Navajo sedge
(*Carex specuicola*)

5-Year Review:
Summary and Evaluation

Photo by John Nystedt
Arizona Ecological Services, U.S. Fish and Wildlife Service

U.S. Fish and Wildlife Service
Arizona Ecological Services Field Office
Phoenix, Arizona

August 2014

5-YEAR REVIEW
Navajo sedge/ *Carex specuicola*

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional or Headquarters Office: Region 2, Southwest Region
Michelle Shaughnessy, Assistant Regional Director Ecological Services, 505-248-6671
Susan Jacobsen, Chief, Division of Classification and Restoration, 505-248-6641
Julie McIntyre, Recovery Biologist, 505-248-6507

Cooperating Regional Office: Region 6, Mountains and Prairies Region
Bridget Fahey, Regional Endangered Species Chief, 303-236-4258
Seth Willey, Assistant Endangered Species Chief and Regional Recovery Coordinator, 303-236-4257
Kathy Konishi, Assistant Regional Recovery Coordinator, 303-236-4212
Tova Spector, Botanist, Utah Ecological Services Field Office, 801-975-3330, Ext 137

Lead Field Office: Arizona Ecological Services Field Office
Steve Spangle, Field Supervisor, Arizona Ecological Services, 602-242-0210
Brenda Smith, Assistant Field Supervisor, 928-556-2157
John Nystedt, Fish and Wildlife Biologist, Flagstaff Sub-office, 929-556-2160

1.2 Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (USFWS) is required by section 4(c)(2) of the Endangered Species Act (ESA) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, or its status reclassified between endangered and threatened. The original listing is based on the species' status considering the five threat factors described in section 4(a)(1) of the ESA. These same five factors are considered in any subsequent reclassification or delisting decisions. In the 5-year review, we consider the best available scientific and commercial data on the species, and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process including public review and comment.

1.3 Methodology used to complete the review:

The USFWS conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 [wildlife] and 17.12 [plants]) as required by section 4(c)(2)(A) of the ESA (16 U.S.C. 132 *et seq.*). We provided notice of this status review in the Federal Register (74 FR 6917) requesting information on the status of 23 southwestern species, including the Navajo sedge (*Carex specuicola*). No comments from the public were received.

This 5-year review was completed by the USFWS lead biologist for this species, using the Navajo Sedge Recovery Plan (USFWS 1987) as the basis for the analysis, with updates from interviews of personnel of tribes and land management agencies with responsibility for the species, ESA section 7 consultations, and literature published since the Recovery Plan was approved. On April 9, 2012, the USFWS solicited information from the Hopi Tribe and the Navajo Nation about the species. In September and October 2012 the USFWS lead biologist visited several populations of *C. specuicola* on the Navajo Nation on two field trips conducted by the Tribe's botanist, Andrea Hazelton. In August 2014, a draft of this 5-year review was reviewed by Ms. Hazelton, Mr. Clayton Honyumptewa of the Hopi Tribe, and Region 6 Utah Ecological Services Field Office; their comments have been incorporated into this document.

1.4.1 FR Notice citation announcing initiation of this review: 74 FR 6917

1.4.2 Listing history

Original Listing
FR notice: 50 FR 19370
Date listed: May 8, 1985
Entity listed: Navajo sedge (*Carex specuicola*)
Classification: Threatened, with critical habitat

1.4.3 Associated rulemakings: None; critical habitat was designated concurrently.

1.4.4 Review History: A 5-year review for all species listed before 1991, including *C. specuicola*, was initiated on November 6, 1991 (56 FR 56882) but no documentation was prepared for this species.

1.4.5 Species' Recovery Priority Number (RPN) at start of 5-year review: 8; meaning the listed entity's taxonomic status is a species, its degree of threat is moderate, and recovery potential is high.

1.4.6 Recovery Plan or Outline

Name of plan or outline: Navajo sedge (*Carex specuicola*) Recovery Plan
Date issued: 9/24/1987
Dates of previous revisions, if applicable: None

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

The DPS policy does not apply to *C. specuicola* because it is a plant.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

No. The species has a final, approved Recovery Plan (Plan), but the Plan does not have recovery criteria. The Plan states, in the summary, that the "criteria for delisting the Navajo sedge have not yet been determined. The implementation of studies in this recovery plan will provide the necessary data from which quantified delisting criteria can be established." The main objective of the plan is to protect the species and its habitat while information is gathered to "quantify habitat and abundance" in the manner needed to establish delisting criteria.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

Not applicable; the recovery plan does not contain recovery criteria.

2.2.2.2 Are all the 5 listing factors relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

Not applicable; the recovery plan does not contain recovery criteria.

2.2.3 Progress in Meeting Recovery Criteria

While the Recovery Plan does not contain recovery criteria, per se, it does identify several recovery actions intended to protect *C. specuicola* while information is gathered to develop criteria. The Plan also states these actions should bring about recovery of the species. It is worthwhile to assess the status of these actions, some of which may serve as the basis for recovery criteria, to understand the current status of the species.

Recovery Actions:

1. Permanently protect all known habitats according to the steps outlined in the Plan.
2. Inventory suitable potential habitat.
3. Census and monitor known populations and establish permanent monitoring plots at these sites.
4. Develop and implement a habitat management plan.
5. Develop formal documentation outlining long-term hydrological potential of the existing and potential habitat of *C. specuicola*.
6. Reintroduce *C. specuicola* onto protected sites within its inferred historical range.
7. Demonstrate long-term stability of populations and habitat.

A summary of progress that has been made toward meeting the recovery actions is as follows:

Recovery Action 1. Permanently protect all known habitats according to the steps outlined in the Plan.

This action has not been accomplished. *Carex specuicola* is protected by Navajo and Federal laws (see section 2.3.2.4). However, a habitat management plan, as described in the Plan, that includes actions that provide on-the-ground-protection of habitat (e.g., close habitat areas to grazing; protect habitat as "natural areas;" monitor groundwater and manage water development) has not been developed.

Recovery Action 2. Inventory suitable potential habitat.

This action has been substantially accomplished (see 2.3.1.2 and 2.3.1.5 below).

Recovery Action 3. Census and monitor known populations and establish permanent monitoring plots at these sites.

Monitoring to date has been informal and qualitative (see 2.3.1.2 and 2.3.1.6 below). In 2013 and 2014, a USFWS contractor set up nine long-term monitoring plots across the species' range on the Navajo Nation. The goals of this monitoring are repeatable, objective measurements to assess population trends and changes in habitat characters, hydrology in particular, and impacts, primarily grazing (Rink and Hazelton, 2014).

Recovery Action 4. Develop and implement a habitat management plan.

This action has not been accomplished.

Recovery Action 5. Develop formal documentation outlining long-term hydrological potential of the existing and potential habitat of *C. specuicola*.

This action has not been accomplished.

Recovery Action 6. Reintroduce *C. specuicola* onto several protected sites within its inferred historic range.

This action has not been accomplished, and may not be necessary. The need for this action was based on the extremely limited distribution and number of populations, known at the time of the Recovery Plan, which has changed considerably since that time (see 2.3.1.2 and 2.3.1.5 below).

Recovery Action 7. Demonstrate long-term stability of populations and habitat.

This action has not been accomplished.

2.3 Updated Information and Current Species' Status

2.3.1 Biology and Habitat

Carex specuicola is a grass-like, slender perennial forb in the sedge family, Cyperaceae. Culms (stems) are 15 to 50 centimeters (cm) (6 to 20 inches [in]) long, lax (not upright), and longer (sometimes shorter) than the leaves. Many culms grow from a rhizome (underground stem), giving the plant a clumped form, often in extensive monospecific mats, with a persistent, dried leaf base. Each plant has male and female flowers, which are inconspicuous. Male flowers only occur on the terminal spike (end of culm), almost always below female flowers; other female flowers occur on lateral spikes (below the terminal spike). Picture Set 1 is of the flowers.

Picture Set 1. *Carex specuicola* flowers on terminal spike (left, by Daniela Roth, NNHP) and on lateral spikes (right, by Max Licher)

Carex specuicola is a wetland obligate of springs, typically in alcoves associated with aeolian sandstone cliffs of varying height and slope (often vertical) at 1,280 to 2,300 meters (m)(4,200-7,600 feet[ft]) elevation (Rink and Licher, in prep) in piñon-juniper woodland. It rarely occurs on level terrain; three *C. specuicola* sites in Sheik Canyon, Utah, are located on the canyon floor (Rink and Hazelton, 2014). Water that supports *C. specuicola* is generally low in mineral content. However, there is one anomalous site, also in Sheik Canyon, described as a "crusty, mineral-rich hill slope spring" (Rink and Hazelton, 2014). Soil development in alcoves is limited; any soil present is sandy to silty, derived from sandstone bedrock and combined with remnants of vegetation.

