Central Valley Landscape Conservation Project

Climate Change Vulnerability Assessment (January 2017 version)

Wetland-dependent Mammals

Vulnerability Assessment Summary

Overall Vulnerability Score and Components:

Vulnerability Component	Score
Sensitivity	Low-moderate
Exposure	Moderate-high
Adaptive Capacity	Moderate-high
Vulnerability	**Low-moderate**

Overall vulnerability of the wetland-dependent mammals species group was rated as low-moderate. The score is the result of low-moderate sensitivity, moderate-high future exposure, and moderate-high adaptive capacity ratings.

Climate factors that may affect wetland dependent mammals include those that reduce water availability, such as reduced snowpack, earlier timing of snowmelt and runoff, increased winter storm frequency, and warmer water temperatures. Many species within this group live on water-intensive agricultural lands (e.g., rice croplands) that face increased challenges as water availability decreases.

The key non-climate factor for this species group is invasive species, which alter the composition and function of natural habitat.

The key disturbance mechanism for wetland dependent mammals is flooding, which provides water for wetlands; however, flooding is now heavily managed. This species group exhibits a moderate degree of specialization due to their dependence on wetland habitats and fish populations.

While some wetland dependent mammals have wide distributions, the salt marsh harvest mouse and Suisun shrew are endemic to the region and have fragmented populations. Small mammals with discontinuous populations may be threatened by development and land use changes that further fragment habitat and limit movement and dispersal.

This species group exhibits moderate-high diversity overall, but genetic diversity is low within the salt marsh harvest mouse and Suisun shrew, increasing their vulnerability to changing climate conditions.

Management potential for wetland-dependent mammals was scored as low-moderate. Most rodents have little societal support for conservation; however, beavers have some public support as they promote healthy riparian ecosystems and restore habitat complexity and functionality to degraded streams, rivers, and floodplains.

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Introduction

Description of Priority Natural Resource

Wetlands provide critical habitat for many species of wetland dependent mammals, including the North American river otter (*Lontra canadensis*), American beaver (*Castor canadensis*), common muskrat (*Ondatra zibethicus*), American mink (*Neovison vison*), Suisun shrew (*Sorex ornatus sinousus*), and the salt marsh harvest mouse (*Reithrodontomys raviventris*). These mammals face the combined threat of severe habitat loss and fragmentation due to changes in land cover and climate. Most of these species are widely distributed and are able to survive on human-altered wetlands, but the Suisun shrew and the salt marsh harvest mouse have extremely small populations and are in critically imperiled status (NatureServe 2016).

As part of the Central Valley Landscape Conservation Project, workshop participants identified the wetlands-dependent mammals species group as a Priority Natural Resource for the Central Valley Landscape Conservation Project in a process that involved two steps: 1) gathering information about the species group's management importance as indicated by its priority in existing conservation plans and lists and, 2) a workshop with stakeholders to identify the final list of Priority Natural Resources, which includes habitats, species groups, and species.

The rationale for choosing the wetlands-dependent mammals as a Priority Natural Resource included the following: the species group has high management importance, and the species group's conservation needs are not entirely represented within a single priority habitat. Please see Appendix A: "Priority Natural Resource Selection Methodology" for more information.

Vulnerability Assessment Methodology

During a two-day workshop in October of 2015, 30 experts representing 16 Central Valley resource management organizations assessed the vulnerability of priority natural resources to changes in climate and non-climate factors, and identified the likely resulting pressures, stresses, and benefits (see Appendix B: "Glossary" for terms used in this report). The expert opinions provided by these participants are referenced throughout this document with an endnote indicating its source1. To the extent possible, scientific literature was sought out to support expert opinion garnered at the workshop. Literature searches were conducted for factors and resulting pressures that were rated as high or moderate-high, and all pressures, stresses, and benefits identified in the workshop are included in this report. For more information about the vulnerability assessment methodology, please see Appendix C: "Vulnerability Assessment Methods and Application." Projections of climate and non-climate change for the region were researched and are summarized in Appendix D: "Overview of Projected Future Changes in the California Central Valley".

Vulnerability Assessment Details

Climate Factors

Workshop participants scored the resource's sensitivity to climate factors and this score was used to calculate overall sensitivity. Future exposure to climate factors was scored and the overall exposure score used to calculate climate change vulnerability.

