Species Status Assessment for Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*)

Photo by Vernon Smith

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VERSION HISTORY

Version 1.0 *We began the original version of this Species Status Assessment in 2024 and completed a draft SSA report in 2025. The draft SSA report underwent peer and partner review in 2024. This version of the SSA was used to inform the draft Recovery Plan.*

EXECUTIVE SUMMARY

This report summarizes the results of the Species Status Assessment (SSA) by the U.S. Fish and Wildlife Service (Service) to inform recovery planning of Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*). To assess the species' viability, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3 Rs). These principles rely on assessing the species at an individual, population, and species level to determine whether the species can maintain its persistence into the future and avoid extinction by having multiple resilient populations distributed across its range.

Sonoma alopecurus is a variety of foxtail grass endemic to Marin and Sonoma Counties, California. It is currently known from nine populations, where it occurs in small numbers and very limited areas. Eight populations are in Point Reyes National Seashore (PRNS) in Marin County. The ninth population is at Ledson Marsh in Trione-Annadel State Park, Sonoma County, but there is some question as to whether this population represents Sonoma alopecurus or a different variety altogether. The number of plants in each population varies annually with occasional extirpations, reappearances, and (much less frequently) discoveries of new populations. The number and range of Sonoma alopecurus populations has been reduced since listing due to the continuing loss and degradation of the small wetlands on which it depends.

Sonoma alopecurus is a freshwater wetland grass variety, whose occurrence is now usually associated with some level of cattle grazing. Other suspected factors affecting its occurrence include nutrient and climate variables, hydrology, co-occurring native and non-native plant species, and the human-caused degradation of wetlands. However, the relationship between its distribution and these factors is not well understood. Demographic needs include freshwater marshes, with some level of disturbance, moist soil, space, and sunlight. For extant populations, disturbance is typically in the form of grazing.

Our analysis of the past, current, and future influences on Sonoma alopecurus revealed the primary threats to Sonoma alopecurus are destruction and modification of wetlands, competition with native and non-native species, and over- or under-grazing. The species is also at greater risk of extinction from chance events due to low genetic diversity resulting from the small size of remaining populations.

To assess the current resiliency, we assessed the condition of each of the nine extant populations using the best available information. Moderate average abundance and a seasonal grazing regime indicate that PRNS P3 is in moderate condition. PRNS P5, P7, P8, P11, P13, P14, and P15 are in low condition due to low abundance, despite grazing availability. The Ledson Marsh population is in low condition due to low abundance and no grazing. Current redundancy and representation for the species are both low.

To assess future conditions, we used two future scenarios to qualitatively project species viability into the future:

Scenario 1: In the upper plausible limit scenario, threats from the effects of climate change increase according to the intermediate Representative Concentration Pathway (RCP) 4.5, a climate change scenario that projects future greenhouse gas concentrations and the resulting climate change. In this scenario, competition with native and non-native vegetation continues, and conservation actions continue. As a result, we project that the resiliency of PRNS P3 will continue to be moderate despite a projected decrease in abundance, and PRNS P5, P7, P8, P11, P13, P14, and Ledson Marsh are projected to remain at low resiliency or potentially become extirpated. Both redundancy and representation are low in Scenario 1 (ES Table 1).

Scenario 2: In the lower plausible limit scenario, threats from the effects of climate change increase according to RCP8.5, a high-emission climate change scenario, threats from vegetation competition increase, and grazing leases are not renewed in their current format at PRNS. As a result, PRNS P3 is projected to have moderate-low resiliency due to the possibility of a decrease in inflorescence counts, and PRNS P5, P7, P8, P11, P13, P14 and Ledson Marsh are projected to remain at low resiliency or potentially become extirpated. Both redundancy and representation are low in Scenario 2 (ES Table 1).

ES Table 1. Summary table of current conditions in comparison with two future conditions, for each Sonoma alopecurus population.

Viability Measure	Population	Current Condition	Upper Plausible Limit Scenario Condition	Lower Plausible Limit Scenario Condition
Resiliency	P3	Moderate	Moderate	Moderate-Low
	P5	Low	Low	Low-Extirpated
	P7	Low	Low	Low-Extirpated
	P8	Low	Low	Low-Extirpated
	P11	Low	Low	Low-Extirpated
	P13	Low	Low	Low-Extirpated
	P14	Low	Low	Low-Extirpated
	P15	Low	Low	Low-Extirpated
	Ledson Marsh	Low	Low	Low-Extirpated
Redundancy		Low	Low	Low
Representation		Low	Low	Low

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CHAPTER 1 – INTRODUCTION

1.1 SPECIES OVERVIEW

Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*) is a variety of perennial foxtail grass endemic to Sonoma and Marin Counties, California. Sonoma alopecurus occurs in or peripheral to wetlands and streams, and most extant populations occur primarily in grazed pasture.

1.2 FEDERAL LISTING STATUS

Sonoma alopecurus was federally-listed as endangered in 1997 (16 U.S.C. § 1531 et seq., Service 1997, entire). The Endangered Species Act (Act) defines "species" to include "subspecies" (16 U.S.C. 1532(16)), and in the field of botany, the term "variety" is used instead of "subspecies" when (as here) only one rank of subspecific taxa is recognized. Therefore, although Sonoma alopecurus is recognized as a taxonomic variety in the scientific community, when we refer to it as a "species" in this SSA report, we mean it in the sense defined by the Act.

No critical habitat has been designated for Sonoma alopecurus, and one status review has been completed (Service 2011, entire). A Recovery Planning Number (RPN) of 9 was assigned to the species at the time of the 2011 Sonoma alopecurus 5-Year Review (Service 2011, p. 2). Our reassessment has shown that the taxon has a low potential for recovery due to moderate threats that are poorly understood, therefore we are changing the RPN to 12 with this Species Status Assessment and corresponding Recovery Plan.

1.3 STATE LISTING STATUS

Sonoma alopecurus is not listed as Threatened, Endangered or Rare under the California Endangered Species Act (CNDDB 2020, p. 1).

1.4 SSA FRAMEWORK

The Service uses the SSA framework (Service 2016, entire) to provide an integrated analytical approach to assess a species' current biological condition and its projected capability of sustaining populations in the wild into the future (Smith et al. 2018, entire). The purpose of the SSA Report is to provide a risk assessment of a species and assist in informing decisions and activities under the Act. Building on the best of our current analytical processes and the latest scientific information in conservation biology, this framework integrates analyses that are common to all functions under the Act, eliminates duplicative and costly processes, and allows the Service to strategically focus on our core mission of preventing extinction and achieving recovery.

Using the SSA framework (Figure 1), we consider what a species needs to maintain its viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (3 Rs) (Shaffer and Stein 2000, pp. 308–311). For the purpose of this assessment, we define viability as the ability of the species to sustain healthy populations in natural ecosystems within a biologically meaningful timeframe, in this case, 75 years to 2100. We chose

75 years because the available data allow us to reasonably predict the potential effects of stressors within the range of Sonoma alopecurus through this timeframe and because 75 years represents a period of time that captures a range of variation in environmental conditions which the species will need to withstand in order to sustain populations into the future. The 3 Rs are defined as follows:

- Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature, rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates such as mortality and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability of a species to bounce back and sustain populations through the natural range of favorable and unfavorable conditions. We can best gauge resiliency by evaluating population level characteristics such as demography (abundance and the components of population growth rate -- survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of habitat types or microclimates) are also important considerations.

- Redundancy is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number, distribution, and condition of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

- Representation is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments-- referred to as adaptive capacity--is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Nicotra et al. 2015, p. 1270; Beever et al. 2016, p. 132). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, pp. 290–291; Zackay 2007, p. 1; Sgrò et al. 2011, p. 327). We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of interpopulation genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess [1] natural levels and patterns of gene flow, [2] degree of ecological diversity occupied, and [3] effective population size. In our species status assessments, we assess all three facets to the best of our ability based on available data.

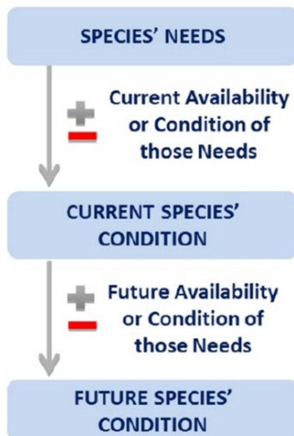

Figure 1. The step-wise process for assessing a species' status, as envisioned by the Services' SSA Framework (Service, 2016, p. 6)

CHAPTER 2 – SPECIES BIOLOGY

In this chapter we provide the basic information about Sonoma alopecurus, detailing its taxonomy, physical description, genetics, historical range and distribution, and general life history traits.

2.1 TAXONOMY

Sonoma alopecurus is a variety of *Alopecurus aequalis*, a widespread and common grass that occurs in North America and Eurasia. *Alopecurus aequalis* var. *aequalis* is the more common variety. Sonoma alopecurus was first described by Rubtzoff (1961, pp. 170–172) when specimens at Bennett Mountain Lake could not be identified using the Hitchcock manual (1950, p. 359).

2.2 PHYSICAL DESCRIPTION

Sonoma alopecurus is a tufted perennial in the grass family Poaceae. It grows from 12 to 30 inches [in] (30 to 75 centimeters [cm]) tall. The stems are mostly erect and either straight or weakly bent near the base. The leaf blades are up to 0.3 in (7.5 millimeters [mm]) wide. The inflorescence (complete flower head) is dense, cylindric, and panicle-like[1] (Crins 2012, entire). The inflorescence ranges from 1.0 to 3.5 in (2.5 to 9.0 cm) long and 0.1 to 0.3 in (4 to 9 mm) wide (Crins 2012, entire). The spikelets[2] are usually tinged violet-gray near the tip. The awn[3] is straight and exceeds the lemma[4] body by 0.04 to 0.1 in (1.0 to 2.5 mm). Sonoma alopecurus is distinguished from the widespread common variety *A. aequalis* var. *aequalis* (shortawn foxtail) that occurs north of Marin County and inland Sonoma County, by its more robust, upright appearance, generally wider panicle, violet-gray tinged spikelets,- and longer awn (Rubtzoff 1961, p. 170, Crins *in litt*. 1993).

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[1] Panicle: A branched inflorescence in which the branches are racemes, so that each flower has its own stalk attached to the branch.
[2] Spikelet: The ultimate (smallest) flower cluster unit in a grass, consisting of two bracts at the base, called glumes, followed by one or more florets.
[3] Awn: A hair- or bristle-like appendage, characteristic of many grasses, which extends from the lemma.
[4] Lemma: A part of the spikelet of grasses; the lowermost of two chaff-like bracts enclosing the floret.

Figure 2. Sonoma alopecurus at Point Reyes National Seashore. Photo Credit: Doreen Smith.

2.3 GENETICS

Genetic studies of Sonoma alopecurus have been initiated, due to recent survey reports that suggest the population at Ledson Marsh may not be Sonoma alopecurus, but potentially the closely related shortawn foxtail (*Alopecurus aequalis* var. *aequalis*) (Bartosh 2018, pp. 8–9). However, since this genetic study has not yet concluded, we continue to assume for purposes of this assessment that the Ledson Marsh population is Sonoma alopecurus.