A cliff-associated spring with a plant community is referred to as a "hanging garden." Hanging gardens are complex, multi-habitat springs that emerge along geologic contacts, and seep, drip or pour onto the underlying substrate. They usually emerge from perched, unconfined aquifers in aeolian sandstone units. The hydrogeologic processes that result in these unique ecosystems also control the geomorphologic processes that shape the rock wall or associated canyons (Springer and Stevens 2009). Originally found on Navajo Sandstone, *C. specuicola* is now also known from Cedar Mesa, De Chelly, and Kayenta sandstone formations. *C. specuicola* springs are often referred to as "seep-springs".

The plant community of hanging gardens predominantly includes *Aquilegia micrantha* (Bluff City columbine), *Epipactis gigantea* (giant helleborine), and *Mimulus eastwoodiae* (Eastwood monkeyflower). Associated sensitive and rare species include *Cirsium rydbergii* (Rydberg's thistle), *Platanthera zothecina* (alcove bog-orchid), *Primula specuicola* (cave primrose), and *Zigadenus vaginatus* (alcove death camas) (NNHP 2001, 2005). Associated non-natives include *Agrostis semiverticillata* (water bentgrass), *Agostis stolonifera* (creeping bentgrass; red top), *Bromus rubens* (red brome), *Bromus tectorum* (cheatgrass), *Poa pratensis* (Kentucky bluegrass), *Elaeagnus angustifolia* (Russian olive), *Taraxacum officinale* (dandelion), *Tamarix* sp. and *Polypogon* spp. (rabbitsfoot grass) (Phillips et al. 1981, NNHP 2012, NPS 2013).

Carex specuicola reproduction appears to be mostly vegetative (Herman 1970), but no species-specific reproduction studies have been conducted. Pollination is likely by wind, as is predominant among sedges (Linder and Rudall 2005). Flowering and fruit set occur from late June through September (NNHP 2008), which is the only time *C. specuicola* can be positively identified. Suitable habitat (Picture Set 2) can be identified year round.

Picture set 2. *Carex specuicola* habitat – upper left by Max Licher, upper right by Andrea Hazelton, NNHP; lower left is critical habitat subpopulation 1A at Inscription House Springs (by Daniela Roth, NNHP) and lower right is subpopulation 1B , with location of plants indicated by the red oval (by Andrea Hazelton).

2.3.1.1 New information on the species' biology and life history:

Carex specuicola type locality is described as moist soil of a shallow cave on a cliff, and was initially recognized as adapted to the specialized habitat of seepages on sandstone cliffs in an arid plateau ecoregion (Howell 1949). Aside from this information and known associated species, little is known about the ecology of *C. specuicola*. Most ecological research of hanging gardens has focused on correlating site conditions with plant community structure (Spence 2008).

Hanging garden floras are comprised of a mix of generalist wetland/riparian species and rare endemic species with boreal-temperate affinities. Hanging garden species' richness correlates most strongly with seep-spring flow rate (Spence 2008, Keate 1996). However, preliminary results of a small sample of nine sites seem to indicate cover of *C. specuicola* within occupied hanging gardens is not correlated with site aspect or soil moisture level (Rink and Hazelton 2014). Richness of endemic species also correlates positively with the elevation of the hanging garden above the stream bed (Keate 1996). More endemic species in a more elevated and therefore isolated and protected site supports the view of hanging gardens as paleorefugia for the descendants of montane-boreal plant species. Paleorefugia are defined as habitats that are older than the surrounding matrix of vegetation, with extinction processes being more important than dispersal (Nekola 1999). Vicariance, a biogeographical speciation concept, hypothesizes that fragmentation of the environment promotes evolution by division of large populations into isolated subpopulations. This is in contrast to dispersal, another common speciation concept, which relies on dispersal of an organism into novel environments as a driver of speciation. Although vicariance and dispersal are both hypothesized to be drivers of speciation, the evidence supports vicariance as the mechanism behind the abundance of endemic plant species in hanging garden habitats. Hanging gardens with higher moisture levels that are more isolated from the stream bed are less likely to have been disturbed by flood, drought, or other disturbance throughout the centuries; these more isolated gardens have likely supported a similar plant community since the end of the Wisconsin Glaciation, 10,000 years ago (Spence 2008).

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends[1]:

[1] The difficulty of assessing population trends and demography for *C. specuicola* should be noted. It is practically impossible to count individuals because of the species' rhizomatous nature, stems that grow so closely together, and age or size classes that are not apparent. Estimating population size based on the area covered by plants is a much more repeatable approach (Elzinga et al. 2001). Even so, making cover estimates of *C. specuicola* is challenging given the complex, vertical, and often inaccessible nature of hanging gardens.

