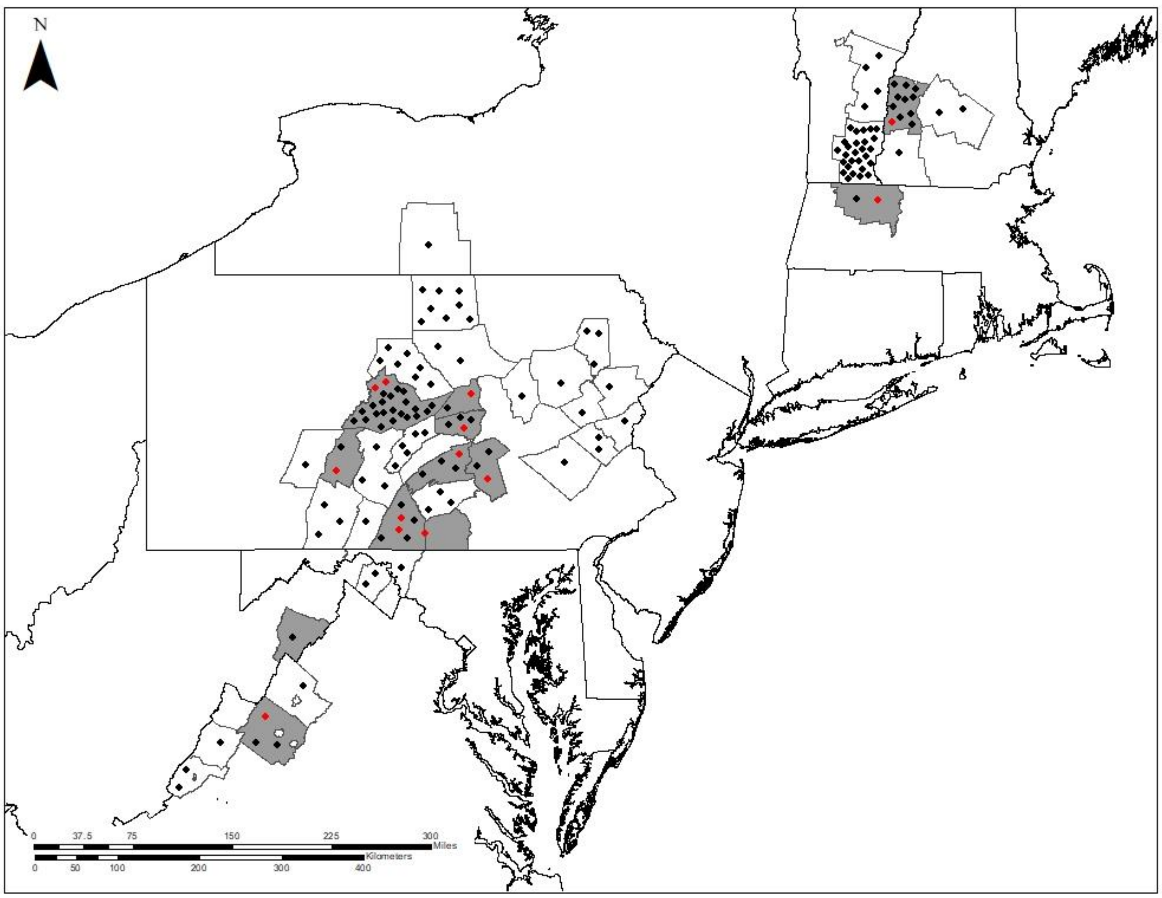

Figure 5-1. Counties in which populations would be extirpated in the future scenario. Red dots indicate the number of extirpated populations in a county but do not necessarily indicate the exact location of the population.

Alternatively, we expect habitat values in beaver wetlands in the future scenario to remain similar to the current condition. Beavers temper water level fluctuations by damming upstream water inputs resulting in a more consistent water level and slower drying cycle. In addition, beaver manage the water levels and canopy cover within the wetlands that they occupy, and therefore we anticipate beaver-influenced wetlands will undergo smaller modifications in response to climate change. EO ranks for populations in beaver wetlands stayed the same from current to future condition.