2.3 HISTORICAL RANGE AND DISTRIBUTION

At the time of listing, Sonoma alopecurus was known historically from 16 populations, however only 8 were extant (Service 1997, p. 55805). Of the 8 extant populations at the time of listing, three were in Sonoma County (Guerneville (Diversity Database #7), Cunningham (Diversity Database #3), and Duncans Mills (Diversity Database #12) marshes) and five in Marin County, all at Point Reyes National Seashore (PRNS) (Service 1997, p. 55805). By the 2011 5-year status review, there were six extant populations: five at PRNS and one in Sonoma County (Ledson Marsh, in Trione-Annadel State Park, formerly called Bennett Mountain Lake, Diversity Database #16) (Service 2011, p. 4). The species is known historically from a moderate number of other small marshes, some with collections, but the continued existence of these populations is highly uncertain, due to negative surveys, confirmed habitat loss at some sites, and to the inability to relocate other sites (Table 1, Figure 3).

Since the 2011 status review, two previously unknown wild populations (P13 and P14, Table 1) have been documented at PRNS within the known range of the species (Parsons 2024, p. 23). Another population (P15) has been introduced, and is still considered extant, although numbers have been dropping continuously since it was first established in 2015, with no inflorescences detected since 2018. In 2014, PRNS biologists also found Sonoma alopecurus plants at a site where the plant had been introduced in 2002, but which had been considered extirpated by the time of the 2011 status review. We consider this population (P11) to be extant, even though the plant was not found by subsequent surveys (in 2015, 2017, and 2019). Another PRNS population (P7) is in a situation similar to P11 and has not been documented since 2015. Finally, since the 2011 status review, P4 has been extirpated because of shifting dune sand (Parsons 2024, pp. 21–22).

As of this report, we consider the total number of extant populations to be nine, although the status of five is questionable due to repeated surveys of 0 inflorescences (Table 6). Apart from the Ledson Marsh population, all remaining Sonoma alopecurus populations occur at Point Reyes National Seashore, in association with some non-zero level of cattle grazing (Gennett 2004, p. 4; Parsons 2024, pp. 2–4).

Table 1. Known current and historical locations of Sonoma alopecurus. PRNS populations 1–15 in the figure, tables, and text are labeled P1–P15, to distinguish them from the numbering system of California Natural Diversity Data Base (Diversity Database) occurrences (1-23); not all PRNS populations are recorded on the Diversity Database. Sources: Sites with Diversity Database Numbers alone: Diversity Database 2020, entire (except as otherwise indicated). Sites with PRNS Numbers: Parsons 2024, pp. 18–28. Diversity Database #16: Howald 2016, pp. 3–5, Bartosh 2017, p. 8, Bartosh 2018, pp. 8–9. Diversity Database #17: Gennet 2004, p. 32.

Diversity Database (PRNS #)	County	USGS 7.5' quad	Location	Years Site Visited	Years Plant Found	Status
1	Sonoma	Two Rock	Bloomfield	1880	1880	Unknown; not relocated
2	Sonoma	Two Rock	Llano Rd	1974	1974	Unknown; not relocated
3	Sonoma	Two Rock	Cunningham Marsh	1947, 1961, 1987, ~2010	1947, 1961	Likely extirpated

Diversity Database (PRNS #)	County	USGS 7.5’ quad	Location	Years Site Visited	Years Plant Found	Status
4	Marin	Drakes Bay	Radio Station vicinity	1948, 1952, 1983	1948, 1952	Unknown; not relocated
5	Marin	Inverness	Bear Valley vicinity	1898, 1983	1898	Unknown; 1987 introduction attempt failed
6	Sonoma	Camp Meeker	Freestone Marsh	1959, 1962, 1987	1959, 1962	Unknown
7	Sonoma	Camp Meeker	Guerneville Marsh	1955, 1987, 2001	1955, 1987	Extirpated; habitat absent
8	Sonoma	Camp Meeker	Schachlly Flat vicinity	1932 (Not relocated)	1932	Unknown
**	Sonoma	Camp Meeker	Near Green Valley School	1936 (Not relocated)	1936	Unknown
9	Sonoma	Camp Meeker	Occidental Marsh	1957, 1987	1957	Unknown; habitat present
10	Sonoma	Camp Meeker	Ross Marsh	1955, 1987	1955	Extirpated; habitat absent
12	Sonoma	Duncans Mills	Duncans Mills Marsh	1955,1987 ,1994, 2001	1955, 1987, 1994	Extirpated; Habitat absent[8]

Diversity Database (PRNS #)	County	USGS 7.5' quad	Location	Years Site Visited	Years Plant Found	Status
13	Sonoma	Camp Meeker	E of Occidental vicinity	1937 (Not relocated)	1937	Unknown
14 (P1)	Marin	Bolinas	Mesa Rd	1945, 1983–1985, 1987[2]–1991, 1999–2001	1945, 1983-1985, 1987-1989, 1991	Extirpated due to lack of grazing[8]
15	Sonoma	Sebastopo l	Pitkin Marsh	1936, 1945, 1951, 1973–1978	1936, 1945, 1951	Unknown
16	Sonoma	Kenwood	Ledson Marsh	1955, 1961, 1987, 1990, 2000, 2001, 2007, 2009, 2010, 2012, 2014, 2015, 2017[4], 2018[5]	1955, 1961' 2000, 2001, 2007, 2009, 2010, 2012, 2015, 2018, 2020	**Extant** (but not seen since 2020)
17	Marin	Inverness	Bear Valley Marsh	1987, 1988, 2000	1987	Extirpated; overgrown
18 (P2)	Marin	Drakes Bay	N Abbots Lagoon	1990, 1991, 1994-1996, 1999-2000	1990, 1991, 1994, 1995	Extirpated

Diversity Database (PRNS #)	County	USGS 7.5’ quad	Location	Years Site Visited	Years Plant Found	Status
18 (P5)	Marin	Drakes Bay	N Abbotts Lagoon	1988[6], 1995, 1996, 1999–2000, 2001[2], 2002–2005, 2008–2019, 2021–2022	All	**Extant** (but not seen since 2022)
19 (P3)	Marin	Drakes Bay	SW of Abbotts Lagoon	1994–1996, 2000–2023	All	**Extant**
20 (P4)	Marin	Drakes Bay	Lower Abbotts Lagoon	1994, 1995, 1998, 2000–2005, 2014, 2017–2019	1994, 1995, 1998, 2000–2005, 2008-2013, 2015-2016	Extirpated; Overrun by dune sand
21	Sonoma	Camp Meeker	Forestville Marsh	1972 (Not relocated)	1972	Unknown
22 (P7)	Marin	Drakes Bay	Northeast of North Beach	2000–2005, 2008–2010, 2012–2016, 2018, 2019, 2021	2000–2005, 2008–2010, 2015	**Extant** (but not seen since 2015)
23 (P8)	Marin	Drakes Bay	Near Coast Guard station	2001-2005, 2008,	All	**Extant** (access halted following 2018)

Diversity Database (PRNS #)	County	USGS 7.5’ quad	Location	Years Site Visited	Years Plant Found	Status
				2010–2018		
(P9)	Marin	Drakes Bay	PRNS (transplant)	2003–2005, 2007–2009, 2013–2015, 2017	2003, 2004	Extirpated
(P10)	Marin	Drakes Bay	PRNS (transplant)	2003–2005, 2007–2009, 2013–2015, 2017	2003, 2004	Extirpated
(P11)	Marin	Drakes Bay	PRNS (transplant)	2003–2005, 2007–2009, 2013–2015, 2017, 2019	2003–2005, 2007, 2014	**Extant**
(P12)	Marin	Drakes Bay	PRNS (transplant)	2003–2005, 2007–2009, 2013–2015, 2017	2003, 2004	Extirpated
(P13)	Marin	Drakes Bay	E of Abbotts Lagoon	2011–2019, 2021-2022	2011–2019, 2021	**Extant** (but not seen since 2021)
(P14)	Marin	Drakes Bay	Unnamed swale	2014–2017, 2019-2021	All	**Extant**
(P15)	Marin	Drakes Bay	Unnamed swale	2015 – 2019, 2021	2015–2018	**Extant** (but not seen since 2018)

Figure 3. Current and historical Sonoma alopecurus populations.

2.4 LIFE CYCLE

Sonoma alopecurus is a short-lived perennial, with individuals surviving one or multiple years (Gennett 2004, p. 36). Inflorescences typically mature in May and continue through August (Gennett 2004, p. 11). Sonoma alopecurus is likely wind pollinated, and individuals can create ample seeds, often from multiple inflorescences from each plant. Sonoma alopecurus can also reproduce vegetatively, rooting at the nodes and producing genets, genetic clones that remain connected to the adult plant (Gennett 2004, p. 2). Timing of natural germination is unknown, but for introduction attempts, seeds have been sown in September and transplanted between January and April (Gennett 2004, pp. 28–33, 41; Ryan and Parsons 2015a, p. 10). The species may have a long-lived seed bank, based on long spans of zero counts observed in populations or areas, but emerging after disturbance, such as grazing, is reintroduced to an area (Parsons 2024, p. 22). However, the distance seeds can disperse is not known and could contribute to re-establishment in some instances. Wetland grasses tend to reproduce more from dropping seeds into flowing water (Soomers et al. 2013, p. 435), which may allow some dispersal capacity through stream corridors. Circumstantial evidence also suggests the possibility of dispersal by cattle at P13, either by foot or seed consumption (Ryan pers. comm. 2024).

CHAPTER 3 – SPECIES NEEDS

In this chapter we provide information about Sonoma alopecurus needs, detailing the habitat and resources that each life stage needs to complete its life cycle. We then highlight the needs for resilient populations of Sonoma alopecurus, and the species' needs in terms of resources and/or circumstances that support redundancy and representation of the species.

3.1 INDIVIDUAL NEEDS (HABITAT/RESOURCES)

First, we describe the ecological resources that each Sonoma alopecurus life stage (seeds, juvenile plants, and adult plants) needs to complete each stage of its life cycle. Given the currently reduced range of the species and limited information about habitat conditions at extirpated populations, we can only describe what the species has at each extant population, which may not fully capture all of the habitat conditions the species can occupy (Gennett 2004, pp. 11–12). The complete range of conditions that favor Sonoma alopecurus remain uncertain, and further study of them is necessary.

Most of the remaining Sonoma alopecurus populations occur in freshwater wetland habitat with cattle grazing. Sonoma alopecurus is described as thriving from disturbance and is easily outcompeted by other species, particularly rhizomatous species that form thick cover, and cattle grazing typically provides the needed disturbance (Ryan and Parsons 2015a, p. 6). Research into the ideal cattle grazing has illustrated that seasonal grazing is the most effective during fall and winter, which helps to control competitive vegetation but reduces disturbance on young plants that are not yet established (Ryan and Parsons 2015b, p. 15). The marshes that Sonoma alopecurus occurs in are characterized by slow moving water or mud, either perennial or ephemeral, and sandy soil (Parsons *in litt.* 2024, Ryan pers. comm. 2024). Specifically, at PRNS, populations occur in grazed coastal prairie and in dune swale wetlands; the Ledson Marsh population occurs in a freshwater marsh formed by the construction of an earthen dam.