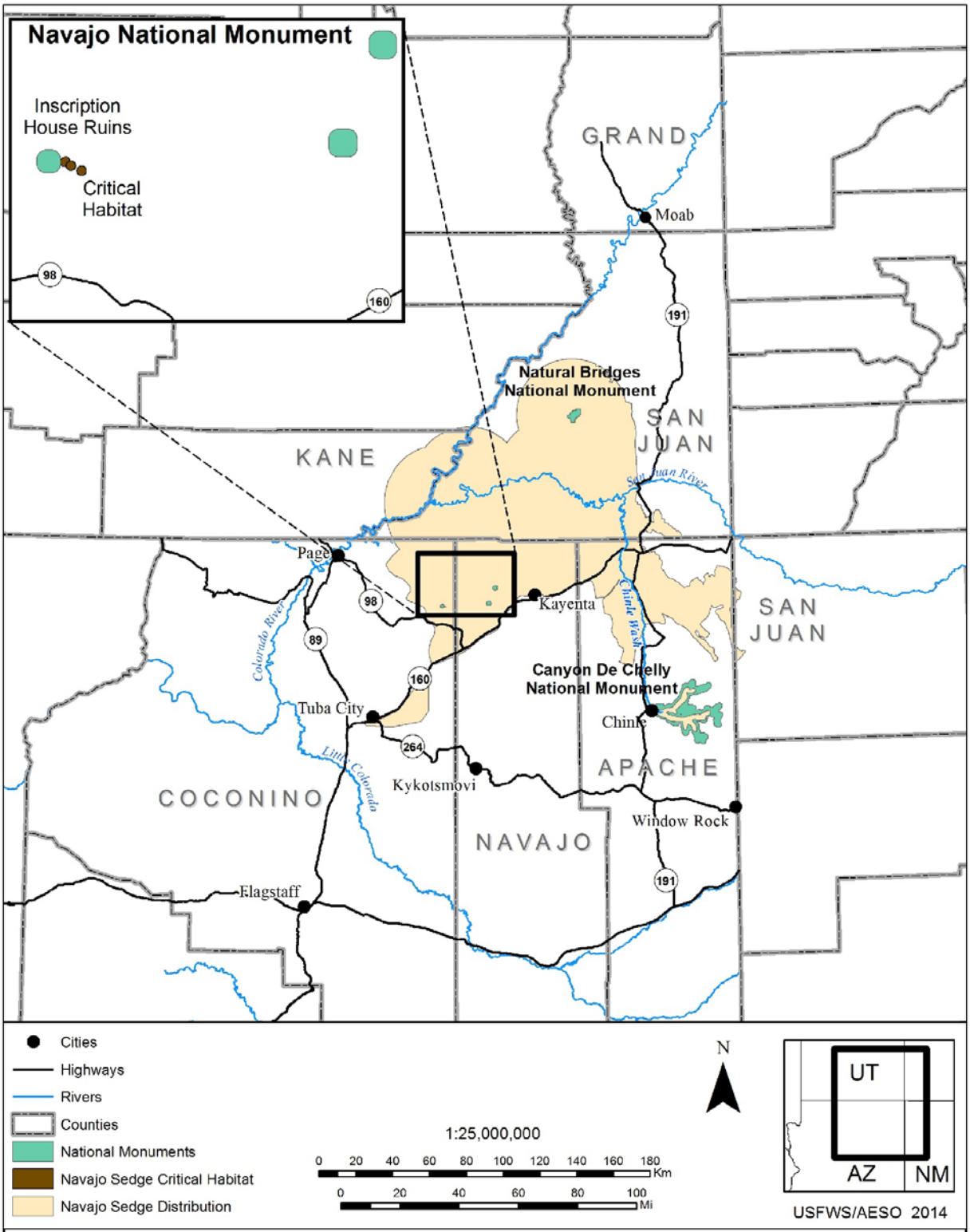

Figure 1. Map of Navajo sedge distribution in the states of Arizona and Utah

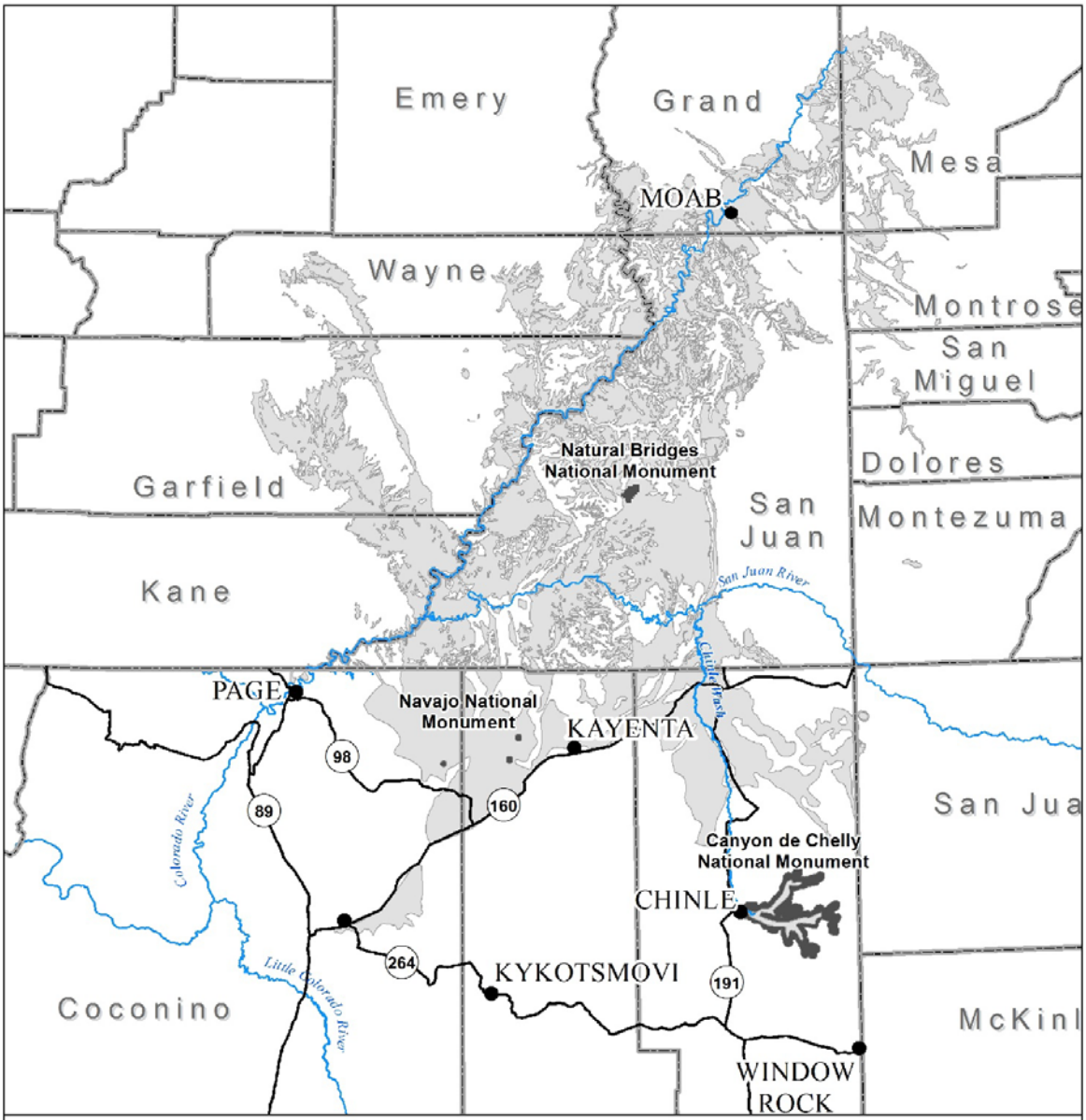

Figure 2. Map of geologic formations on which Navajo sedge is known to occur, including areas outside its known distribution.

Carex specuicola type locality is along the trail from Inscription House Trading Post to Inscription House Ruin on the Navajo Indian Reservation in Coconino County, Arizona (Howell 1949). At the time of listing in 1985, it was known only

from three springs (considered then to constitute three populations), all within a mile stretch along this trail, and estimated to consist of about 700 individuals (USFWS 1987). These three sites are now considered to constitute one population, or one "element occurrence record" (EOR) by the Navajo Natural Heritage Program (NNHP) (NNHP 2004). EOR is a term used by Natural Heritage Programs and is delineated based on standardized methods (NatureServe 2004). For this species, a population or EOR refers to *C. specuicola* occupying one or more hanging gardens within a single canyon (in series of alcoves or single alcove). Per standardized methods, *C. specuicola* occupying gardens that are in the same canyon and within one kilometer (km) of each other are grouped as a single record (or population) (NNHP 2012). The Recovery Plan refers to the three original sites as subpopulation 1A, 1B and 1C, which correspond to the mapped critical habitat sites 1, 2 and 3 (USFWS 1987, 1985).

Today, we know of a total of 57 populations cross the range of this species on lands managed by the Navajo Nation, National Park Service, Hopi Tribe, and Bureau of Land Management (NNHP 2012, Hopi Tribe 2012, NPS 2013, Rink and Hazelton 2014). There are 43 populations on the Navajo Nation. As of 2012, the NNHP had population size data on 33 of these as follows: 5 had "thousands" of plants, while the rest were evenly split between those with less than 100 plants and those with 100 to 1,000 plants (NNHP 2012). Figure 1 depicts our current understanding of the distribution of *C. specuicola* based on known occurrences and the geologic formations with which this species is associated. The area within this distribution, as mapped, is about 14,850 km^2 (5,700 mi^2). In Utah, where large areas with apparently appropriate geology has not been assessed for suitability, let alone surveyed, mapped distribution is based primarily on occurrence information. Based on geology, Navajo sedge distribution has the potential to extend farther north and west in Utah (Figure 2).

The difference in the number of populations between 1985, when the species was listed, and now is almost certainly due to increased survey effort, not a change in abundance. However, dispersal and establishment in previously unoccupied gardens has not been previously noted or monitored. Although considerable effort has been expended surveying for *C. specuicola,* much of the area where suitable Navajo sedge habitat occurs remains unsurveyed due to a canyon land terrain that limits both access into the area and into sites with suitable habitat.

On the Navajo Nation, 10 *C. specuicola* populations for which abundance, vigor, and site condition were recorded from 2000 to 2003 were revisited in 2010 and 2011 (NNHP 2012). These 10 populations (about 25% of known Navajo Nation populations) consist of 15 hanging gardens. Of these hanging gardens, two increased in plant abundance, three decreased, and nine showed either no change in *C. specuicola* abundance or not enough information was available to assess a population trend. One population, consisting of one hanging garden, was not relocated during the 2010-2011 surveys, but was found after the 2012 NNHP report (A. Hazelton pers. comm). Average plant vigor increased at six and

decreased at two of the gardens. Of the six gardens with increased plant vigor, one had undergone a decrease in grazing pressure, two had experienced both a decrease in grazing pressure and an increase in water availability, and three of the gardens had not evidently undergone a change in either of those stressors.

As of 2012, on the Navajo Nation there were 32 populations with enough status information for the NNHP to assign a viability rank. This ranking system uses information on the size and condition of the population, as well as the condition of the surrounding landscape, to assess the likelihood that the population will persist in a similar or improved state for 20 to 30 years. These assessments were done by a series of four NNHP staff botanists using visual estimates and recorded in a qualitative fashion. Of the 32 populations, 16 were assigned a rank of good or excellent viability. The rest were of fair viability, indicating some reason for concern. No populations were assigned a rank of poor viability. Although grazing effects were factored into the viability assessment, the long-term effects of grazing should be determined in order to fully assess the viability of livestock-accessible populations (NNHP 2012).