Climate Factor	Sensitivity	Future Exposure
Extreme events: drought	-	High
Extreme events: storms	Low-moderate	-
Snowpack amount	Moderate	Moderate
Overall Scores	**Low-moderate**	**Moderate-high**

Snowpack amount

Sensitivity: *Moderate (moderate confidence)*
Future exposure: *Moderate (moderate confidence)*

Wetland-dependent mammals are sensitive to snowpack amount because snowpack from mountainous areas surrounding the Central Valley plays a large part in water storage and supply, which includes wetland irrigation (Knowles & Cayan 2002; Scanlon et al. 2012). Reduced snowpack is associated with reduced streamflow, delayed groundwater recharge, changes in natural flooding regimes, and summer water shortages (Miller et al. 2001; Knowles & Cayan 2002; Kiparsky & Gleick 2003; Vicuna et al. 2007; Yarnell et al. 2010; Perry et al. 2012).

Storms

Sensitivity: *Low-moderate (high confidence)*

Atmospheric rivers are corridors of moisture transport in the atmosphere created by warm, wet storms that typically occur in the winter (Dettinger 2011). Storms associated with atmospheric rivers may become more frequent, although the average number of storms per year will likely not change significantly (Cayan et al. 2008; Dettinger 2011). Over the course of the 20th and early 21st centuries, there has not been significant changes in the pattern of winter storms in California (Diffenbaugh et al. 2015).

Storms may impact the salt marsh harvest mouse and beaver, but other wetland-dependent species are unlikely to be sensitive to storms[1].

Water temperature

Sensitivity: *Not scored*

Water temperature impacts the abundance and composition of aquatic vegetation, invertebrates, and fish in wetlands, potentially altering the food web (Poff et al. 2002). Water temperatures are highly correlated with air temperatures (Morrill et al. 2005; Null et al. 2013), and changes in water temperature can reduce water quality and decrease dissolved oxygen, altering life history traits that are mediated by water temperature (e.g. growth, metabolism, migration, reproduction, etc.) in aquatic organisms (Morrill et al. 2005).

Timing of snowmelt & runoff

Sensitivity: *Not scored*

Changes in the timing of snowmelt & runoff impact wetland-dependent mammals indirectly by changing the timing and amount of water available in regions that receive much of their water from snowmelt (Moser et al. 2009; Yarnell et al. 2010; Thorne et al. 2015). Earlier snowmelt accelerates the release of water from snowpack, leading to earlier and higher peak flows followed by reduced summer flows and longer periods of summer drought (Yarnell et al. 2010). The timing of runoff is also important for seed germination and vegetation production in wetlands (Naylor 2002).

Drought

Future exposure: *Moderate-high (high confidence)*
Potential refugia: *Riparian buffers connected to wetlands may be refugia, but there are very few of these areas.*

Over the coming century, the frequency and severity of drought is expected to increase due to climate change (Hayhoe et al. 2004; Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015), as warming temperatures exacerbate dry conditions in years with low precipitation, causing more severe droughts than have previously been observed (Cook et al. 2015; Diffenbaugh et al. 2015). Regardless of changes in precipitation, warmer temperatures are expected to increase evapotranspiration and cause drier conditions (Cook et al. 2015). Recent studies have found that anthropogenic warming has substantially increased the overall likelihood of extreme California droughts, including decadal and multi-decadal events (Cook et al. 2015; Diffenbaugh et al. 2015; Williams et al. 2015).

Climatic changes that may benefit the species group:

- Drying wetlands benefit otters and mink because prey become stranded and are easier to catch

Non-Climate Factors

Workshop participants scored the resource's sensitivity and current exposure to non-climate factors, and these scores were then used to assess their impact on climate change sensitivity.

Non-Climate Factor	Sensitivity	Current Exposure
Invasive & other problematic species	Moderate-high	Moderate-high
Land use change	Moderate	Moderate
Urban/suburban development	Moderate	Moderate
Overall Scores	**Moderate**	**Moderate**

Wetland-dependent mammals are primarily sensitive to the impacts of non-climate factors on their wetland habitat, and their sensitivity and exposure are similar to that identified for seasonal and permanent wetland habitats (land use change, invasive & problematic species, nutrient loading, groundwater overdraft, pollution and poisons, hunting[1].