As a freshwater marsh obligate, all Sonoma alopecurus life stages need moist soil to germinate, grow, and reproduce. Additionally, all life stages require suitable nutrients for growth, but the specific nutrient composition is unknown. Cattle grazing may simultaneously add nutrients to wetlands while lowering soil nitrate levels, and seasonally grazed plots have been observed to host the greatest number of inflorescences (Ryan and Parsons 2015b, pp. 13–14). It is also hypothesized that higher soil nitrate levels can promote the establishment of competing plant species, thus reducing space for Sonoma alopecurus (Ryan and Parsons 2015b, pp. 13–14, Cui et al. 2023, p. 7).

Seeds need bare soil and light for germination. In occupied marshes, bare ground is often the result of grazing, but other disturbances (e.g., fire) may be effective (Ryan and Parsons 2015a, p. 6). Light is also needed for growth of established plants, though more light is needed for seeds than mature plants (Gennett 2004, p. 73). Juvenile and adult plants also need sufficient space to access light and nutrients (Ryan and Parsons 2015b, p. 13).

Plants that co-occur and may compete with Sonoma alopecurus include sedges (*Carex* sp.), common rush (*Juncus effusus*), water parsley (*Oenanthe sarmentosa*), spring monkeyflower (*Erythranthe guttata*), weak mannagrass (*Torreyochloa pallida*), spikerush (*Eleocharis macrostachya*), coastal brush lupine (*Lupinus arboreus*), coyote brush (*Baccharis pilularis*), thimbleberry (*Rubus parviflorus*), Marsh pennywort (*Hydrocotyle* sp.), fowl mannagrass (*Glyceria* sp.), panicled bulrush (*Scirpus microcarpus*), common velvetgrass (*Holcus lanatus*) and rabbitfoot grass (*Polypogon monspeliensis*) (Parsons *in litt.* 2024, Parsons 2024, pp. 3, 8).

3.2 POPULATION NEEDS

Here we evaluate what influences Sonoma alopecurus population resiliency, or their ability to withstand stochastic events or fluctuations in environmental conditions. The measure of resiliency is based on a population's ability to withstand and recover from environmental or demographic events, such as population declines and changes in the availability of resources. The factors that populations need to be more resilient are influenced by the presence of resource and habitat characteristics that correspond to the needs of Sonoma alopecurus individuals.

More resilient Sonoma alopecurus populations have larger populations, positive or stable growth rates, or other demographic factors that facilitate recovery from random events. Stochastic events that may affect Sonoma alopecurus include drought, fire, and extreme weather events, such as atmospheric river events that result in flooding (see *4.1 Threats*).

Each Sonoma alopecurus population requires a wetland that, seasonally to perennially, contains open, slow-moving water (Gennett 2004, p. 11). The wetland soil may need to sustain a minimum of 8% soil moisture, as no plants have been found in soils with less than that amount of moisture (Ryan and Parsons 2015b, p. 14). Populations can also be found in small gaps in marshes that are vegetated and poorly-drained (Gennett 2004, p. 11). Given the differences in habitat types among populations, PRNS biologists hypothesize that the species may exhibit alternate stable habitat states, contrasting populations in dune swale habitats with sandy soils and more gently-sloped habitats with clay-rich soils (Parsons 2024, p. 30). For populations in sandier soil, such as dune swales, modeling has shown a positive relationship between fall and winter rainfall and inflorescence counts (Parsons 2024, pp. 28–29). This relationship may be mediated by grazing, such that if there isn't a large amount of winter rain but grazing is substantial enough to suppress competitors, inflorescence counts in the following year may still be high. Alternatively, for populations in soils with higher water-holding capacity, winter rainfall may result in excessive ponding and therefore be detrimental to the plants. However, Sonoma alopecurus often occurs in standing water, suggesting more research is needed regarding habitat tolerance (Ryan pers. comm. 2024).

For a population to be sustained, sufficient bare ground is needed for germination, and disturbance is needed to relieve pressure from competing plants, both native and non-native. That disturbance is most often found in the form of grazing, but hand pulling of vegetation may be used to mimic some degree of disturbance, and fire may temporarily create adequate disturbance for species emergence (Gennett 2004, p. 60, Freeman *in litt*. 2024). Table 2 summarizes the resiliency needs of the species that are feasible to monitor, and metrics that could be used for this analysis to evaluate each of those resiliency needs.

Table 2. Individual and population factors considered when assessing current and future conditions.

Factors	Need for Resiliency	Metric
Population size	Sufficiently large population size to withstand periodic population crashes and avoid inbreeding depression or loss of genetic variation.	Number of inflorescences
Disturbance	Disturbance induces the space needed for seeds to germinate and for juvenile and adult plants to grow without excessive competition	Grazing regime

3.3 SPECIES NEEDS

We evaluated the species' needs in terms of the redundancy and representation of the species. We assessed redundancy based on the number of Sonoma alopecurus populations, and their distribution across the range, relative to potential catastrophic events (Smith et al. 2018, p. 306). As a species, high redundancy for Sonoma alopecurus would mean several highly resilient populations distributed across the current and historical range of the species. Having multiple resilient populations distributed widely across the species range would spread the risk of a catastrophic event that adversely affects multiple populations (Table 3).

We assessed representation based on the extent of ecological, morphological, physiological, behavioral, and genetic diversity across populations, as well as on the extent of genetic interconnectedness between those populations, allowing the species to adapt to longer-term environmental changes (Smith et al. 2018, p. 306). For such adaptation to take place, any genes that happen to be beneficial under the new conditions must be able to travel between populations. This means Sonoma alopecurus populations need to be close enough together for some gene flow via wind pollination or seed dispersal. For seeds to transfer among populations, connectivity via water (i.e., streams) is likely needed, and although pollen may be able to move among populations, the functional distance of connectivity via seed and pollen is currently unknown. At present, Sonoma alopecurus populations are suspected to be reproductively isolated (Ryan and Parsons 2015a, p. 10). Viable representation would also mean multiple resilient populations representing both alternate states in sandy dune swales and clay-rich marshes, to represent ecological diversity.

Table 3. Species-level needs. Redundancy and representation are species-level metrics that, combined with the population-level metric of resiliency, support the viability of the species. Redundancy spreads risk among multiple populations or areas to minimize the risk due to catastrophes or large-scale, high-impact events. Representation uses diversity and genetic interconnectedness as a proxy for adaptive capacity (Smith et al. 2018, p. 306).

Species-Level Needs	Summary	Details
Redundancy	Resilient subpopulations distributed across geographical areas reduces the influence of catastrophic events.	Widespread enough to ensure all subpopulations are not exposed to a single or series of catastrophic events.
Representation	Having healthy, genetically connected, subpopulations distributed across the breadth of genetic and phenotypic diversity, maintaining evolutionary processes.	Preserve the breadth of variation in biological traits and genetic diversity; maintain adaptability by ensuring populations occupy an array of environments.

3.4 SUMMARY OF NEEDS

To summarize the needs of Sonoma alopecurus, individuals and populations need wetlands with sufficient disturbance (e.g., grazing, fire) to expose bare soil for germination, and open space to limit competition with other plants. Precise population needs are unknown, but may differ between alternate stable states, varying in soil type, slope, moisture levels greater than 8%, and water holding capacity. For the species to have high redundancy, there needs to be enough resilient populations that are distributed across the range for the species to persist in the face of a catastrophic event that may affect multiple populations. For Sonoma alopecurus to have high representation, there needs to be resilient populations distributed widely enough to be robust to catastrophic events, that are close enough to facilitate the transfer of genetic information, enhancing the ability to adapt in the face of environmental change.

CHAPTER 4 – INFLUENCES ON VIABILITY

The following discussion provides a summary of the factors that are affecting, or could be affecting, the current and future condition of Sonoma alopecurus throughout its range, including threats and conservation actions. We use the term threat to refer in general to actions or conditions that are known to, or are reasonably likely to, negatively affect individuals of a species, or species viability. The term threat includes actions or conditions that have a direct impact on individuals, as well as those that affect individuals through alteration of their habitat or required resources. The term threat may encompass, either together or separately, the source of the action or condition or the action or condition itself. Actions taken by people to help the species avoid or minimize threats are referred to as conservation actions.

Based on the best scientific and commercial information available and our assessment across the range of the species, we assessed the following threats that we consider influential to the viability of Sonoma alopecurus:

- Habitat modification and destruction,
- Incompatible grazing,
- Vegetation competition,
- Lack of genetic diversity,
- Effects of climate change (including increasing temperatures, drought, extreme weather events, and high severity fire).

We also assessed the following conservation actions:

- Grazing management,
- Vegetation management,
- Introduction attempts,
- Land conservation.

4.1 THREATS

Habitat modification and destruction

At the time of listing, the primary threat to Sonoma alopecurus was destruction and modification of its wetland habitat due to urbanization, land use changes, or alterations in hydrology (Service 1997, pp. 55798–55803). Many of the small marshes that supported historical populations of Sonoma alopecurus likely experienced substantial, human-caused changes in land use prior to the decline or extirpation of the species. For example, Pitkin Marsh was already somewhat disturbed when the species was last seen there in 1951 (Diversity Database #15), and since then has been impacted by further effects of surrounding residential and agricultural land use on hydrology and water quality (Service 2009, pp. 14–15).

Given that the historical occurrences (except those at PRNS) appear to have been located in low-lying marshland areas in the vicinity of minor stream courses near Cotati, Sebastopol, and near the Russian River, many areas may have been subject to low density residential and vineyard development, as well as continued grazing. Any populations of Sonoma alopecurus within these wetlands were likely small and localized and could easily have been extirpated by grading and/or changes in hydrology associated with these changes in land use, including groundwater use, and urban flood control and drainage systems. Degradation or destruction of habitat due to changes in land use continues to be a threat today in much of the area for any remaining (albeit undiscovered) populations outside of PRNS. These continuing threats, as well as the separation of any remaining habitat from seed sources, likely reduce the potential for natural establishment of new populations.

Generally, lands surrounding a wetland, often termed "upland buffer," are important to wetland functions that otherwise might be impaired by sediments, nutrients, contaminants, changes in hydrology, or some other factor associated with proximity to human disturbance (McElfish et al. 2008, p. 1). Changes in these buffers can affect Sonoma alopecurus as well. For example, removal of a non-native invasive beachgrass on PRNS near (but not within) a Sonoma alopecurus population, resulted in encroachment of sand into a wetland swale where the species was found, thereby reducing habitat suitability and reproductive output (Parsons 2024, p. 21).

Stresses on wetland habitat that could otherwise support Sonoma alopecurus potentially include deleterious nutrient input, other chemical pollutants, over-grazing, general changes in water chemistry such as pH, and sediment-laden runoff. Excess sediments have a cumulative long-term effect similar to that of filling of wetlands and may also alter soil characteristics. At the time of listing, the species appeared to have "very strict" habitat requirements based on its limited distribution within PRNS and the inability to establish sustainable populations elsewhere by transplanting (Service 1997, p. 55805). Baye (2005, p. 10) postulated that relict marshes such as Cunningham and Pitkin Marsh, which support several rare plants (and supported Sonoma alopecurus historically), were originally oligotrophic (nutrient poor), which favored stress resistant, slower growing (or colonizing) species. Sedimentation, nutrient enrichment, altered hydrology, and frequent disturbance are factors that likely favor ruderal plant species with high growth rates and strong colonizing/competitive ability. These ruderal plants include several non-native species that now occur in the remaining potential habitat. Habitat modification and destruction are primarily a historical threat as all extant populations are on state or federally protected lands. The threat remains for populations and associated habitat yet undiscovered, or unmonitored on private lands. It may also be an occasional factor on public lands, such as when beachgrass removal resulted in sand encroachment and population extirpation, as discussed above (Parsons 2024, p. 21).