Of the 14 populations known off the Navajo Nation, 7 were found in the last year (Rink and Hazelton 2014).

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

There was no discussion of *C. specuicola* genetics in the Recovery Plan. No species-specific genetic research has been conducted. However, the isolated nature of *C. specuicola* populations has implications for genetic variation. Based on limitations of wind-born pollination outside the immediate vicinity of the source (Culley et al. 2002, Friedman and Barrett, 2009), large distance between known populations of *C. specuicola*, and the short duration of pollen viability in many wind-pollinated species (Dafni and Firmage 2000), gene transfer between populations of this species may be limited. If these populations have persisted in isolation since the Pleistocene, then they could be significantly genetically divergent from one another. Genetic analysis of *Anticlea vaginata* [*Zigadenus vaginatus*], another rare, hanging garden endemic, concluded that populations across the Colorado Plateau may be on individual evolutionary trajectories because they have been isolated from each other for so long (Palmquist 2011).

Although morphological differences have been noted between populations, mainly in terms of stature, it is unknown whether this is due to environmental factors or genetic differences.

Research is needed to understand genetic variation, and implications, within and between populations of *C. specuicola*.

2.3.1.4 Taxonomic classification or changes in nomenclature:

In Goodrich's treatment of *Carex specuicola* for *A Flora of Utah*, he concluded it belonged in *C. parryana* (in Welsh et al. 2003). That treatment was based on a limited number of specimens, particularly within Utah. A morphological re-evaluation of *C. specuicola*, using a large series of specimens, provides evidence that *C. specuicola* is a distinct species and the Utah "parryana" is a new species, *C. utahensis* (Reznicek and Murray 2013). The relationship between these three species may have implications for their conservation.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g. increasingly fragmented, increased numbers of corridors, etc.), or historical range (e.g. corrections to the historical range, change in distribution of the species within its historical range, etc.):

Considerable survey effort between the time of listing and today has increased the known distribution of from one population in a 1.6 km (1 mile) stretch to several regional groupings across a range of about 160 km (100 mi) east to west, and 160 km (100 mi) north to south, extending well into Utah (NNHP 2012, Rink and Hazelton 2014). We do not have a good understanding of C. *specuicola* distribution and numbers in Utah, as much of the suitable habitat has not been surveyed, particularly on non-Federal lands. Populations are typically separated by large distances, even within regional groupings. More survey effort, if possible in this difficult terrain, may result in an increased number of intervening populations. However, the nature of *C. specuicola* habitat (springs on cliffs in an arid environment) indicates its distribution pattern will always be uncommon, scattered, and isolated.

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem):

The amount, distribution, and suitability of *C. specuicola* habitat does not appear to be changing significantly due to impacts from livestock activity and associated water development, changes in water availability, or both. Although habitat conditions at certain populations have been reported as poor at given points in time, there is no apparent long-term trend, based on the information we have from the visual/qualitative monitoring methods used on a sample of populations to date. Because monitoring information about habitat condition is incomplete, the discussion below combines information about habitat condition with threats and plant cover and vigor, the latter two indicating habitat condition.

When the species was listed, two of three seep-springs in the only known *C. specuicola* population were impacted by livestock trampling, grazing, and water development (USFWS 1985). Based primarily, if not exclusively, on increased survey effort, we now know of 57 populations with a far broader distribution. From 2000 to 2003, 35 of the 39 *C. specuicola* populations known on the Navajo Nation were visited. In these populations there were 49 hanging gardens, 39

(80%) of which were accessible to livestock and, of those, livestock impacts were considered medium or heavy at 23%. Eighteen (37%) of the 49 gardens showed signs of drought stress such as high mortality rates, no water discharge/dry soils, and sloughing vegetation mats (NNHP 2004). In 2010 and 2011, NNHP staff re-visited 10 of these populations, consisting of 15 hanging gardens, which represented about 25% of the then known populations on the Navajo Nation. Grazing pressure did not appear to have increased at any gardens, yet it decreased at three, and there was no change or not enough information to discern a change at 11 gardens. Moisture level increased at three gardens, decreased at one, and there was no change or not enough information to discern a change at ten. (One hanging garden could not be relocated in 2011 so was not included.) Six of the 18 drought stressed or "dry" gardens were revisited. One of these, with the decreased moisture level just mentioned, was extirpated due to continued drying from the drought. At one formerly dry garden the population increased, accompanied by an increase in spring flow rate. There was no change in cover or vigor of the plants at four gardens. The conclusion of NNHP's 2012 report was that their data set indicated stability with a slight improvement of conditions.

In 2014, a seep in Lime Creek West Fork, Utah, was found to have been developed as a water source for livestock. The site was heavily impacted by the development and associated cattle use. A few tufts and isolated stems of *C. specuicola*, covering 0.5 m^2 (5.4 ft^2), were found nearby, 2 m (6.6 ft) above the ground and "out of reach" presumably by livestock. It is possible that considerably more *C. specuicola* existed in association with the seep before development and subsequent use by cattle (Rink and Hazelton 2014), which appears to have rendered the site largely unsuitable for *C. specuicola* and other hanging garden plants.

In 25 years of monitoring this species on the Navajo Nation, there have been four recorded instances of extirpation from a hanging garden following the drying of a seep. In all these cases, another moist seep with *C. specuicola* remained within the same alcove or side canyon, so the population was not considered extirpated (NNHP 2012). However, we do not know how the loss of a garden could affect the population, or whether the loss of a garden indicates long term drying that could impact more seeps in the population. Certainly, the amount and suitability of habitat in the four populations had decreased.

Little is known about the groundwater hydrology of the region in which *C. specuicola* occurs, and no studies have been conducted on the dynamics of the aquifers, upon which *C. specuicola* depends for water. The effects of groundwater pumping also need to be studied (see 2.3.2.1).

2.3.1.7 Other Natural or Manmade Factors Affecting the Species' Continued Existence

Other factors include climate change, demography and invasive plants (see section 2.3.2.5). No conservation measures have been taken to address climate change or invasive plants. Climate change is a new, potential threat. There is no evidence invasive plants are a threat, but their presence in hanging gardens warrants monitoring. Conservation measures to address demographic threats (e.g., establishing new populations) does not appear necessary based on our new understanding of the number and distribution of *C. specuicola* populations.

2.3.1.8 Conservation Measures:

At this time, measures to conserve *C. specuicola* have involved surveys, which have dramatically increased our knowledge about distribution, abundance and habitat. Hanging gardens are naturally protected due to the remoteness of their locations and the inaccessibility of sites. The plant could benefit from livestock management in occupied livestock-accessible sites.

There has been one formal section 7 consultation regarding *C. specuicola*. This consultation involved U.S. Environmental Protection Agency approval of the Navajo Nation's Water Quality Standards (WQS), and resulted in development of implementation procedures to strengthen the WQS Antidegradation Policy and provide enforcement of the Implementation Plan, which strengthened the protection of water quality on the Navajo Nation (see 2.3.2.4).

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

Threats at listing continue today as discussed below.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

Habitat Loss from Water Development

Two of the three main threats that were the basis for listing *Carex specuicola* were water development for livestock at occupied springs, and livestock trampling of areas around the water sources, which could result in habitat deterioration (USFWS 1985). Water development, which involves the construction of spring boxes and piping of spring water to troughs, removes water from the hanging garden, results in less water availability for *C. specuicola*, and could result in drying of its habitat. Water development at these springs also concentrates livestock activity around the hanging garden, leading to more intense hoof action resulting in disturbance to plants and the soil in which they grow. Soil disturbance could lead to erosion. Two of the three known *C. specuicola* sites at the time of listing were developed for livestock water and had associated heavy trampling by livestock (USFWS 1985). However, of 57 *C. specuicola* populations known today, only three have been impacted by development of water for livestock: Inscription House, Skeleton Mesa, and Lime Creek West Fork

(NNHP 2012, Rink and Hazelton 2014, A. Hazelton pers. comm.). (Again, note that the original three sites at Inscription House are now considered one population, which is one of the three populations listed here.)