Invasive & other problematic species

Sensitivity: *Moderate-high (high confidence)*
Current exposure: *Moderate-high (high confidence)*
Pattern of exposure: *Localized.*

Wetland-dependent mammals are sensitive to the impact of invasive species on wetlands, where invasives compete with and/or prey on native species. Examples of invasive wetland species include bullfrogs (*Rana catesbeiana*), the Louisiana red crayfish (*Procambarus clarkii*), Brazilian milfoil (*Myriophyllum aquaticum*), invasive cordgrass (*Spartina alterniflora*), bluegill (*Lepomis macrochirus*), and green sunfish (*Lepomis cyanellus*; Natural Resources Agency 2010). Changes in climate conditions, such as increased temperatures, changes in precipitation, or altered flooding regimes may allow invasive plants and wildlife to encroach further into wetlands, and may also allow new invasive species to become established (Rahel & Olden 2008; CA Natural Resources Agency 2010; Reynolds & Cooper 2010).

Land use change

Sensitivity: *Moderate (high confidence)*
Current exposure: *Moderate (moderate confidence)*
Pattern of exposure: *Consistent across the landscape.*

The vast majority of Central Valley wetlands (>95%) have already been lost through conversion to urban development or agriculture (Gilmer et al. 1982). The remaining wetlands are heavily managed, but most privately-owned wetlands remain unprotected, making them vulnerable to future land use conversion (Central Valley Joint Venture 2006).

Urban/suburban development

Sensitivity: *Moderate (moderate confidence)*
Current exposure: *Moderate (high confidence)*
Pattern of exposure: *Localized.*

Other Factors

Overall degree to which other factors affect adaptive capacity: *Low (high confidence)*

Beaver removal

Beaver removal

Beavers can have a positive impact by creating and maintaining wetlands, providing habitat for many species in multiple taxa, including endangered species (Lanman et al. 2013). Hood and Bayley (2008) found that beavers could significantly contribute to reducing the impact of climate change by increasing wetland presence in Canada. However, beavers have been hunted for fur in the past (Lanman et al. 2013), and are often targeted for removal because of land use conflicts (Pollack et al. 2015). However, non-lethal options to mitigate unwanted effects by beavers are available (Pollack et al. 2015).

Disturbance Regimes

Workshop participants scored the resource's sensitivity to disturbance regimes, and these scores were used to calculate climate change sensitivity.

Overall sensitivity to disturbance regimes: *Low-moderate (moderate confidence)*

Flooding

Altered flooding regimes impact wetland habitats, which historically were flooded by winter precipitation and spring snowmelt (Duffy & Kahara 2011). However, most river systems are now highly managed by dams, levees, and bypasses, which control flow variability and essentially eliminate natural flood regimes (Central Valley Joint Venture 2006), and most wetlands rely on managed water supplies for seasonal flooding (CA Natural Resources Agency 2010). These water sources, typically captured in dams and delivered by canals or through stream channels, are in high demand as they provide water for agriculture and urban use, wetland irrigation, and maintaining instream flows for fish. Demand for this water increases every year, as does the cost, and many wetland managers now rely on irrigation drain water, wastewater discharges, low priority water contracts, non-binding agreements with water districts, and groundwater pumping (CA Natural Resources Agency 2010).

Increased large flooding events could benefit beaver and mink, which are adapted to flooding regimes[1]. However, the salt marsh harvest mouse and Suisun shrew are sensitive to flooding associated with sea level rise, which may inundate salt marsh refugia[1].

Dependency on habitat and/or other species

Workshop participants scored the resource's dependency on habitat and/or other species, and these scores were used calculate climate change sensitivity.

***Overall degree of specialization**: Moderate (high confidence)*
***Dependency on one or more sensitive habitat types:** High (high confidence)*
***Description of habitat:** Wetlands, but can also cross over into riparian/riverine*
***Dependency on specific prey or forage species:** Low-moderate (moderate confidence)*
***Dependency on other critical factors that influence sensitivity:** Low (moderate confidence)*
***Description of other dependencies:** Fish populations*

Although they are dependent on wetlands, most of the species in this group are generalists with relatively opportunistic diets and large distributions across the country (e.g. North American river otter, American beaver, common muskrat, and American mink (NatureServe 2016). Although these species are associated with wetlands, their generalist diets may make them less sensitive to community changes seen on those wetlands.