Incompatible Grazing

At the time of listing, 7 of the 8 then-known sites of Sonoma alopecurus were currently grazed or had been grazed in recent years by cattle (CNDDB 2020, Norris, *in litt.* 1995, R. Soost, *in litt.* 1996). The listing rule also stated that some grazing may be necessary to maintain populations of Sonoma alopecurus in the face of competition from other plants but noted that excessive grazing by cattle can adversely impact the species (Service 1997, pp. 55793, 55800). Further study since listing supports that hypothesis by showing that too much or too little grazing may be detrimental to a population. PRNS populations P1, P2, and part of P5 were extirpated after installation of fences that prevented cattle grazing (Parsons 2024, pp. 18–22). Early attempts to transplant the species within PNRS to potentially suitable habitat proved unsuccessful (Gennett 2004, pp. 27–33). This may have been because of drought or insufficient water and nutrients, but it may also have been caused by overgrowth of other vegetation resulting from minimal or no grazing at those locations.

Grazing activities may result in trampling of individual plants, soil compaction, and other impacts that may enhance the presence of invasive species. Overgrazing of foliage could limit the plant's ability to photosynthesize, which could result in death or diminished reproductive output. Consumption of inflorescence or seed could decrease the overall reproductive output of the individual plant. Trampling may reduce the plant's reproductive output by breaking immature inflorescences before fruit ripening. Alternatively, trampling may scarify seed present in the soil, which would be beneficial to recruitment into the population. Soil compaction may affect water infiltration, the ability of roots to penetrate the soil, and the ability of seedlings to establish. These effects have not yet been examined for Sonoma alopecurus.

Finally, following recent litigation, it is possible that the retirement of some commercial grazing operations will occur at PRNS, although it is also possible that conservation grazing could continue in areas with Sonoma alopecurus through a new grazing program (Parsons pers. comm 2024). Although PRNS supports populations of native Tule elk, there is concern that they don't graze like cattle and may not be sufficient to 1) create the disturbance needed for seed germination, and 2) counter competitive species, particularly non-native species, such as velvetgrass (Parsons pers. comm. 2024).

Vegetation Competition

Recent evidence supports that Sonoma alopecurus is threatened by competition (Parsons 2024, p. 10). Two non-native grasses (common velvetgrass and rabbitfoot grass) were negatively correlated with Sonoma alopecurus at PRNS sites and may be excluding Sonoma alopecurus at some locations (Parsons 2024, p. 8). Panicled bulrush was found to increase in the absence of grazing (thereby crowding out Sonoma alopecurus), and then decline when grazing was reintroduced (Parsons 2024, p. 8). For example, the lower portion of PRNS P5 was eliminated in 1987 following fence installation which precluded grazing, resulting in that portion of the site becoming dominated by bulrush. In 2009, the fence was relocated to expose the formerly occupied area to grazing, reducing bulrush, and Sonoma alopecurus was observed again in 2010 after an absence of 22 years, and abundance expanded again by 20-fold in 2011 (Parsons 2024, p. 22). Although the mechanism of reemergence in this area is unknown (e.g., long-lived seed bank, seed dispersal), the reduction in competition from bulrush likely released competitive pressure. The Diversity Database (2020) also lists velvetgrass as an associated species with mention of threats of competition or invasive species for two other occurrences on PRNS in addition to P5 (Diversity Database #14 and #20).

Several examples of potential competition have also been observed at Ledson Marsh. In 2010, velvetgrass was sufficiently abundant to warrant control attempts by hand removal (Herrick *in* *litt*. 2010). The native water fern (*Azolla filiculoides*) has also increased tremendously in recent years (Ryan *in litt.* 2010), and while it is not clear that there has been a direct effect of the species on Sonoma alopecurus, it does fix nitrogen and may contribute to changes in marsh chemistry (Bhuvaneshwari and Singh 2015, p. 523). In addition, emergent plants such as cattail and bulrush appear to have increased at Ledson Marsh at the expense of shallow open water habitat of the type occupied by Sonoma alopecurus (Howald *in litt*. 2015).

Lack of Genetic Diversity

All remaining populations of Sonoma alopecurus are small, and many are frequently less than 200 individuals (Table 1). Populations that are continually small or that occasionally fluctuate to small sizes (e.g., undergo population bottlenecks) may be subject to increased genetic drift and inbreeding (Ellstrand and Elam 1993, p. 220; Zackay 2007, p. 3). Increased homozygosity of deleterious alleles resulting from genetic drift and inbreeding may lead to a loss of fitness (ability of individuals to survive and reproduce) in small populations. Additionally, reduced genetic variation in small populations may make any species less able to successfully adapt to future environmental changes (Ellstrand and Elam 1993, p. 224). Populations with low rates of population growth and short lifespans also exhibit greater sensitivity to environmental stochasticity (Menges 1992, p. 265).

Various failed attempts to reintroduce Sonoma alopecurus are discussed below (see *Conservation Actions* section). No one has yet been able to establish clearly viable, persistent populations of Sonoma alopecurus by means attempted thus far (outplanting, transplanting, or free-seeding). This difficulty exacerbates the effect of chance extinction events because there is no proven means of intervention to reintroduce the species to areas in which it has been lost. Sonoma alopecurus populations are suspected to be reproductively isolated, and resistance to introduction also decreases the ability to bridge population gaps to increase gene flow (Ryan and Parsons 2015a, p. 10).

Effects of Climate Change

An additional threat to the species noted since listing is the resulting effects of climate change. Even modest increases in average temperatures could result in a reduction of the spring snowpack, earlier snowmelt, more runoff in winter, and reduced runoff in spring and summer. The result will be more winter flooding, and drier summer soils (Diffenbaugh et al. 2015, p. 3935; Ackerly et al. 2018, pp. 17–24). The predicted impacts on California's ecosystems projected with a high certainty include: higher sea level; decreased suitable habitat for many terrestrial species as climate change intensifies human impacts; increased wildfire activity; and increased competition among urban, agricultural, and natural ecosystem uses (Wilson et al. 2016, p. 1; Ackerly et al. 2018, pp. 13, 27, 31). Although the specific effects of climate change on Sonoma alopecurus are unknown, the effects of increased winter flooding and drought conditions in the spring have the potential to adversely affect populations of this species based on studies of other varieties of the species overseas (Kaneko and Nakamura 2011, p. 387). In general, wetland plants such as Sonoma alopecurus would be expected to be more sensitive to drought conditions.

Predictions suggest that Point Reyes will receive increased rainfall, more intense and frequent El Niño events, and a rise in sea surface temperature (National Park Service 2019, p. 267). Sea level is projected to rise 2.5 to 3.5 feet (0.76 to 0.91 meters) by 2100 at PRNS (California Ocean Protection Council 2018, p. 54), which will result in shoreline erosion, saltwater intrusion into groundwater aquifers, inundation of wetlands, and modification of estuaries. Research shows one half of the park's coastline is highly vulnerable to these effects based on six variables: geomorphology, historical shoreline change rate, regional coastal slope, relative sea level change, mean significant wave height, and tidal range. This area of vulnerability includes several lower elevation populations of Sonoma alopecurus, which could be lost because of changes in these variables.

Wet grasslands and rangelands may also be more susceptible to fire following droughts (Joyce et al. 2016, p. 4), and large, severe fires have occurred in proximity to areas occupied by Sonoma alopecurus (Ackerly et al. 2018, p. 29). In addition to potentially directly impacting individuals and the soil seed bank, depending on the severity of the fire, fire-adapted or non-native plant species may become more prevalent following fires (Joyce et al. 2016, p. 9). The extent of the effect an increase in fire would have on Sonoma alopecurus is unknown but has the potential to be a threat under certain circumstances.

4.2 CONSERVATION ACTIONS

Grazing Management

Although incompatible grazing is listed above as a threat, grazing management is one of the primary management tools that has produced positive results for Sonoma alopecurus. PRNS has conducted several conservation actions involving grazing management. In 2002, PRNS acquired a 522-acre parcel of inholding land that was previously owned by AT&T and includes the location of PRNS P3. Although the gate remained open to cattle during the ideal grazing windows, use of the area was limited by a lack of water for the cattle. Sonoma alopecurus declined at the location until watering troughs were provided for the cattle in 2008. Additional cattle were moved to the location in the winter of 2010–2011, increasing the grazing activity further, and leading to additional increases in Sonoma alopecurus numbers (Parsons 2024, p. 5).

In October 2007, PRNS received private funding to address a section of the Abbotts Lagoon trail that borders population P5. In 1987, this trail had been formalized by installing a cattle-exclusion fence across the upper section of the drainage. After the installation, the lower portion filled in with panicled bulrush. In 2008, the former trail was closed, and the existing trail infrastructure was removed. In an effort to expand P5 and to reestablish Sonoma alopecurus plants in the lower portion of the drainage in the cattle pasture, fencing was moved downstream to re-expose the area to grazing (Parsons 2024, p. 5). Sonoma alopecurus has returned to that area, and the competitor bulrush has declined (see Vegetation Competition, above; Parsons 2024, p. 7).

Grazing, at appropriate times and in appropriate levels, reduces competition from more abundant or invasive species. All natural populations of Sonoma alopecurus within the PRNS are currently managed by grazing at varying levels (Parsons 2024, p. 4).

The population at Ledson Marsh, outside of PRNS, is the only population not associated with grazing.

Vegetation Management

In 2008, with financial assistance from the Service, PRNS installed seven groundwater monitoring wells around one population, and conducted monitoring of Sonoma alopecurus populations and other plants in the community in relation to groundwater and presence of grazing through 2011 (Parsons 2024, pp. 7–8). Presence of Sonoma alopecurus was not related to groundwater level (except the species was absent in the driest areas), new individuals were found in a newly grazed area for the first time in two decades, and abundance of the species was negatively correlated with non-native perennial grasses.

In June 2010, biologists noted dense stands of velvetgrass on the upper margin of Ledson Marsh, adjacent to shallow water areas that are habitat for Sonoma alopecurus. In 2010, only 4 Sonoma alopecurus individuals were counted in a census of Ledson Marsh (Herrick *in litt.* 2010). A work crew was organized by a California State Park resource ecologist to hand pull the velvetgrass and an invasive mint (*Mentha pulegium)* in shallow water habitat that Sonoma alopecurus had occupied in recent years (Ryan *in litt.* 2010). Removal of velvetgrass by hand has been conducted several times since 2010 (Howald *in litt.* 2014). In 2014, the marsh edge adjacent to Sonoma alopecurus habitat was cleared of velvetgrass, after which the area previously occupied by velvetgrass was colonized by a native species of spikerush (*Eleocharis* sp.) which has not been indicated as a negative competitor. Hand-pulling of velvetgrass has occurred in most, but not all, subsequent years (McDermott *in litt* 2018, Freeman pers comm 2024).