Representation

In our future scenario, just as with current condition, we evaluated two facets of the northeastern bulrush's adaptive capacity: genetics and environmental diversity. Based on the species' genetic diversity, life history, and habitat diversity and distribution, we anticipate northeastern bulrush representation will not change or will decline slightly before 2050.

<u>Genetics</u>

The best available information indicates the northeastern bulrush demonstrates low genetic representation across its range, and the functional isolation of populations limits the benefits of higher genetic diversity in the Appalachian region than the New England region. We anticipate the following with regard to genetic representation in the future scenario:

1. <u>The Appalachian region will see a reduction in genetic diversity, because the species will experience a net loss of approximately 10 populations, and the genetic contribution contained therein, before 2050.</u> The species will lose 2 populations in the New England region and 11 populations in the Appalachian region. The loss of these populations will decrease the species' adaptive capacity; however, the impact on genetic representation will be minor:
    a. *New England* - Two populations is 4.2 percent of the New England populations, and our understanding of the homogeneity of the New England region's genetics suggests the loss of two populations will have a negligible effect on the region's adaptive capacity via genetic diversity. Seventeen New England populations will remain in seasonal wetlands.
    b. *Appalachian* - Although 11 percent of the Appalachian populations will be lost, some of this loss may be offset by discovery of previously unknown populations. Populations will be extirpated in two states—Pennsylvania (11), which has many populations with a similar haplotype/genotype, but also has at least one population of unique representative value (Cipollini *et al.* 2017, p. 692); and Virginia (1). Eighty-six Appalachian populations will remain in seasonal wetlands.

2. <u>The species may harbor undescribed genetic diversity.</u> Cipollini *et al*. (2017) examined only eight loci and suggested that developing additional markers could increase the known diversity, at least within the relatively homogenous New England region (Cipollini *et al*. 2017, pp. 67, 75). Improved genetic diversity, especially in the New England region, would increase adaptive capacity and counter a predicted reduction caused by extirpated Appalachian populations.

3. Limited genetic diversity in the New England region will not have deleterious effects before 2050. The species' limited dispersal ability and low genetic diversity in New England suggest the potential for inbreeding depression or genetic drift in the future; however, we are not aware of any evidence of adverse effects of small population size in the northeastern bulrush. In addition, to some extent, differential selective pressures of two habitat types mitigate the risk of homogenous genotypes. Further, the available information includes only a portion of the species' genotype, and additional diversity may be present but undescribed.

Environmental Diversity

Habitat Diversity – The northeastern bulrush occurs in two habitats: seasonal wetlands and beaver-influenced wetlands. We anticipate changing climatic conditions to differentially affect the two habitats—negative effects on seasonal wetlands and neutral effects on beaver wetlands.

More winter and spring precipitation and more frequent extreme precipitation events, coupled with hotter summers, generally suggest longer growing seasons, greater canopy cover, more frequent flood and drought conditions, and increased interspecific competition for space in seasonal wetlands, reducing the quality of the habitat for the northeastern bulrush.

We expect beavers to mitigate anticipated climate changes at beaver wetlands by thinning canopy cover and regulating water levels by damming. In addition, while we are not aware of climate studies examining specific effects on beavers, the species occurs outside the range of the northeastern bulrush in diverse landscapes, some of which are hotter and have different precipitation regimes. Accordingly, we anticipate beavers will remain within the range of the northeastern bulrush through 2050. Therefore, we expect no reduction in representation at beaver wetlands before 2050 beyond that which could occur through normal beaver use and disuse of wetlands.

Physiographic Provinces – Northeastern bulrush populations currently occur in four physiographic provinces. While we generally expect populations to persist through 2050, our future scenario includes a net loss of approximately 10 populations. However, the northeastern bulrush would retain good representation across physiographic provinces.

Only two of the most vulnerable populations occur in the New England Province, which has dozens of other populations. Eleven of the 13 most vulnerable populations occur in the other 3 physiographic provinces.[6] The Valley and Ridge Province contains dozens of populations, and while the Appalachian Plateau Province contains as few as 10 populations, a maximum of 3 of these populations fall into the most vulnerable category. The Blue Ridge Province contains as few as one population, and it could fall into the most vulnerable category. Therefore, under a worst-case future scenario in which the Blue Ridge Province has one population and that population is extirpated, the northeastern bulrush will retain representation in three physiographic provinces. Given the minor contribution the Blue Ridge Province makes to the species' representation, this will be of limited significance to the species' overall viability.