Livestock trampling, not associated with water development, also occurs in hanging gardens when livestock access sites for forage, shade, or water (e.g., naturally pooling). As of 2011, on the Navajo Nation, damage by livestock, from grazing and/or trampling, had been noted at 7 of 42 populations, which has resulted in decreased cover and vigor, and may have impacted reproduction. There is no long-term monitoring data on the effects of livestock. There is no record of a population becoming extirpated due to grazing and/or trampling (NNHP 2012). It is likely that a substantial proportion of all *C. specuicola* sites is not disturbed by livestock because many are physically inaccessible to livestock. Although 35 of 42 (83%) currently reported populations contain a hanging garden accessible to livestock, this number appears to be skewed, as an artifact of preferential survey access by foot (NNHP 2012).

Some impacts of groundwater development on *C. specuicola* have been evaluated. The listing rule noted a "coal mining operation about ten miles" (16 km) away from the known populations/critical habitat, but that the mine was located in a different geologic formation and had a different water source than that of the critical habitat. This was undoubtedly Peabody Western Coal Company's Kayenta Mine Complex (KMC), located about 32 km (20 mi) southeast of the originally known populations. The KMC is composed of the currently operating Kayenta Mine and the Black Mesa Mine, which closed in 2005. Today, locations of *C. specuicola* are known closer to the mine, one within eight miles of the KMC water production well field. All populations within 60 km (37 mi) of the mine occur to the north. The mine pumps water from the N-aquifer, the same aquifer that supports hanging gardens in which *C. specuicola* grows. Average annual use of N-aquifer water by Peabody is currently about 1,236 acre-feet. Prior to 2006, average annual use was roughly 4,310 acre-feet. The decrease was due to the shutdown of the Mohave Generating Station, its associated coal slurry pipe line and mining at the Black Mesa Mine. Overall, regional groundwater withdrawals from the N-aquifer were 39 % less in 2011 compared to 2005 (4,480 versus 7,330 acre-feet per year) due to the shutdown (Macy and Unema 2014).

In a biological assessment for the Kayenta Mine Permit Renewal, the Office of Surface Mining (OSM) concluded that pumping to support mine operations would not decrease flows in seeps/springs that support *C. specuicola* (OSM 2011), based on hydrogeology of the area and groundwater monitoring. The OSM determined that the locations of *C. specuicola* populations are hydrologically isolated from the effects of Peabody's pumping due to the presence of two hydrogeological factors. First, a large monocline located along the northern edge of Black Mesa is believed to be an area of lower permeability that limits drawdown in areas north of the monocline. Second, the N-aquifer is unconfined north of this monocline, and drawdown due to Peabody's pumping in the unconfined area is very small.

Monitoring data of N-aquifer spring flow in the mine action area for 20 to 25 years show that the discharges have fluctuated but long-term trends are not apparent (Truini et al., 2005, Macy and Unema 2012). Assuming the monitored springs provide an indication of spring flow at *C. specuicola* population locations, the OSM concluded that Peabody's pumping, to date, has not measurably reduced the N-aquifer groundwater flow at these springs. Furthermore, USGS monitoring indicates that since Peabody reduced pumping after 2005, there has been a slight improvement in groundwater discharge in one area (OSM 2011).

There may be future impacts on *C. specuicola* from regional groundwater pumping. Recent estimates show large losses to groundwater reserves in the Colorado River Basin due to prolonged drought in the southwestern U.S. coupled with a regulatory framework to manage surface waters but not groundwater (Castle et al. 2014). Loss of significant groundwater reserves may result in further drying of seeps on which Navajo sedge depends and exacerbate effects of drought and from climate change.

In summary, two of the three main threats that served as the basis for listing *C. specuicola*, water development for livestock at occupied springs, and livestock trampling of areas around these water sources, can significantly impact individual hanging gardens but do not pose a threat across all or a significant portion of the range of the species. Water development is documented within only 3 of 57 populations. Trampling occurs at more sites, but is limited by the inaccessibility of many sites. Groundwater development is not known to affect any populations but needs to be evaluated, particularly if the current drought continues.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

No threats from overuse are known to exist. Formerly, collection of *Carex specuicola* by scientists and other interested parties was of concern based on its endemism and rarity (USFWS 2001). This concern has been lessened by our current understanding of this species distribution and population numbers.

2.3.2.3 Disease or predation:

Disease
Knowledge of diseases significantly affecting *Carex specuicola* is undeveloped.

Herbivory
One of the three main threats that served as the basis for listing *Carex specuicola* was livestock grazing of the species, which could damage populations (USFWS 1985). As of 2004, one of the three original subpopulations (1B) had been all but eliminated by grazing, with only 12 plants remaining (NNHP 2012). Many species within the *Carex* genus are very palatable and desired forage sources for both livestock and wildlife (Phillips et al., 1981). Grazing, to varying degrees, at

various *C. specuicola* sites, and at the same site over time, has been noted for nearly 35 years (Phillips et al. 1981: USFWS 1985; NNHP 2004; NNHP 2012; Rink 2014). Early reports found healthy plants with good vigor and good overall reproductive success at sites where there was grazing (Phillips et al. 1981; USFWS 1985). Phillips et al. (1981) noted that the rhizomatous nature of *C. specuicola* will aid in its resistance to grazing pressures, but any increase in plant utilization would probably be detrimental to the survival of the species.

As described above, on the Navajo Nation, damage by livestock from grazing and/or trampling has been noted at 7 of 42 populations. In 2000-2003, these impacts were considered medium to heavy (NNHP 2004). In 2000, one particular hanging garden on the Navajo Nation in Geshi Canyon was described as having sparse *C. specuicola* that had been "grazed to an inch of stubble"; the garden was described as drying up with part of the vegetation mat falling off the seep wall. In 2011, the same seep had flowing surface water, a diverse hanging garden flora, and a nearly continuous cover of exceptionally healthy *C. specuicola* across the 100 m-long (328 ft-long) seep (NNHP 2012, A. Hazelton pers. comm.). The intervening frequency and intensity of grazing is unknown but, in general, grazing on the Navajo Nation is unregulated (NNHP 2004). Of the 15 hanging gardens (in 10 populations) compared between 2000-2003 and 2010-2011, there was a decrease in grazing pressure at 3 gardens and there was no change, or no information to indicate a change, at 11 gardens. (One additional hanging garden could not be relocated.) Plant vigor increased at all three gardens where there was a decrease in grazing pressure, with two of those gardens also experiencing an increase in water availability. Of the 42 populations on the Navajo Nation with information about livestock use, 35 (83%) of these contain a hanging garden accessible to livestock. Many hanging gardens have not been surveyed because they are too remote or difficult to access. Therefore, it is probable that a substantial proportion of the total number of hanging gardens that support *C. specuicola* are not disturbed by livestock because they are physically inaccessible to livestock. There are no records of any entire population becoming extirpated due to grazing and/or trampling.

On the Hopi Reservation, the known *C. specuicola* population is reported to be thriving. Its situation is nearly inaccessible, on a high bench 20 feet above the valley floor, which acts as a barrier and protects the site from domestic livestock (Hopi Water Resources Program 2012).

Currently, we do not have any data to understand the relationship between grazing pressure and *C. specuicola* cover and vigor. The monitoring plots recently established by Rink and Hazelton should shed some light on this issue. Interestingly, one of these monitoring sites is in Geshi Canyon, formerly described as intensely impacted by grazing in 2004 but having, by far, the most cover of any of the monitoring plots (G. Rink, A. Hazelton, pers. comm.).

One of the three main threats that served as the basis for listing *C. specuicola*,

livestock grazing, has been documented to impact gardens at a limited number of sites over the short term. Long-term impacts have not been studied. Based on the fact that no population has been extirpated due to grazing and given the probable inaccessibility of most sites to livestock, grazing does not appear to pose a threat across all or a significant portion of the species range. However, it is important to continue monitoring livestock grazing to determine if it may be an additional stressor that, when combined with other factors, acts as a cumulative threat.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

At this time, *Carex specuicola* is protected to varying degrees by the following Federal, Tribal, and international trade regulations:

- Navajo Nation Code Title 17 section 507 (Endangered Species), listed pursuant to Resources Committee Resolution No. RCS-41-08 (Navajo Endangered Species List, Group 3)
- Endangered Species Act (16 U.S.C. 1531 et seq.), as amended
- Arizona Native Plant Law (ARS Chapter 7, Article 1, 3-903)
- Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
- Lacey Act (16 U.S.C. 3371 et seq.), as amended

The Navajo Nation manages their natural resources; states laws do not apply. However, if *C. specuicola* were transported off the Navajo Nation into Arizona, the Arizona Native Plan Law would be applicable.