Introduction Attempts

Three introduction attempts have been made for Sonoma alopecurus at sites near existing or former populations at PRNS.

In 1987, introduction was attempted at three locations, mostly by transplanting from a source population and once by seed. These all failed within 1–2 years, and no germination from seed was noted. A summary of the 1987 work by Gennet (2004, pp. 26–33) suggests several causes of this failure: too much or too little grazing, overgrowth by weeds and shrubs, or prior alteration of hydrology that made a site unsuitable.

In 2002, Gennet (2004, entire) transplanted greenhouse stock grown from seed into 4 more sites, which were selected to best match the conditions of naturally-occurring populations of Sonoma alopecurus but varied to some degree in grazing use and hydrology. Additionally, some plots were clipped to mimic grazing. Three of these sites (populations P9, P10, and P12) persisted for two years before dying out completely (Parsons 2024, pp. 27–28). One site (P11) persisted for 5 years until 2008. In 2014, two plants (11 inflorescences) were found at the P11 location. Following the 2014 sightings, no plants were found at this site until 2024, when another 4 inflorescences were discovered (Park Service, 2025, p. 19). We consider the population to remain extant at this time based on the demonstrated potential to produce new plants after several years of negative surveys.

The third introduction attempt began in the winter of 2014 with the transplanting of Sonoma alopecurus at three sites that were chosen using a complex model characterizing the biotic and abiotic factors present at occupied locations (Ryan and Parsons 2015a, p. 19). Two of those transplanted sites failed the first year, but the third (P15) produced 1,351 inflorescences in the first year. Unfortunately, the number of inflorescences dropped off precipitously in subsequent years: from 1,351 to 291, to 35, to only 4 in 2018, which is the most recent year for which we have positive sightings. Although Sonoma alopecurus introduction attempts to date have not proven successful long-term, each has provided valuable information to inform future efforts.

Land Conservation

There have also been conservation actions in other wetlands that historically supported Sonoma alopecurus, but in which it has not been seen recently. In 1998, the California Department of Fish and Game recorded a permanent conservation easement on 19 acres of Cunningham Marsh and 2.3 acres of adjacent upland (the "southern" marsh, *in* Service 2009, pp. 15–16). In 2007, the Sonoma Land Trust purchased a 27-acre portion of Pitkin Marsh for conservation (the "northern" marsh, *in* Service 2009, p. 15). Gennet (2004, p. 7) mentions that there is a possibility that Cunningham Marsh supports Sonoma alopecurus, although it has not been seen there since 1987. The Sonoma County Agricultural Preservation and Open Space District holds some easements in Pitkin Marsh and other locations with possible habitat for the species. The Marin Agricultural Land Trust has created 46,000 acres of conservation easements (many of which were established since the listing of Sonoma alopecurus) that prohibit non-agricultural uses. Some of these lands may include small wetlands which may harbor undiscovered populations of Sonoma alopecurus. The Sonoma Land Trust has about 13,000 acres of protected land, which could include other wetlands with potential to support the species. No survey information is available currently on the extent of such wetlands or presence of listed species in these trust-protected areas. Park lands include the Ledson Marsh occurrence and other areas with unsurveyed wetlands.

4.3 SUMMARY OF FACTORS INFLUENCING VIABILITY

In summary, the primary threats currently impacting Sonoma alopecurus are 1) destruction and modification of its wetland habitat due to urbanization, land use changes, alterations in hydrology, nutrient regimes, or sediment regimes, 2) lack of and/or incompatible timing and intensity of grazing, 3) vegetation competition, 4) lack of genetic diversity and 5) effects of climate change. Destruction and modification of wetland habitat is primarily a historical threat that resulted in the loss of several known populations and includes conversion of land into residential and agricultural land (e.g., grazing, vineyards). If Sonoma alopecurus occurs in areas outside of Point Reyes National Seashore and Ledson Marsh, those populations are likely still threatened by habitat degradation and destruction, but threat levels are unknown. Grazing can be a threat if allowed during sensitive time periods, such as seedling establishment, and population introduction attempts can be thwarted by areas fenced off from cattle, wherein trampling or overgrazing of seedlings can lead to losses.

Finally, following recent litigation, it is likely that the retirement of some commercial grazing operations will occur at PRNS, although it is possible that conservation grazing could continue in areas with Sonoma alopecurus through a new grazing program (Parsons pers. comm 2024).

Competitive exclusion by both native and non-native vegetation currently threatens the species at all populations, so removal of cattle grazing at Point Reyes National Seashore would tend to increase impacts from competitive exclusion throughout almost the entire known range (other than Ledson Marsh). The species is likely threatened by a lack of genetic diversity resulting from small population sizes and limited exchange of genetic information among populations; however, the extent of remaining genetic diversity and genetic interchange remains uncertain. Finally, the species may be affected by the impacts of climate change, such as increased temperatures leading to longer and more intense droughts and more prevalent fires, and increased variability in precipitation leading to occurrences of localized flooding.

Conservation actions that positively influence the viability of Sonoma alopecurus include 1) land conservation, 2) grazing management, 3) introduction attempts and 4) vegetation control. Although not expressly for the purpose of conserving Sonoma alopecurus, all known, currently extant populations of Sonoma alopecurus are on state or federally owned land and therefore are not currently at risk of land conversion due to development, but past occupied areas could be considered for future introduction attempts or resurveyed in the future. At Point Reyes National Seashore, P3 and P5 have fencing to allow the populations to undergo targeted grazing during the fall and/or winter with the intention of inducing disturbance for the species, although P5 does not appear to have been grazed at sufficient levels in recent years. Three known introduction attempts have occurred, and, although two introduced populations remain extant at low numbers, none have yet demonstrated long-term success.

CHAPTER 5 – CURRENT CONDITION

The following discussion provides a summary of our analysis of the past and ongoing changes in a species' habitat, demographics, and distribution (Smith et al. 2018, p. 306), including the effects of imminent and near-term threats. To assess the current condition of Sonoma alopecurus viability, we used the best scientific and commercial data available to analyze and describe past and ongoing changes in the species' habitat, demographic parameters, and distribution at the population scale. The methods and results of our assessment of current condition are described below.

5.1 SUMMARY OF METHODS

We assessed current condition of Sonoma alopecurus in terms of the conservation biology principles of resiliency, redundancy, and representation. Sonoma alopecurus resiliency, or having sufficiently robust populations for the species to withstand stochastic events, is a function of the health of each population. We defined populations as element occurrences in the Diversity Database or occurrences designated by PRNS if not in the Diversity Database, that have presumed suitable habitat and have had at least one inflorescence observed in the last ten years. To categorize resiliency of each population, we then evaluated the average of the last five inflorescence counts and the current disturbance regime, usually grazing, to designate a current condition of high, moderate, or low.

Sonoma alopecurus redundancy and representation were evaluated at the species scale. Redundancy, or the ability of the species to withstand catastrophic events, was determined by the number, distribution, and resiliency of populations across the current occupied range. Representation, or the ability of the species to adapt to change, was determined by the current diversity of ecological conditions and genetic diversity across the species' range.

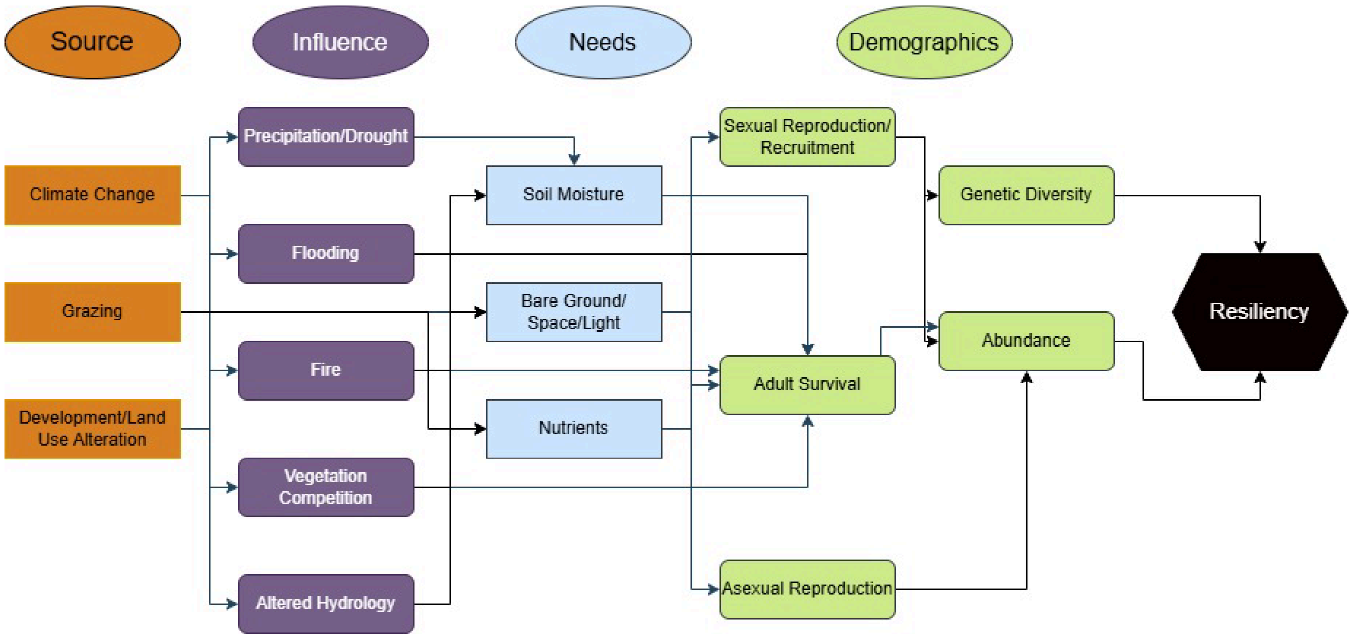

Figure 4. Sonoma alopecurus core conceptual model evaluating species resiliency.