[6] The available information includes the county in which each population occurs but does not include geographic coordinates. Therefore, for many populations, we cannot determine the physiographic province in which the population occurs but can only narrow the possibilities to two provinces.

Redundancy

Catastrophic events in the Northeast are uncommon, but hurricanes, tornadoes, and floods do occur. Other catastrophes, like disease, are not known to affect the species currently, but it is reasonable to expect they could occur some time before 2050. However, we expect the northeastern bulrush to be able to withstand these events. The strengths of the northeastern bulrush's redundancy are (1) its 600-mile north/south distribution of 148 populations and geographic diversity of 4 physiographic provinces, which guards against fire, climatic catastrophe, etc.; and (2) a large gap between the New England and Appalachian regions that could slow or preclude transmittable catastrophic events, such as disease.

In our future scenario, the northeastern bulrush will lose 13 populations causing some reduction in redundancy. However, these will be scattered across 11 counties in 4 states, and the species will retain much of its current redundancy strength including multiple, resilient populations distributed across all counties, and 3 of the 4 physiographic provinces, in which the species currently occurs.

In addition, the number of known populations has increased dramatically since listing, with the newest known populations discovered as recently as 2019. We expect survey efforts to occasionally detect new populations and offset some of the redundancy lost with the most vulnerable populations.

For these reasons, we anticipate the northeastern bulrush will have a slight reduction in redundancy compared to its current condition.

Summary of Future Condition

Tables 5-1 and 5-2 summarize projected trends in the future condition of the northeastern bulrush in the context of resiliency (decline), representation (slight decline), and redundancy (slight decline). We predict that approximately 135 populations of the northeastern bulrush will remain in 2050, assuming loss of populations that currently have poor resiliency. This number would be slightly higher if offset by discovery of a few new populations. The species likely will retain low genetic diversity, especially in the New England region, and over the long term, may have difficulty adapting to changing environmental conditions. Low genetic representation will continue to be mitigated by diversity of habitat type and physiographic provinces. The species will retain its redundancy driven by a wide geographic distribution and variety of environmental settings, although the species' apparent dispersal difficulty will limit its ability to shift its range in response to changing climate.

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Appendix 1. Element Occurrence description from the 2008 5-year review for the northeastern bulrush.

General Heritage Network Criteria:

A: Excellent occurrence.

Community requirements:

1. Nearly undisturbed by humans or has nearly recovered from early human disturbance
2. Extensive, well buffered, etc. occurrence

Plant/Animal Requirements:

1. Large in area and number of individuals
2. Stable population (if not growing), and/or shows good reproduction
3. exists in a natural habitat

An average of 1,000 stems (fertile and vegetative) over a 5-year period; buffer and hydrology more or less undisturbed.

B: Good Occurrence.

Community requirements:

1. Still recovering from early or recent light disturbance
2. Will reach A-rank requirements

OR

3. Nearly undisturbed or nearly recovered from disturbance
4. Less than A-ranked: significantly smaller size, poorer buffers, etc.

Plant/Animal Requirements:

1. At least stable
2. In minimally disturbed habitat
3. Moderate size and number

An average of 251 to 1,000 stems (fertile and vegetative) over a 5-year period; buffer and hydrology more or less undisturbed; OR more than 1,000 stems over a 5-year period, with the buffer and hydrology having considerable disturbance.

C: Fair Occurrence.

Community Requirements:

1. In an early stage of recovery from disturbance

OR

2. Structure and composition have been altered such that the original vegetation will never rejuvenate, yet with management and time, partial restoration of the community is possible

Plant/Animal Requirements:

1. In a clearly disturbed habitat
   Small in size and/or number, and possibly declining

An average of 51 to 250 stems (fertile and vegetative) over a 5-year period; buffer and hydrology may have considerable disturbance.

D: Poor Occurrence.