At the time of Federal listing, we described the protection afforded by the Navajo Nation Code (NNC) as limited because its only regulatory control was the requirement for a permit to study or collect plants. However, 17 NNC 507 generally prohibits the take of endangered species under penalty of fine and/or imprisonment. Furthermore, the Navajo Nation has a project review system for land-use that involves the review of land-use applications by the Navajo Nation Department of Fish and Wildlife for compliance with both Tribal and Federal law, including 17 NNC 507 and the ESA and its implementing regulations. The requirement of Federal agencies to consult the USFWS under section 7 of the ESA is relevant because of the significant number of actions on Navajo Nation land that are authorized, funded, or carried out by a Federal agency. However, Tribal or Federal project review would not necessarily address impacts associated with livestock grazing and water development since grazing permits on the Navajo Nation are renewed automatically (USFWS 1985) and water development may be accomplished by private tribal initiative.

The Navajo Nation also has land use planning guidance in the form of their Biological Resource Land Clearance Policies and Procedures (RCP) (approved September 10, 2008, by Resources and Development Committee resolution RCS-44-08). The purpose of the RCP is to assist the Navajo Nation government and

chapters (local governance units) ensure compliance with Federal and Navajo laws that protect wildlife resources. Based on decades of surveys, research, and study by the Navajo Nation's Department of Fish and Wildlife (which includes the NNHP), the RCP directs development to areas where impacts to wildlife resources will be less significant (see http://www.nndfw.org/clup.htm).

Utah does not have state laws to protect rare plants on private and state lands. The requirement of Federal agencies to consult the USFWS under section 7 of the ESA applies on Federal lands and for actions that are federally authorized, funded or carried out on private, state or tribal land.

Critical habitat for *C. specuicola* was designated, concurrent with listing, to include the plant's known range (USFWS 1985). The designated area covered the plants and seeps, forming three rectangles about 5 m (16.4 ft) x 40 m (130.1 ft) in dimension and covering a total of 600 m^2 (6,458 ft^2 or about 0.15 acres). Moist sandy to silty soils at shady seep-springs within the Navajo Sandstone Formation were the constituent elements.

In 2001, the EPA consulted with the USFWS, under section 7 of the ESA, on their approval of the Navajo Nation's Water Quality Standards (WQS). Our opinion was that their action would not jeopardize the continued existence of *C. specuicola* (and several other species) or adversely modify its critical habitat (USFWS 2001). We did not concur with the EPA's determination that the WQS' Antidegradation Policy and Implementation Plan would not likely adversely affect the species covered in the consultation, including *C. specuicola*. The Terms and Conditions of the biological opinion, for the animal species, included the development of implementation procedures to strengthen the Antidegradation Policy and provide enforcement of the Implementation Plan. These conditions, which would also benefit *C. specuicola*, were partially implemented as of 2007 (Navajo Nation Environmental Protection Agency 2007) and are more fully addressed in the current version of the Navajo Nation's WQS currently pending approval by the Resources and Development Committee (E. Rich, pers. comm.).

The Lacey Act prohibits the import, export, sale, acquisition, purchase, interstate commerce, or foreign commerce of any plant and/or animal taken, possessed, or sold in violation of any law, treaty, or regulation of the United States (U.S.), any Indian tribal law, or any regulation of any state. If transported or exchanged for currency, *C. specuicola* would be protected under the Lacey Act.

C. *specuicola* could benefit from development of management plans by each land managing entity, with the offered assistance of the USFWS. These management plans could provide a standardized monitoring protocol, address recently recognized or emerging threats such as aquifer water withdrawals, climate change and invasive weeds, and provide plans for habitat management and protection.

Existing regulatory mechanisms are probably adequate to address impacts to *C. specuicola* from development that requires Federal or Tribal involvement. However, so far they have been ineffective at protecting the species from the impacts of grazing (NNHP 2012). Furthermore, it is questionable whether these mechanisms could address threats associated with climate change.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC 2007a), "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level." Various environmental changes, such as shifts in the ranges of plant and animal species, conditions more favorable to the spread of invasive species, changes in amount and timing of water availability, are occurring in association with changes in climate (IPCC 2007a; Global Climate Change Impacts in the U.S., 2009).

For the next two decades, warming of about 0.2 degrees Celsius (°C) (0.4 degrees Fahrenheit [°F]) per decade is projected (IPCC 2007a, p. 6). Afterwards, projections increasingly depend on specific emission scenarios (IPCC 2007a). Various emissions scenarios suggest that by the end of the 21st Century, average global temperatures are expected to increase 0.6°C to 4.0°C (1.1°F to 7.2°F) with greatest warming expected over land (IPCC 2007a).

Localized projections suggest the Southwest may experience the greatest temperature increase of any area in the lower 48 states (IPCC 2007a), with warming in southwestern states greatest in the summer (IPCC 2007b). The IPCC also predicts hot extremes, heat waves, and heavier precipitation events will increase in frequency (IPCC 2007a). There is also high confidence that many semi-arid areas like the western U.S. will suffer a decrease in water resources due to climate change (IPCC 2007a) as a result of less annual mean precipitation and reduced length of snow season and snow depth (IPCC 2007b). Milly et al. (2005) project a 10 to 30 % decrease in precipitation in mid-latitude western North America by the year 2050 based on an ensemble of 12 climate models. In the southwestern U.S., precipitation forecasts involving the summer monsoons are uncertain with some possibility that annual precipitation might increase (Notaro et al. 2012). Even so, projected warming trends are expected to exacerbate droughts by increasing evapotranspiration and further drying the soil (Weiss et al. 2009). The conditions that are suitable to maintain viable populations of various species in the southwestern U.S. are simulated to shift geographically an average of 93 km (58 mi) in the 21st Century (Notaro et al. 2012).

Long-term increased temperatures and changes in precipitation patterns, as projected by climate change models, represent a previously unidentified potential threat to *C. specuicola*. However, how these changes will influence spring

discharge is unclear for at least three reasons as described by Spence (2008). First, the numbers, sizes, distribution, and relationships of aquifers upon which *C. specuicola* relies are unknown. What is known is that the age of the water that recharges springs in the region varies considerably. Water discharging from springs elsewhere on the Colorado Plateau, in Zion Canyon for example, varies in age from relatively recent to about 4,000 years old (Kimball and Christensen 1996). In general, "old water" indicates regional aquifers, which are relatively stable, while "young water" indicates localized recharge areas, which tend to be more ephemeral. Second, little is known about recharge and depletion rates for most aquifers in the region. And third, the relative contribution of winter and summer precipitation to regional aquifers is not well understood. Despite this uncertainty, Spence points out that the vicariance hypothesis for the presence of boreal-temperate and endemic species in many springs suggests that these springs have been flowing for most of the Holocene, including the thermal maximum of the mid-Holocene.

Locally, within the range of *C. specuicola*, precipitation has decreased over the last 35 years. Between 1980 and 2013, mean annual precipitation decreased from about 14.8 in/yr (37.6 cm/yr) to 9.2 in/yr (23.2 cm/yr), or 38%, based on rain gage information from Betatakin, in Navajo National Monument (Peabody 2013). Betatakin is located within the largest regional grouping of *C. specuicola*, constituting about two-thirds of all known populations on the Navajo Nation. If this trend continues or even if precipitation amount stabilizes, aquifers would receive less recharge than before, resulting in less discharge of water into hanging garden springs, which would negatively affect *C. specuicola*.

Fluctuations in spring flow at seeps supporting some *C. specuicola* populations have been noted by the NNHP over three decades. In 2000-2003, 37% of *C. specuicola* sites showed signs of drought stress, such as high mortality rates, no water discharge, dry soils, and sloughing off of vegetation mats (NNHP 2004). Most often, the drying of a seep leads to a reduction in the size of the associated population, and occasionally smaller plant stature or a failure to flower or fruit. At 10 hanging gardens monitored in 2000-2003, six were noted as "dry". When revisited in 2010-2011, all of these populations had remained relatively stable. There was no change in the size or vigor of the *C. specuicola* population at four of the six gardens. At one garden, the spring flow rate had increased and the size of the population increased substantially, suggesting a positive response to increased water availability. At the sixth dry garden, the "drought became more extreme" and the garden was extirpated by 2011 (NNHP 2012). It should be noted that the region, which encompasses all of these populations, is considered to still be in a long-term drought condition.