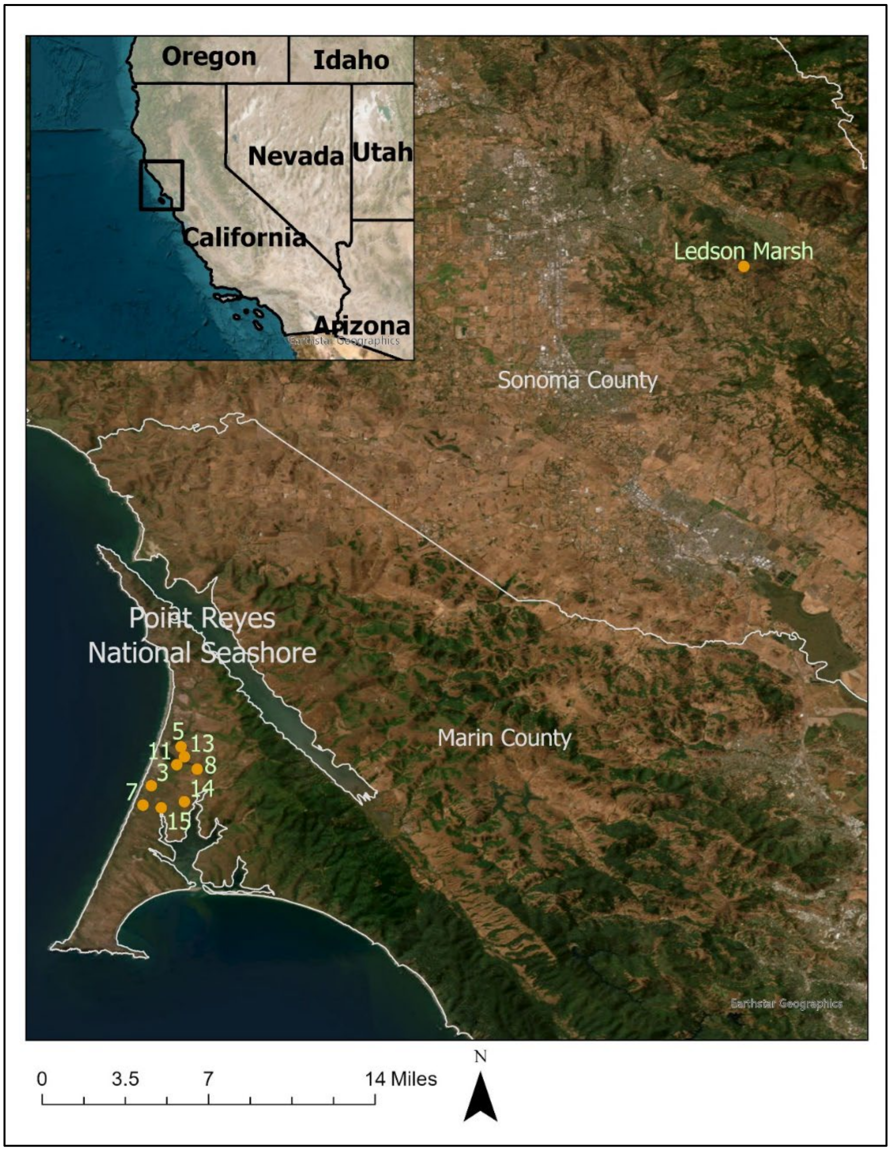

Figure 5. Map of extant Sonoma alopecurus populations. Point Reyes National Seashore numbers are labeled according to the number assigned by the PRNS, and the Ledson Marsh population is labeled as such.

5.2 CURRENT RESILIENCY

Methods

To evaluate the current status of Sonoma alopecurus resiliency, we developed a condition category table to assess the individual and population needs for each population. We determined the overall resiliency rating for each population by averaging the scores assigned to individual and population needs, where 'low' is scored as 1, 'moderate' as 2, and 'high' as 3. Populations were scored based on the average number of inflorescences as an indicator of the population size and also based on the population's current disturbance regime.

The Diversity Database defines a population as occurrences separated by 0.25 mi (0.40 km) when a biologically informed distance is unknown (CNDDB 2020, p. 10). We use that methodology here to define Sonoma alopecurus populations. Each population also has varying trends, management regimes and potentially stable habitat types, making populations appropriate for separate consideration (Parsons 2024, p. 30).

Stochastic events that may affect Sonoma alopecurus include drought, fire, and flooding caused by severe weather events. Having a high number of individuals buffers a population against stochastic events by increasing the likelihood of a robust soil seed bank and the chance that individuals will survive.

Population Size

Population size in Sonoma alopecurus is historically variable, but an adequate number of individuals is needed in each population to maintain genetic diversity, and to reduce extinction risk and ensure resiliency. Minimum viable population size (MVP) is the number of individuals in a population above which the risk of extinction is low (Menges 1992, p. 255). MVP varies depending on the species in question, but requires long-term, high-quality data sets for accuracy (Flather et al. 2011, p. 307). To develop the minimum viable population size by which to evaluate current conditions of Sonoma alopecurus, we used two rare plant minimum viable population studies to dictate the upper and lower bounds within and above which a species would likely remain resilient to environmental stochasticity. Pavlik (1996, p. 137) outlined a continuum of characteristics that inform MVP for rare plants, which we evaluated relative to Sonoma alopecurus. Sonoma alopecurus exhibits life history characteristics on both ends of the sensitivity spectrum, with more characteristics on the lower MVP end of the spectrum (Table 4). We therefore use 1000 individuals (mid-way between 50 and 2500 but closer to 50), as an estimate of a population size above which a population would be in 'high' condition.

To identify the population size below which a population would be in 'low' condition, we used a study by Menges (1992, entire) relating population size with extinction risk given environmental stochasticity. This study indicated populations of 200 or fewer individuals have a high extinction risk from environmental stochasticity (Menges 1992, p. 270). Therefore, we consider 200 individuals or fewer to be a population in 'low' condition. Populations between 200 and 1000 individuals represent 'moderate' resiliency.

When monitoring Sonoma alopecurus, inflorescences are counted rather than individuals because the rhizomatous nature of the species makes distinguishing individual plants difficult. For example, prior analysis of PRNS population abundance measured in this way revealed significant correlation with climatic variables, but with varied directional responses by individual populations (Parsons 2024, pp. 28–30). It is typical for a single plant to have multiple inflorescences (e.g., average of 3.4 and 4.3 inflorescences per plant for PRNS P13 and P5, respectively) (Ryan and Parsons 2015a, p. 13), and we used the average of 3.4 inflorescences per plant from PRNS P13 as a conservative estimate and multiplied it by the upper (1000) and lower (200) MVP bounds, resulting in inflorescence counts of 3400 or more representing high resiliency, and counts of under 680 representing low resiliency (Table 6). To evaluate current condition, we used an average of the last five inflorescence counts (including years where zero were seen), given the inherent variability in population size among years.

Table 4. Pavlik (1996) life history characteristics of rare plant MVP, where bold traits indicate the characteristic exhibited by Sonoma alopecurus.

Life History Characteristics	50 individuals	2500 individuals
Longevity	perennial	annual
breeding system	selfing	outcrossing
growth form	woody	herbaceous
Fecundity	high	low
ramet production	common	rare or none
survivorship	high	low
seed duration	long	short
environmental variation	low	high
successional status	climax	seral or ruderal

Disturbance Regime

Given the apparent importance of disturbance to this species, primarily in the form of grazing, we further evaluated resiliency based on the current disturbance regime for each population. Hand-pulling vegetation, water level moderation, and fire have relatively unknown effects on this species, so these disturbances were not considered for the current condition assessment. The ideal grazing regime for resilient Sonoma alopecurus populations appears to be high intensity grazing during the fall or winter (Ryan and Parsons 2015b, p. 15). We classified seasonal grazing during the fall and winter as the 'high' resiliency condition. We considered a population with any other grazing system, such as continuous availability throughout the year, to be in 'moderate' condition, as in most cases grazing is occurring at a low intensity in those areas and therefore acts beneficial rather than detrimental, and no grazing or evidence of overgrazing was considered 'low' condition.

Condition Categories

We used a condition category table approach to evaluate the overall resiliency for each population. We averaged the scores (low = 1, moderate = 2, and high = 3) of average population size and disturbance categories across each population, weighting the number of inflorescences double that of the disturbance from grazing, because population size is directly affected by a wider variety of possible influences (Table 5).

Table 5. Condition category table for evaluating the current condition of Sonoma alopecurus. Number of inflorescences was weighted twice that of the base score of the condition category.

Condition Category	Average Number of Inflorescences over last 5 Survey Years	Disturbance from Grazing
High (3)	> 3400	Seasonally appropriate grazing (fall/winter)
Moderate (2)	681–3400	Continuous grazing
Low (1)	< 680	No grazing or overgrazing

Resiliency Results

Currently, we consider nine Sonoma alopecurus populations to be extant. Historically, PRNS P3, P4 (now extirpated), P5, and P8 had the largest populations, as indicated by large counts of inflorescences (Table 6). All populations occur in wetlands, and all PRNS populations are grazed, although in varying seasons and at varying intensities. The Ledson Marsh population is not grazed, but in most years velvetgrass is hand-pulled (Freeman pers. comm. 2024). In recent years, only P3 has had inflorescence counts in the thousands.

P3 is the only population currently in moderate condition, due to moderate average inflorescence counts and consistent targeted grazing in the fall/winter (Table 5). However, the 2024 growing season had around one-third fewer inflorescences than in 2023, despite ideal grazing methods, hypothesized to have been impacted by annual weather conditions (Parsons *in litt.* 2024).

Although historically a population stronghold, P5 is currently in low condition, due to low inflorescence counts in recent surveys. Although P5 has fencing to promote grazing and a historical system of fall and winter grazing, the population was overgrown and seemingly ungrazed during recent surveys (Parsons 2024, p. 22, Parsons *in litt* 2024). We therefore decided to categorize the current disturbance regime as 'continuous grazing' rather than seasonal grazing. P5 has also declined precipitously since a high count of 6561 inflorescences in 2012 (Table 6) and no inflorescences were observed when surveyed in 2024 and 2025 (Parsons *in litt.* 2024, Parsons *in litt.* 2025). This population occurs in clay soils high in nutrients and organic matter, as compared to P3 which occurs in sandy soils. Recent conditions may have been favoring the habitat type of P3 and similar populations; P3 has been experiencing an increasing inflorescence trend from 2020 to 2023 and has been exposed to consistent intensive seasonal grazing relative to other populations.

The number of inflorescences found during the most recent surveys of P7, P8, P11, P13, P14, and P15 all fall into the 'low' category (Table 5, Table 6). As habitat is still present, individuals may be persisting at zero-count populations, because individuals in poor quality may not be as obvious as high quality individuals (Ryan pers. comm. 2024). Also, given the species' propensity to rebound or reappear under the right circumstances, current resiliency at these populations may be higher than indicated by the conditions measured in this report, because of the unknown status of the soil seed bank. All of these populations were in areas leased for grazing by PRNS, placing them in a ‘moderate’ condition for the disturbance category, but ultimately in the low resiliency category (Table 5).

The Ledson Marsh population was last surveyed in 2020, at which time 117 inflorescences were counted from an estimated 15 plants and a 5-year average of 25 inflorescences (Table 6, Table 7). This population is not grazed and therefore is in low condition for both categories and ‘low’ resiliency overall. Historically, hand pulling of velvetgrass was done at Ledson Marsh, but this has not been done recently. Notes from the most recent survey indicate that the vegetation is very dense in some places, which would also make it difficult to detect small or unhealthy plants (Freeman pers. comm. 2024, Ryan pers. comm. 2024, Curry pers. comm. 2025).

We lack data to be able to evaluate the resiliency of any populations on private land in Sonoma County, but none were considered extant for the purposes of the 2011 status review (Service 2011, p. 3). None of the historical populations in Sonoma County, besides Ledson Marh, have been observed in the last ten years, and the status of the habitat at most sites is unknown (Table 1).

Table 6. All survey data for extant Sonoma alopecurus populations, encompassing data used to evaluate current condition, which includes the last ten years of surveys for each population. Blanks indicate the population was not surveyed in that year, whereas zeros indicate no inflorescences were located.