Community Requirements:

1. Severely disturbed: structure and composition has been greatly altered
2. No chance of recovery to original conditions, despite management and time

Plant/Animal Requirements:

1. Very small
2. High Likelihood of dying out or being destroyed
3. Exists in a highly disturbed and vulnerable habitat

An average of 50 or fewer stems (fertile and vegetative) over a 5-year period; buffer and hydrology may have considerable disturbance.

F: Failed Occurrence.

1. Habitat still exists for the element
2. Reasonably intensive field searches by a qualified person at the right time of year have failed to locate the occurrence

H: Historical.

No recent field information

X: Extirpated from site.

1. Not located by repeated reasonably intensive field searches
2. Habitat significantly altered and no longer suitable for maintenance of the element

Criteria Specific to the Northeastern Bulrush

A: Excellent occurrence: An average of 1,000 stems (fertile and vegetative) over a 5-year period; buffer and hydrology more or less undisturbed.

B: Good Occurrence: An average of 251 to 1,000 stems (fertile and vegetative) over a 5-year period; buffer and hydrology more or less undisturbed; OR more than 1,000 stems over a 5-year period, with the buffer and hydrology having considerable disturbance.

C: Fair Occurrence: An average of 51 to 250 stems (fertile and vegetative) over a 5-year period; buffer and hydrology may have considerable disturbance.

D: Poor Occurrence: An average of 50 or fewer stems (fertile and vegetative) over a 5-year period; buffer and hydrology may have considerable disturbance.

Appendix 2. Current and Future Condition Resiliency Sorted by Population ID. This table does not include the four previously unknown populations our future scenario anticipates will be discovered.

			Current Condition		Future Condition	
State	Population ID	Habitat type	EO Rank	Resiliency	EO Rank	Resiliency
MA	MA1	seasonal wetland	D	Poor		Extirpated
MA	MA2	seasonal wetland	B	Good	BC	Good
MD	MD1	seasonal wetland	C	Fair	CD	Fair
NH	NH1	beaver flowage	AB	Excellent	AB	Excellent
NH	NH10	seasonal wetland	C	Fair	CD	Fair
NH	NH11	seasonal wetland	D	Poor		Extirpated
NH	NH12	seasonal wetland	C	Fair	CD	Fair
NH	NH13	beaver flowage	B	Good	B	Good
NH	NH14	beaver flowage	B	Good	B	Good
NH	NH2	beaver flowage	D	Poor	D	Poor
NH	NH3	beaver flowage	B	Good	B	Good
NH	NH4	beaver flowage	C	Fair	C	Fair
NH	NH5	beaver flowage	A	Excellent	A	Excellent
NH	NH6	beaver flowage	B	Good	B	Good
NH	NH7	beaver flowage	BC	Good	BC	Good
NH	NH8	beaver flowage	D	Poor	D	Poor
NH	NH9	beaver flowage	A	Excellent	A	Excellent
NY	?	seasonal wetland		Extirpated		Extirpated
NY	NY3	seasonal wetland	B	Good	BC	Good
PA	PA1	beaver flowage	A	Excellent	A	Excellent
PA	PA10	beaver flowage	D	Poor	D	Poor
PA	PA11	seasonal wetland	D	Poor		Extirpated
PA	PA12	beaver flowage	BC	Good	BC	Good
PA	PA13	seasonal wetland	B	Good	BC	Good
PA	PA14	seasonal wetland	D	Poor		Extirpated
PA	PA15	seasonal wetland	C	Fair	CD	Fair
PA	PA16	seasonal wetland	B	Good	BC	Good
PA	PA18	seasonal wetland	CD	Fair	D	Poor
PA	PA2	seasonal wetland	H	Extirpated	H	Extirpated
PA	PA20	seasonal wetland	BC	Good	C	Fair
PA	PA21	seasonal wetland	B	Good	BC	Good
PA	PA22	seasonal wetland	B	Good	BC	Good
PA	PA23	seasonal wetland	CD	Fair	D	Poor
PA	PA24	seasonal wetland	CD	Fair	D	Poor
PA	PA25	seasonal wetland	BC	Good	C	Fair