In 25 years of monitoring the species by the NNHP, there have been four instances when *C. specuicola* was reported as being extirpated from a hanging garden following the drying of a seep. However, in each case, another seep with *C. specuicola* remained at a garden within the same alcove or side canyon, so the

population was not extirpated, but was reduced. This suggests that the population may have become less viable. However, no information was provided in the 2012 NNHP report about the condition of *C. specuicola* in other gardens or the overall viability of each of the four populations. In four additional cases during the 25 years of monitoring, no hanging garden could be relocated at a previously mapped location; this could be either the result of complete drying of the site or because of a mapping error.

Climate change may also confer a competitive advantage to some invasive species, facilitating the spread of stronger competitors and possibly exacerbating this threat to *C. specuicola* as described below.

Demography

Factors affecting this species at the time of listing involved its specific habitat requirements, limited distribution, and small number of populations, which made its existence especially precarious in the event of habitat disturbance or any activity that results in the loss of a significant number of individuals. Threatened status was deemed appropriate, despite the noted vigor and good reproductive success of these populations, because of these demographic factors combined with threats from livestock and related water development. Since the time of listing, the number of known populations has increased over 50-fold and the range of the species has increased even more (based on survey effort as opposed to population expansion). Therefore the threat of stochastic or catastrophic events to the species seems to have been reduced, even though the species' range remains relatively small, making it susceptible to range wide threats such as drought or groundwater pumping.

Invasive Plants

The Recovery Plan identified the potential threat of invasive weeds, which may compete with *C. specuicola* for resources. However, *C. specuicola* populations are likely more resilient to and naturally protected from invasion by weeds because of the general lack of disturbance in hanging gardens and the lower likelihood of seeds dispersing to small, elevated, remote, and widely spaced sites. Though exotic species are present at some of the hanging gardens supporting *C. specuicola*, in no case are weeds noted to dominate the vegetation. Instead, weeds inhabiting *C. specuicola* habitats generally tend to coexist in low abundance with the rest of the vegetation. However, *Agrostis stolonifera* has recently invaded the Slickhorn Canyon *C. specuicola* population, and may be associated with a small decline in population size since its discovery in 1997 (NPS 2013). In conjunction with subsequent surveys the National Park Service plans selected hand pulling of the *Agrostis* at this site. Therefore, land managers should continue to monitor for the spread of invasive species into and within *C. specuicola* habitat and, if appropriate, implement a control program.

In summary, increased temperature and altered precipitation patterns associated with climate change in the western U.S. are previously unidentified threats that

may have significant implications for a species that inhabits sites that depend on continuous discharge of small volumes of water in an arid environment.

2.4 Synthesis

From the original one known population of Navajo sedge (*Carex specuicola*) on Navajo Nation lands in Arizona at the time of listing, this species currently consists of 57 known populations, ranging in size from under 100 plants to 5 populations with a few thousand plants. Lands where C. *specuicola* occurs are managed by the Navajo Nation, National Park Service, Hopi Tribe, and Bureau of Land Management, with the majority of populations occurring on the Navajo Nation. Of 32 populations on the Navajo Nation with enough status information for a viability rank, 16 were considered good or excellent, and 16 were of fair viability. This means half of those populations had a moderate likelihood of persisting in a similar or improved state for 20 to 30 years, which is cause for concern about their persistence into the foreseeable future. There are no documented cases of population extirpation for *C. specuicola*, although four populations have lost gardens due to the drying of seeps. The main threats identified in the Recovery Plan, livestock-associated water development and livestock grazing/trampling, can significantly impact individual gardens but are probably not a threat across all or a significant portion of the species range. However, impacts from these activities, grazing in particular, could exacerbate the effects of climate change and/or groundwater pumping and should continue to be monitored and factored in to future status assessments.

In the 29 years since *C. specuicola* was listed as a threatened species, no definitive population trends have been documented. However, increased temperature and altered precipitation patterns associated with climate change are previously unidentified threats that may have significant implications for this relict species that inhabits sites that depend on continuous discharge of small volumes of water. In addition, water withdrawals from Colorado Basin aquifers that supply water to the seeps may solely and in combination with climate change pose a threat to the species. We lack long-term demographic data to assess population trends and specific information about the dynamics of the sources of water for seeps that support *C. specuicola*. Due to the relative rarity of its isolated aquatic habitats amid an arid region and its sensitivity to drying of the seeps, which may be significantly affected by climate change and groundwater pumping, *C. specuicola* remains likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

3.0 RESULTS

3.1 Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*
____ *Extinction*
____ *Recovery*
____ *Original data for classification in error*
_X_ No change is needed

3.2 New Recovery Priority Number (RPN): No change, remain as 8.

We recommend maintaining the RPN of 8, indicating the degree of threat is moderate, the recovery potential is high, and the taxon is a species.

Brief Rationale:

Based on our 2008 draft RPN guidance and the Recovery Plan, the taxonomic status, degree of threats to, and the recovery potential of *C. specuicola* at this time are consistent with a RPN of 8. The recovery potential remains high based on indications of the species' short-term tolerance of desiccation, its ability to positively respond to an increase in available water flow and adjacent suitable habitat, and its potential resilience to livestock grazing. Although threats of small population size; isolation of localities; and livestock consumption, trampling, and aquatic habitat alteration originally described in the Recovery Plan are less severe than originally thought, climate change represents a new and significant threat to the plant and its habitat of seeps in hanging gardens in an arid region. Hanging garden habitats are rare and not likely to increase in quantity, either naturally or anthropogenically, because they are a relict ecosystem associated with an unusual geologic situation. The rarity of these specialized spring habitats makes the associated plants also rare. Because we lack specific information to project the effects of climate change on this species or the enduring reliability of its wet habitat, we do not recommend changing the RPN based on the predicted threat of climate change until we have more information regarding how this threat is likely to affect these habitats.

3.3 Listing and Reclassification Priority Number: Not applicable.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

1) We recommend revising the 1987 Navajo sedge (*Carex specuicola*) Recovery Plan, specifically to include recovery criteria and updated population, management, and climate information.

2) We recommend development of management plans by the respective land managing entities with the offered assistance of the USFWS. These management plans should address newly understood or emerging threats such as climate change and groundwater pumping.

3) We recommend standardized monitoring to determine demographic trends in *C. specuicola* populations. This will allow the USFWS to determine trends in species or population stability, in support of Recovery Action 7. The USFWS can assist in coordinating this effort to facilitate consistency and comparability between the monitoring methods employed by each agency.

4) We recommend studying the dynamics of the aquifers upon which *C. specuicola* depends to understand how climate change, groundwater pumping, and other water use may affect seep discharge. This study would include an understanding of the sizes and connection of local and regional aquifers, and the distribution of seeps supporting *C. specuicola* within each of those aquifers; recharge and depletion rates; and the relative contributions of winter and summer precipitation.

5) We recommend quantifying the drought threshold for *C. specuicola* existence in hanging gardens. Threshold parameters would include soil moisture content and/or spring discharge rate, and variability in that moisture level over time. *C. specuicola* appears resilient to some amount of drought, but recovery of a population is dependent on the intensity, duration, and variability of the drought, along with site conditions. To determine these survival thresholds, data would need to be collected on a much finer scale than has been to date.

6) We recommend additional surveys for *C. specuicola* in Utah, particularly at the northern end of its range where large areas with apparent suitable geology are unsurveyed.

7) We recommend studying the reproductive strategy (including breeding success, seed viability, and pollination) and genetic diversity of *C. specuicola* to inform management for the species' long-term conservation. Genetic studies should include the relationships between *C. specuicola*, *C. parryana* and *C. utahensis*.

5.0 REFERENCES

Castle, S.L., B.F. Thomas, J.T. Reager, M. Rodell, S.C. Swenson, and J.S. Famiglietti. (in press). Groundwater depletion during drought threatens future water security of the Colorado River Basin. American Geophysical Union. doi: 10.1002/2014GL061055.

Culley, T.M., S.G.Weller and A.K. Sakai. 2002. The evolution of wind pollination in angiosperms. Trends in Ecology & Evolution 17(8):361-369.

Dafni, A., and D. Firmage. 2000. Pollen viability and longevity: practical, ecological and evolutionary implications. Plant Systematics and Evolution 222:113-132.