PRNS Population	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
3	406	311	996	534	1698	815	527	717	2460	722	2269	125	309	2525	3609	960	990
5	203	310	1183	6561	1643	2750	601	543	716	183	277		17	441		0	0
7	4	18		0	0	0	15	0		0	0		0				
8		2471	1655	891	476	90	2	52		126							
11	0	0	0	0	0	11	0		0		0					4	0
13			732	859	376	327	218	170	210	24	57		16	0		0	0
14						788	16	19	357		236	9	350			0	0
15							1351	291	35	4	0		0				
Ledson Marsh	150	7	0	600	0	0	54	0	0	8		117					0

Table 7. Current condition of extant Sonoma alopecurus populations.

Population	Number of inflorescences (average of last 5 counts)	Grazing (i.e., space, competition, and bare ground)	Condition
P3	1678	Yes, Seasonal	Moderate
P5	147	Yes	Low
P7	3	Yes	Low
P8	149	Yes	Low
P11	1	Yes	Low
P13	15	Yes	Low
P14	119	Yes	Low
P15	66	Yes	Low
Ledson Marsh	25	None	Low

5.3 CURRENT REDUNDANCY

Redundancy is limited for narrow endemic species that have naturally small ranges and populations small enough to be at risk from large-scale catastrophic events. For Sonoma alopecurus, high redundancy would mean multiple highly resilient populations across a large area (ideally in both Sonoma and Marin counties), and low redundancy would mean few clustered populations currently with low resiliency. Relative to the historical condition of Sonoma alopecurus, there are few extant populations on the landscape. The status of several previously documented populations is currently unknown because they are on private lands where we are unable to conduct surveys. Eight of the nine populations presumed to be extant are in an area of Point Reyes National Seashore that only spans 2.65 miles (4.23 km).

Potential catastrophic events that could impact the species include extreme drought, replacement-level fires, and flooding from extreme weather events such as atmospheric rivers. A single fire could impact every population at PRNS simultaneously; however, given the reemergence of Sonoma alopecurus after the Nuns Fire in 2017 that affected Ledson Marsh (Parsons 2024, p. 33), the disturbance generated by a large fire could be positive for the species if the soil seed bank was not destroyed. Severe flooding would be localized and dependent on the soils, slope, and elevation of each population, so it would be unlikely to cause extirpation of all populations simultaneously. Catastrophic drought, such as California has experienced in recent years (Ackerly et al. 2018, p. 6) would affect all populations simultaneously and negatively. However, Sonoma alopecurus may have a long-lived seed bank (Ryan and Parsons 2015a, p. 8) and could rebound if circumstances improved (e.g., weather, disturbance).

Given that eight of the nine presumed extant populations are in ‘low’ condition and the close proximity of the eight PRNS populations, a catastrophic event could impact most of the populations simultaneously, including the only moderate condition population. Therefore, the species currently has low redundancy, due to the high likelihood that most populations are simultaneously at threat of extirpation from catastrophic events.

5.4 CURRENT REPRESENTATION

Genetic studies have not been conducted for Sonoma alopecurus, however populations are assumed to be reproductively isolated (Ryan and Parsons 2015a, p. 10). There are limited stream connections for seeds to move among populations at PRNS, and the dispersal distance of pollen in this species is unknown but unlikely to be substantial enough for meaningful genetic transfer (U.S. Geological Survey 2019). The Ledson Marsh population is likely genetically dissimilar from the PRNS populations, given the different environmental conditions of the population (notwithstanding the potential for a different taxonomy). However, this population is likely also reproductively isolated, given there is a high degree of separation (approximately 27.4 miles (44.1 km)) and development between the two core areas creates an inhospitable barrier to dispersal (Figure 5).

Sonoma alopecurus likely has naturally low adaptive capacity, although most measures of adaptive capacity are unknown (Thurman et al. 2020, p. 522). We know that Sonoma alopecurus has high reproductive potential, given a high volume of seed production (Gennett 2004, p. 66). However, Sonoma alopecurus occupies, both historically and currently, a narrow climatic niche breadth, primarily in the fog belt of the Bay Area of California in a Mediterranean climate. Within that narrow climate, the species appears to have a high degree of habitat specialization based on the challenge to introduce it into apparently suitable habitats. The species also has a small extent of occurrence (approximately 48.3 mi^2 (125 km^2)), especially given the unknown status or extirpation of most populations in Sonoma County. Sonoma alopecurus individuals are unable to shift in space (Thurman et al. 2020, p. 522) and lack of connectivity has likely left populations highly specialized to their particular environment (Ryan and Parsons 2015a, p. 10). Based on this, Sonoma alopecurus current representation is low.

5.5 SUMMARY OF CURRENT CONDITIONS

In summary, we currently consider nine Sonoma alopecurus populations to be extant, although four have had no inflorescences detected in recent years. Of the nine populations, we consider one to have moderate resiliency and the remaining eight to have low resiliency, based on the average number of inflorescences and the current grazing management scheme. We consider the current redundancy of Sonoma alopecurus to be low, based on most populations being in close proximity and in low condition. We consider the current representation of Sonoma alopecurus to be low, based on being reproductively isolated and with low adaptive capacity. Overall, the status of Sonoma alopecurus viability is decreased from historical levels, based on the number of extirpated populations, with the soil seed bank representing an unknown variable in the consideration of species viability.

CHAPTER 6 – FUTURE CONDITION

Scenario planning is a comprehensive exercise that involves the development of scenarios that capture a range of plausible future conditions, which is then followed by an assessment of the potential effects of those scenarios on a given species. Scenarios are not predictions or forecasts of what will happen in the future for a species but are projections or explorations into the range of conditions that may exist based on current information. The scenarios are intended to provide the "upper" and "lower" bounds of plausible conditions, outline uncertainties, and provide a means for evaluating risk in current and future decisions.

6.1 SUMMARY OF METHODS

To develop future scenarios, we considered the plausible range of values for each, and the outcome of on-going conservation efforts through 2100. We selected this timeframe based on the current projections of climate predictions. We used Scenario 1 as an 'upper plausible limit' scenario, in which current trajectories of climate-change effects increase slowly and level off mid-to-late century, and we used Scenario 2 as a 'lower plausible limit scenario' in which climate change effects increase continuously. The two scenarios represent upper and lower bounds of climate projections (Representative Concentration Pathway (RCP) 4.5 and RCP8.5) and include the effects of vegetation competition and conservation efforts (Table 8).

For each scenario, a description is given of the scenario assumptions, and Table 8 presents predicted changes in stressors and threats driving Sonoma alopecurus population dynamics, using the best available projections. The overall condition was determined as described in the current condition section of the SSA, in the context of resiliency, redundancy, and representation. We considered the future conditions qualitatively, given limited capacity to precisely predict how the species will respond to varying changes in future stressors and threats.

6.2 UPPER PLAUSIBLE LIMIT SCENARIO

The upper plausible limit scenario considers the viability of Sonoma alopecurus as climate change and conservation actions continue along roughly current trends. The primary threats facing the species under this scenario are the effects of climate change and competition with native and non-native vegetation. Conservation actions will also continue at their current level, which includes targeted seasonal grazing at Point Reyes National Seashore and hand-pulling of velvetgrass at Ledson Marsh.

RCP4.5, which accounts for a moderate increase in greenhouse gas emissions from current levels, is currently the most conservative estimate for climate change recommended to use for scenario planning. Climate predictions between RCP4.5 and RCP8.5 are not drastically different for the Bay Area of California in 2100, likely due in part to moderation from coastal effects (Ackerly et al. 2018, pp. 14–21). However, we would expect the effects of climate change under RCP4.5 to be milder than RCP 8.5. Currently, under RCP4.5, average temperature may increase as much as 4–5 °C in Marin and Sonoma counties (Ackerly et al. 2018, p. 15). Under both pathways, climate models predict an increase in extreme precipitation events (Ackerly et al.

2018, p. 19), and an increase in drought severity and duration in association with rising temperatures, including hydrological drought that would affect stream flow and groundwater levels necessary to maintain freshwater marshes (Ackerly et al. 2018, pp. 22–24). Changes due to climate change may also shift grassland communities towards species adapted to warm and dry conditions, which could result in negative trends for wetland species (Zhu et al. 2024, p. 2). We do not have data to be able to precisely predict the effect of climate change on Sonoma alopecurus but instead consider the scenario from the perspective of the best available information.

The current condition of populations PRNS P5, P7, P8, P11, P13, P14, P15 and Ledson Marsh is low resiliency. With increased temperatures, increased severity and intensity of drought, and more extreme weather, those eight populations are likely to remain in a state of low resiliency, as those conditions would not improve the habitat of those populations. In this scenario, the grazing regime will remain in the current status, which may help to mitigate some climate driven effects, such as by reducing vegetation competition in years of drought (Parsons 2024, p. 33). It is plausible that under this scenario that resiliency for P3 could decline due to continued competition for space and nutrients with native and non-native vegetation and a decrease in soil moisture from more frequent and intense droughts ultimately decreasing population size. However, as long as targeted seasonal grazing continues, we project the population could remain at moderate resiliency.

In this scenario, the chance of drought and extreme weather events will increase, which has the potential to affect all PRNS populations simultaneously. With 8 of 9 Sonoma alopecurus populations remaining in low resiliency, and the chance of populations becoming extirpated, the future redundancy of Sonoma alopecurus will likely remain low. With the possibility of populations becoming extirpated, existing genetic diversity may be lost, and gene flow may further decrease due to an increase in distance between populations. If the populations that are extirpated are all within one habitat type, habitat specialties would also be lost. Therefore, we would expect the representation of Sonoma alopecurus under the upper plausible limit scenario to also remain low.

6.3 LOWER PLAUSIBLE LIMIT SCENARIO

The lower plausible limit scenario considers the viability of Sonoma alopecurus as the threats from climate change increase and vegetation competition increases in intensity, but conservation actions continue. We consider the threat of climate change under the RCP8.5, which may result in temperature increases as much as 7–8 °C in Marin and Sonoma counties (Ackerly et al. 2018, p. 15). The RCP8.5 also may result in larger precipitation events, with increases as much as 37%, although variability in predictions is high (Ackerly et al. 2018, p. 20). The chance of severe drought is also predicted to increase with a related increased chance of wildfire intensity and return interval (Joyce et al. 2016, p. 5). Due to both a change in the climate, and an increase in drought and/or wildfire, we could expect to see an increase in invasive non-native vegetation growth as plants with better adaptive capacity thrive (Joyce et al. 2016, p. 5). Increases in drought and/or flooding could result in the ultimate loss of shallow wetland habitat, reducing available habitat for Sonoma alopecurus. Predictions for PRNS include a possible transition of the vegetative community to shrubland or unsuitable habitat types for Sonoma alopecurus (Chornesky et al. 2015, p. 257). Finally, in this scenario, we considered the threat to Sonoma alopecurus if the current system of grazing leases is eliminated at PRNS, but that cattle could be brought in to selectively graze some populations if conservation funding was available (Parsons pers. comm. 2024). We consider that other conservation efforts would continue at their current level.