PA	PA26	seasonal wetland	CD	Fair	D	Poor
PA	PA27	seasonal wetland	AB	Excellent	B	Good
PA	PA3	seasonal wetland	A	Excellent	AB	Excellent
PA	PA353	seasonal wetland	C	Fair	CD	Fair
PA	PA4	seasonal wetland	B	Good	BC	Good
PA	PA5	seasonal wetland	CD	Fair	D	Poor
PA	PA501	seasonal wetland	X?	Extirpated	X?	Extirpated
PA	PA502	UNKNOWN	F	Extirpated	F	Extirpated
PA	PA503	seasonal wetland	C	Fair	CD	Fair
PA	PA504	seasonal wetland	C	Fair	CD	Fair
PA	PA505	seasonal wetland	F	Extirpated	F	Extirpated
PA	PA506			Extirpated		Extirpated
PA	PA507	UNKNOWN	X?	Extirpated	X?	Extirpated
PA	PA508	seasonal wetland	X	Extirpated	X	Extirpated
PA	PA509	seasonal wetland	C	Fair	CD	Fair
PA	PA510	seasonal wetland	D	Poor		Extirpated
PA	PA511	seasonal wetland	C	Fair	CD	Fair
PA	PA512	seasonal wetland	AB	Excellent	B	Good
PA	PA513	seasonal wetland	B	Good	BC	Good
PA	PA514	seasonal wetland	BC	Good	C	Fair
PA	PA515	seasonal wetland	BC	Good	C	Fair
PA	PA516	seasonal wetland	C	Fair	CD	Fair
PA	PA517	seasonal wetland	B	Good	BC	Good
PA	PA518	seasonal wetland	D	Poor		Extirpated
PA	PA519	seasonal wetland	C	Fair	CD	Fair
PA	PA520	seasonal wetland	D	Poor		Extirpated
PA	PA521	seasonal wetland	B	Good	BC	Good
PA	PA522	seasonal wetland	BC	Good	C	Fair
PA	PA523	seasonal wetland	CD	Fair	D	Poor
PA	PA524	seasonal wetland	B	Extirpated	B	Extirpated
PA	PA525	seasonal wetland	BC	Good	C	Fair
PA	PA526	seasonal wetland	C	Fair	CD	Fair
PA	PA527	seasonal wetland	A	Excellent	AB	Excellent
PA	PA528	seasonal wetland	D	Poor		Extirpated
PA	PA529	seasonal wetland	C	Fair	CD	Fair
PA	PA530	seasonal wetland	C	Fair	CD	Fair
PA	PA531	seasonal wetland	D	Poor		Extirpated
PA	PA532	seasonal wetland	B	Good	BC	Good
PA	PA533	seasonal wetland	BC	Good	C	Fair
PA	PA534	seasonal wetland	BC	Good	C	Fair
PA	PA535	seasonal wetland	B	Good	BC	Good