Elzinga, C.L., D.W. Salzer, J. W. Willoughby, and J.P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Oxford.

Friedman, J., and S.C.H. Barrett. 2009. Wind of change: new insights on the ecology and evolution of pollination and mating in wind-pollinated plants. Annals of Botany 130:1515-1527.

Global Climate Change Impacts in the United States. 2009. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds). Cambridge University Press, Cambridge, UK, and New York, NY. 189 pp.

Hermann, F.J. 1970. Manual of the Carices of the Rocky Mountains and Colorado Basin. Agricultural Handbook #374, USDA Forest Service.

Hopi Water Resources Program. 2012. Unpublished report to the U.S. Fish and Wildlife Service for the Navajo Sedge 5-Year Review. Department of Natural Resources, Hopi Tribe, Kykotmovi, AZ.

Howell, J.T. 1949. Three new Arizona plants. Leaflets of Western Botany 5(9):148.

Intergovernmental Panel on Climate Change (IPCC). 2007a. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K., and A. Reisinger (eds.). IPCC, Geneva, Switzerland. 104 pp.

Intergovernmental Panel on Climate Change (IPCC). 2007b. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor, and H.L. Miller (eds.). Cambridge University Press, Cambridge, UK, and New York, NY. 996 pp.

Keate, N.S. 1996. Quantitative Analysis of Hanging Garden Endemic Species Richness in the Moab Region, Utah. Thesis (Ph.D) dissertation. Department of Geography, University of Utah.

Kimball, B.A., and P.K. Christensen. 1996. Residence time of water discharging from the hanging gardens of Zion National Park. Journal of the American Water Resources Association 32(3):531-540.

Linder, H.P., and P.J. Rudall. 2005. Evolutionary history of Poales. Annual Review of Ecology and Systematics 36: 107-124.

Macy, J.P., and J.A Unema. 2014. Groundwater, surface-water, and water-chemistry data, Black Mesa area, northeastern Arizona—2011–2012: U.S. Geological Survey Open-File Report 2014–1304, 42 p., *http://dx.doi.org/10.3133/ofr20131304*.

Milly, P.C.D., K.A. Dunne, and A.V. Vecchia. 2005. Global pattern of trends in streamflow and water availability in a changing climate. Nature. The Nature Publishing group. Vol. 438. pp. 347-350.

National Park Service. 2013. *Carex specuicola* J.T. Howell Status Report, Glen Canyon National Recreation Area, December 3, 2013. National Park Service, Page, AZ.

NatureServe Explorer. 2004. Habitat-based Plant Element Occurrence Delimitation Guidance. http://www.natureserve.org/explorer/decision_tree.htm

Navajo Water Quality Program. 2007. Navajo Nation Surface Water Quality Standards 2007. Navajo Nation Environmental Protection Agency, Window Rock, AZ.

Navajo Natural Heritage Program. 2004. *Carex specuicola* (Navajo Sedge) Status Report (unpublished report). Navajo Nation Fish and Wildlife Department, Window Rock, AZ.

Navajo Natural Heritage Program. 2008. Species account for *Carex specuicola*. Navajo Nation Fish and Wildlife Department, Window Rock, AZ.

Navajo Natural Heritage Program. 2012. Status Report for Navajo Sedge on Navajo Nation Lands (unpublished report). Navajo Nation Department of Fish and Wildlife, Window Rock, AZ.

Nekola, J.C. 1999. Paleorefugia and Neoreguia: The Influence of Colonization History on Community Pattern and Process. Ecology 80(8):2459–2473.

Notaro, M., A. Mauss and J.W. Williams. 2012. Projected vegetation changes for the American Southwest: combined dynamic modeling and bioclimatic-envelope approach. Ecological Applications 22(4):1365-1388.

Office of Surface Mining (OSM). 2011. Biological assessment supplement, Kayenta Mine Permit Renewal (Navajo County, Arizona). October 2011. U.S. Department of Interior, Office of Surface Mining Reclamation and Enforcement 2012, Denver, CO. 46 pp.

Palmquist, E.C. 2011. Phylogeny and Evolutionary History of *Anticlea vaginata* Rydb. (Melanthiaceae): A Hanging Garden Endemic. Unpublished report for the Colorado Plateau Cooperative Ecosystems Unit. 76 pp.

Peabody Western Coal Company. 2014. 2013 Reclamation Status and Monitoring Report Black Mesa and Kayenta Mine, May 2014. Peabody Western Coal Company, Kayenta, AZ.

Phillips, A.M., B.G. Phillips, L.T. Green, J. Mazzoni, and N. Brian. 1981. Status report for *Carex specuicola* J.T. Howell, prepared for the U.S. Fish and Wildlife Service, Albuquerque, N.M.

Reznicek, A.A., and D.F. Murray. 2013. A re-evaluation of *Carex specuicola* and the *Carex parryana* complex (Cyperaceae). Journal of the Botanical Research Institute of Texas 7(1):37-51.

Rink, G. and A. Hazelton. 2014. Demography Studies for *Carex specuicola* (Navajo sedge, Cyperaceae). 2014 section 6 final report for the U.S. Fish and Wildlife Service. Reference No. 2013-2014-07.

Rink, G., and M. Licher. (in review). *Carex* of Arizona. Canotia, a Journal of Arizona Botany and Mycology. Arizona State University, Tempe, AZ.

Rutman, S. 1992. Handbook of Arizona's endangered, threatened and candidate plants. Arizona Ecological Services Field Office, Phoenix, Arizona.

Spence, J.R. 2008. "Spring Supported Vegetation along the Colorado River on the Colorado Plateau." In L.E. Stevens & V.J. Meretsky (Eds.), Aridland Springs in North America: Ecology and Conservation. Tucson, AZ: University of Arizona Press.

Springer, A.E., and L.E. Stevens. 2009. Spheres of discharge of springs. Hydrogeology Journal 17:83-93.

Truini, M., J.P. Macy, and T.J. Porter. 2005. Ground-water, surface-water, and water-chemistry data, Black Mesa area, northeastern Arizona—2003–04: U.S. Geological Survey Open-File Report 2005–1080, 44 p.

U.S. Department of the Interior (USDI). 1985. Final rule to determine *Carex specuicola* (Navajo sedge) to be a threatened species with critical habitat. Federal Register 50(89):19370-19373. May 8, 1985.

U.S. Fish and Wildlife Service (USFWS). 1987. Navajo Sedge (*Carex specuicola*) Recovery Plan. U.S. Fish and Wildlife Service, Albuquerque, New Mexico. 39 pp.

U.S. Fish and Wildlife Service (USFWS). 2001. Biological opinion for U.S. Environmental Protection Agency approval of the Navajo Nation's Water Quality Standards. December 16, 2001. Arizona Ecological Services Field Office, Phoenix, Arizona. 60 pp.

Weiss, J. L., C. L. Castro, and J. T. Overpeck. 2009. Distinguishing pronounced droughts in the southwestern United States: seasonality and effects of warmer temperatures. Journal of Climate 22:5918–5932.

Welsh, S.L., N.D. Atwood, S. Goodrich, and L.C. Higgins, eds. 2003. 3rd edition revised. A Utah Flora. Brigham Young University, Provo, Utah.

5.1 PERSONAL COMMUNICATION

Andrea Hazelton, Botanist, Natural Heritage Program, Navajo Fish and Wildlife Department, 2012 -2014.

Eric Rich, Senior Hydrologist, Navajo Environmental Protection Administration, 8/28/14.

Glenn Rink, Contractor, Far Out Botany, 2012 – 2014.

U.S. FISH AND WILDLIFE SERVICE

5-YEAR REVIEW of
Navajo sedge (*Carex specuicola*)

Current Classification: Threatened with critical habitat

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable: Not Applicable.

Review Conducted By: John Nystedt, Fish and Wildlife Biologist, Arizona Field Office - Flagstaff

FIELD OFFICE APPROVAL:

Field Supervisor, Fish and Wildlife Service

Approve _____ Date 8/22/14

REGIONAL OFFICE APPROVAL:

Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Region 2

Approve Michelle Shaughnessy Date 8/26/14

Cooperating Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Region 6

X Concur ____ Do Not Concur

Signature _____ Date 9/5/14

W:\John Nystedt\5-Year Review Navajo Sedge140821final-wfigures,pics.doc