An increase in the effects of climate change in this scenario could result in decreased abundance for all populations. Increases in drought and fire, and a reduction in grazing could increase prevalence of generalist species with superior competitive ability at all populations, increasing competition for bare ground, space, sunlight, and nutrients. A loss of grazing at PRNS could further reduce disturbance of the competitive vegetation in the occupied marshes. However, even if grazing is removed entirely, it is possible cattle could be brought in to seasonally graze some of the marshes, such as P3, which could help the population maintain a seasonal grazing regime and moderate-low resiliency (Parsons pers. comm. 2024).

Although the effects of climate change on this species are ultimately unknown and variable, an increase in drought duration and intensity and temperature could increase fire risk. Fires may increase bare-ground and space in the short-term. However, in the long-term, fire could also increase the encroachment and competition with non-native invasive species, as species colonize newly disturbed land and reduce available space, particularly in the long-term, for Sonoma alopecurus (Joyce et al. 2016, p. 5). Although extreme storm and flooding events tend to favor ruderal species (Joyce et al. 2016, p. 8), there is also a chance of an increase in extended droughts (Diffenbaugh et al. 2015, p. 3931), which would reduce the groundwater available at marshes, altering the hydrology, and reducing available water necessary for soil moisture (Ryan pers. comm. 2024).

Under the lower plausible limit scenario, we predict that worsening threats due to climate change and the potential for the removal of grazing in most populations will result in one population in moderate-low condition (P3), and eight populations in either low condition or extirpated (P5, P7, P8, P11, P13, P14, P15 and Ledson Marsh). Chances of extirpation are relatively high under this scenario for at least four of those populations, given recent repeated zero-inflorescence counts and history of populations at PRNS becoming extirpated following increased competition with vegetation due to reductions or elimination of grazing.

Under this scenario, we also expect an increase in the chance of catastrophic weather events and replacement-level fires. Severe weather events and widespread severe fires could affect all the PRNS populations simultaneously, based on the size of prior fires at PRNS. Having alternate stable habitat types may result in differential impacts from climate change at different populations (Parsons 2024, p. 32). Regardless, with all but one population in low resiliency, and climate suitability reduced for the one moderate population, all populations may have the possibility of extirpation, which would result in the future redundancy under the lower plausible limit continuing as low.

Even with populations exhibiting alternate stable habitat types, which may represent genetic diversity, without regular grazing, it is likely that some populations currently in low resiliency will be extirpated, resulting in lower species-wide genetic diversity and lowered possibilities of gene flow among populations. The resistance of Sonoma alopecurus to introduction attempts could further limit the ability to bridge gaps in-between populations. In addition, Sonoma alopecurus has a history of populations becoming extirpated because of localized changes in the vegetation and grazing treatment, illustrating low adaptive capacity. Given this, the future representation of Sonoma alopecurus under the lower plausible scenario is low.

Table 8. Predicted changes in stressors, threats, and conservation actions under two plausible future scenarios for Sonoma alopecurus.

Scenario	Climate Change Effects	Vegetation Competition	Conservation Efforts (incl. grazing, prescribed fire, invasive plant removal)
1 – Upper plausible limit: Continuation of current threats	Continue	Continue	Continue
2 – Lower plausible limit: Increased Climate Effects, worsening effects	Increase	Increase	Continue

6.4 KEY UNCERTAINTIES

Climate Predictions and Grazing

Our ability to predict the condition of Sonoma alopecurus is limited due to uncertainty concerning the predictions under climate projection scenarios, and the complex trends the species exhibits given different habitat types, climatic conditions, and grazing regimes. There is a high degree of variability in climate projections, and without a better understanding of how the species responds to variation in temperature and precipitation, the potential effects of climate change will remain uncertain.

Ledson Marsh

An additional key assumption in the current and future condition analysis is that the *Alopecurus aequalis* at Ledson Marsh in Sonoma County is Sonoma alopecurus.

In 1955 and 1961, during the process of describing Sonoma alopecurus as a unique taxon, Peter Rubtzoff made collections of *Alopecurus* plants at Ledson Marsh (Bartosh 2018, p. 9; Howald 2016, p. 3). Rubtzoff identified the specimens from Ledson Marsh as shortawn foxtail (*Alopecurus aequalis* var. *aequalis*), the more common variety that is conspecific to the Sonoma alopecurus. Rubtzoff identified Sonoma alopecurus only in Marin County and on the west side of Sonoma Valley; the Ledson Marsh population, however, is on the east side of the Sonoma Valley (CNDDB 2025, unpaginated).

The two *Alopecurus aequalis* varieties are morphologically similar, but Sonoma alopecurus grows more robust and upright with a broader panicle, violet-gray tinged spikelets, and longer awn (Service 1997, p. 55793). To most accurately differentiate between the two varieties, the Jepson Manual has identified ranges of measurements for four key features: inflorescence width, glume length, anther length, and the difference between awn and lemma length (Jepson 2025, unpaginated). Measurements for three of these features (inflorescence width, glume length, and anther length) can overlap between Sonoma alopecurus and shortawn foxtail.

In 2000, Sonoma alopecurus was identified at Ledson Marsh in two subpopulations, one in shallow water habitat of the marsh and one on the shoreline of the marsh (Howald 2016, p. 2). Sonoma alopecurus was also identified within the same subpopulations in 2001 (Howald 2016, p. 2). Subsequent recorded observations of Sonoma alopecurus occurred at Ledson Marsh in 2007, 2009, 2010, 2012, and 2015 (Howald 2016, pp. 4–5). The 2011 status review described the population as the only known extant population of Sonoma alopecurus in Sonoma County (Service 2011, pp. 1, 4).

In 2018, two plants with nine inflorescences were located during a survey at Ledson Marsh. The survey report indicated these plants may be shortawn alopecurus due to certain features not matching those in Sonoma alopecurus (Bartosh 2018, pp. 8–9). Based on the measurements observed in these plants, some individuals displayed traits associated with Sonoma alopecurus, shortawn alopecurus, or both, as summarized in Table 9. These discrepancies in characteristics create ongoing uncertainty in the final identification of the Ledson Marsh population.

Table 9. Comparison of measurements from the *Alopecurus* plants at Ledson Marsh to the Jepson Manual dichotomous key characteristics for Sonoma alopecurus (*Alopecurus aequalis* var. *sonomensis*) and shortawn alopecurus (*Alopecurus aequalis* var. *aequalis*) (Jepson 2025, unpaginated).

Characteristics of plants at Ledson Marsh	Matches Sonoma alopecurus?	Matches shortawn alopecurus?	Comments
Inflorescence widths: 3–4 mm	Yes	Yes	Inflorescences measuring 3 mm in width correspond exclusively to the description of shortawn alopecurus, whereas those measuring 4 mm align with descriptions of either variety.
Glume lengths: 2 mm		Yes	Glume lengths of 2 mm only match the description of shortawn alopecurus.

Anther lengths: ~ 0.9–1 mm	Yes	Yes	Anther lengths of 0.9 mm align with descriptions of both, while those of 1 mm only match the description of Sonoma alopecurus.
Awn lengths exceed lemma lengths by 0.5 mm to just over 1 mm	Yes	Yes	Differences in awn and lemma length under 1 mm only match the description of shortawn alopecurus, while differences of 1 mm or greater only match the description of Sonoma alopecurus.

Whether this population represents an intergrade between the two *Alopecurus aequalis* varieties, or a new variety altogether, genetic testing will be the next step to resolve the taxonomic questions surrounding *Alopecurus aequalis* at Ledson Marsh. Collection of genetic material at Ledson Marsh is currently the limiting factor for conducting this work. Collection of genetic material was unsuccessful in 2025 at Ledson Marsh (Curry *in litt*. 2025) but will be reattempted in 2026 (C. Freeman, California State Parks, *in litt.* 2026).

If the Ledson Marsh population is genetically identified as shortawn alopecurus, this would represent the most southern and disjunct population in the San Francisco Bay Area (CalFlora 2025, unpaginated). Alternatively, if the Ledson Marsh population is confirmed to be Sonoma alopecurus, it would remain the most eastern and disjunct population (CNDDB 2025, unpaginated).

Limited Information

This assessment is also limited by a lack of recent data for several of the historical Sonoma alopecurus populations. There are multiple historical sites on private lands, particularly in Sonoma County, that have not been revisited and assessed for current habitat conditions.

We also do not know the pollen dispersal distance of Sonoma alopecurus, nor the distances seeds are likely to travel and by which vectors, although likely wind and waterflow. However, we assume here that the populations are reproductively isolated. Lastly, we lack information on the robustness and longevity of the soil seed bank. It is possible that all populations that have plants in the recent past sustain a robust soil seed bank, and under the right climatic and disturbance conditions, populations could rebound.

6.5 SUMMARY OF FUTURE CONDITIONS

Under both future scenarios, the resiliency of most Sonoma alopecurus populations will be low due to intensification of the effects of climate change and a reduction in grazing in the lower plausible limit scenario, with only P3 having moderate resiliency. It is possible that one or more populations will become extirpated in the future, with greater risk for populations that have not been observed in recent surveys, or in areas with limited or no grazing.

Redundancy is likely to remain low for Sonoma alopecurus, as most populations will have low resiliency and the possibility to become extirpated in the future. Representation is also likely to remain low as genetically isolated populations become extirpated, the opportunity for gene flow among populations will be limited; therefore, increasing the chance of genetic bottlenecks and small population effects.

CHAPTER 7 – OVERALL ASSESSMENT OF SPECIES VIABILITY

This SSA report describes the current condition and two plausible future scenarios we considered important to determining the viability of Sonoma alopecurus. This species is already considered one of the most imperiled within Point Reyes National Seashore (Parsons 2024, p. 33) and only occurs at one other location outside of the NPS property. Table 9 provides a summary of the overall current condition and the predicted future conditions under the lower and upper plausible limit scenarios for each population.

Under the current condition, one of the populations is in moderate condition, and eight are in low or low-extirpated condition. The species redundancy is low relative to the historical condition, as there are only nine extant populations, as compared to over 20 in the historical Diversity Database, and most are in low condition. The species representation is also low, as the species occupies a narrow habitat type and likely has low adaptive capacity.

Under both the upper and lower plausible limit scenarios, in which the current climate trajectory continues and worsens, at RCP4.5 and 8.5, respectively, one will be in moderate-low condition and eight will remain in low-extirpated condition. For either climate pathway, the temperature is likely to increase, along with the risk of increased severity and duration of droughts, and increased risk of wildfire. The redundancy of Sonoma alopecurus will remain low, as most populations will be in low condition with the possibility of extirpation in the future. The representation of the species will also be low, with the lack of population connectivity and resistance to introduction attempts decreasing adaptive capacity.

Table 10. Current and future population and species conditions for Sonoma alopecurus.

Viability Measure	Population	Current Condition	Upper Plausible Limit Scenario Condition	Lower Plausible Limit Scenario Condition
Resiliency	P3	Moderate	Moderate	Moderate-Low
	P5	Low	Low	Low-Extirpated
	P7	Low	Low	Low-Extirpated
	P8	Low	Low	Low-Extirpated
	P11	Low	Low	Low-Extirpated
	P13	Low	Low	Low-Extirpated
	P14	Low	Low	Low-Extirpated
	P15	Low	Low	Low-Extirpated

	Ledson Marsh	Low	Low	Low-Extirpated
Redundancy		Low	Low	Low
Representation		Low	Low	Low

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