PA	PA536	seasonal wetland	AB	Excellent	B	Good
PA	PA537	seasonal wetland	BC	Good	C	Fair
PA	PA538	seasonal wetland	B	Good	BC	Good
PA	PA539	seasonal wetland	B	Good	BC	Good
PA	PA540	seasonal wetland	B	Good	BC	Good
PA	PA541	seasonal wetland	B	Good	BC	Good
PA	PA542	seasonal wetland	CD	Fair	D	Poor
PA	PA543	seasonal wetland	A	Excellent	AB	Excellent
PA	PA544	seasonal wetland	BC	Good	C	Fair
PA	PA545	seasonal wetland	CD	Fair	D	Poor
PA	PA546	seasonal wetland	BC	Good	C	Fair
PA	PA547	seasonal wetland	B	Good	BC	Good
PA	PA548	seasonal wetland	B	Good	BC	Good
PA	PA549	seasonal wetland	AB	Excellent	B	Good
PA	PA550	seasonal wetland	CD	Fair	D	Poor
PA	PA551	seasonal wetland	BC	Good	C	Fair
PA	PA552	seasonal wetland	D	Poor		Extirpated
PA	PA553	seasonal wetland	BC	Good	C	Fair
PA	PA554	seasonal wetland	BC	Good	C	Fair
PA	PA555	seasonal wetland	C	Fair	CD	Fair
PA	PA556	seasonal wetland	E	Poor		Extirpated
PA	PA557	seasonal wetland	BC	Good	C	Fair
PA	PA558	seasonal wetland	B	Good	BC	Good
PA	PA559	seasonal wetland	BC	Good	C	Fair
PA	PA560	seasonal wetland	D	Poor		Extirpated
PA	PA561	seasonal wetland	C	Fair	CD	Fair
PA	PA563	seasonal wetland	B	Good	BC	Good
PA	PA565	seasonal wetland	B	Good	BC	Good
PA	PA566	seasonal wetland	AC	Excellent	B	Good
PA	PA567	seasonal wetland	A	Excellent	AB	Excellent
PA	PA568	seasonal wetland	B	Good	BC	Good
PA	PA569	seasonal wetland	AC	Excellent	B	Good
PA	PA572	seasonal wetland	C	Fair	CD	Fair
PA	PA573	seasonal wetland	BC	Good	C	Fair
PA	PA6	seasonal wetland	CD	Fair	D	Poor
PA	PA7	seasonal wetland	CD	Fair	D	Poor
PA	PA8	seasonal wetland	C	Fair	CD	Fair
PA	PA9	seasonal wetland	CD	Fair	D	Poor
PA	UNK	seasonal wetland	A	Excellent	AB	Excellent
VA	VA1	seasonal wetland	B	Good	BC	Good
VA	VA2	seasonal wetland	A	Excellent	AB	Excellent

VA	VA3	seasonal wetland	A	Excellent	AB	Excellent
VA	VA4	seasonal wetland	A	Excellent	AB	Excellent
VA	VA5	seasonal wetland	B	Good	BC	Good
VA	VA6	seasonal wetland	B	Good	BC	Good
VA	VA7	seasonal wetland	D	Poor		Extirpated
VA	VA8	seasonal wetland	A	Excellent	AB	Excellent
VT	VT1	beaver flowage	C	Fair	C	Fair
VT	VT10	beaver flowage	B	Good	B	Good
VT	VT11	seasonal wetland	CD	Fair	D	Poor
VT	VT12	beaver flowage	C	Fair	C	Fair
VT	VT13	beaver flowage	C	Fair	C	Fair
VT	VT14	seasonal wetland	C	Fair	CD	Fair
VT	VT15	seasonal wetland	BC	Good	C	Fair
VT	VT16	seasonal wetland	B	Good	BC	Good
VT	VT17	beaver flowage	B	Good	B	Good
VT	VT18	seasonal wetland	B	Good	BC	Good
VT	VT19	seasonal wetland	C	Fair	CD	Fair
VT	VT2	beaver flowage	AB	Excellent	AB	Excellent
VT	VT20	seasonal wetland	B	Good	BC	Good
VT	VT21	seasonal wetland	C	Fair	CD	Fair
VT	VT22	beaver flowage	BC	Good	BC	Good
VT	VT23	seasonal wetland	C	Fair	CD	Fair
VT	VT24	beaver flowage	A	Excellent	A	Excellent
VT	VT25	beaver flowage	BC	Good	BC	Good
VT	VT26	seasonal wetland	A	Excellent	AB	Excellent
VT	VT27	seasonal wetland	BC	Good	C	Fair
VT	VT28	seasonal wetland	C	Fair	CD	Fair
VT	VT29	beaver flowage	BC	Good	BC	Good
VT	VT30	beaver flowage	AB	Excellent	AB	Excellent
VT	VT30	beaver flowage	BC	Good	BC	Good
VT	VT31	seasonal wetland	BC	Good	C	Fair
VT	VT4	beaver flowage	BC	Good	BC	Good
VT	VT5	beaver flowage	B	Good	B	Good
VT	VT6	beaver flowage	C	Fair	C	Fair
VT	VT7	beaver flowage	AB	Excellent	AB	Excellent
VT	VT8	beaver flowage	B	Good	B	Good
VT	VT9	beaver flowage	B	Good	B	Good
WV	WV1	seasonal wetland	B	Good	BC	Good
WV	WV2	seasonal wetland	B	Good	BC	Good
WV	WV3	seasonal wetland	C	Fair	CD	Fair