However, the Suisun shrew and the salt marsh harvest mouse are far more specialized, and both are restricted to tidal salt marshes along a part of the northern edge of the San Francisco Bay estuary and tributaries (Hays & Lidicker, Jr. 2000; Bias & Morrison 2006), an area recognized for its biodiversity uniqueness (Davis 2014). Because of their dependence on salt marshes and very limited distribution, these species are extremely sensitive to habitat loss, whether from anthropogenic factors (e.g., development) or climate change (e.g., sea level rise; Shellhammer 1989; Smith et al. 2014). However, the salt marsh harvest mouse is able to use anthropogenic habitats (e.g., diked wetlands; Geissel et al. 1988; Sustaita et al. 2011; Smith et al. 2014), which may expand their ability to cope with other threats (Smith et al. 2014).

Adaptive Capacity

Workshop participants scored the resource's adaptive capacity and the overall score was used to calculate climate change vulnerability.

Adaptive Capacity Component	Score
Extent, Status, and Dispersal Ability	Moderate-high
Landscape Permeability	Moderate-high
Intraspecific Species Group Diversity	Moderate-high
Resistance & Recovery	Moderate-high
Overall Score	**Moderate-high**

Extent, status, and dispersal ability

Overall degree extent, integrity, connectivity, and dispersal ability: *Moderate-high (high confidence)*
Geographic extent: *Transcontinental (high confidence)*
Health and functional integrity: *Increasingly healthy (moderate confidence)*
Population connectivity: *Continuous with some breaks (high confidence)*
Dispersal ability: *Moderate-high (high confidence)*

Both the Suisun shrew and the salt marsh harvest mouse are endemic to very small areas of California, and are critically imperiled (NatureServe 2016) or listed as Species of Concern in California (Williams 1986). The Suisun shrew has a small, very fragmented distribution (Suisun and San Pablo bays, CA; NatureServe 2016), which puts this subspecies under a high threat of extinction (Maldonado 2000). Salt marsh harvest mice are sensitive to habitat fragmentation, as adults tend to move within small home ranges (Geissel et al. 1988; Bias & Morrison 2006); however, juveniles can move considerable distances relative to their size (Geissel et al. 1988).

Landscape permeability

Overall landscape permeability: *Moderate-high (moderate confidence)*
Impact of various factors on landscape permeability:
Land use change: *Moderate (moderate confidence)*
Urban/suburban development: *Low-moderate (moderate confidence)*

In fact, the presence of flooded fields can enhance the landscape permeability for some wetland species (Frayer et al. 1989; Elphick 2000), and the associated canals may also provide wildlife corridors used by species that move between wetlands, canals, and flooded cropland.

Small mammals such as the Suisun shrew may be able to persist in small patches of habitat and their movements may be less affected by fragmentation (Hanski & Kaikusalo 1989). In fact, Laakkonen et al. (2001) found that *S. ornatus* presence in southern California was not affected by patch size when sites were otherwise placed in areas suitable for the species.

The salt marsh harvest mouse has some capacity to cross barriers; Bias and Morrison (2006) found that 13.6% of the mice radiotracked were able to cross physical barriers to movement (e.g., 1-2 m wide permanent water canals, 3-4 m wide roads on levees, 1-2 m wide levees). However, larger barriers may block the movement of this species, which has a relatively small home range (Geissel et al. 1988; Bias & Morrison 2006).

Resistance and recovery

Overall ability to resist and recover from stresses: *Moderate-high (high confidence)*
Resistance to stresses/maladaptive human responses: *Moderate-high (high confidence)*
Ability to recover from stresses/maladaptive human response impacts: *Moderate-high (high confidence)*

Given that the salt marsh harvest mouse is one of the most restricted and specialized species in this group (Hays & Lidicker, Jr. 2000; Bias & Morrison 2006), it is likely that it will have the lowest ability to cope with change. However, this species is able to use dike vegetation (Smith et al. 2014), and they have some evolutionary adaptations that may allow them to respond to changes in habitat better than other species in the same genus (Haines 1964; Smith et al. 2014). For example, they are stronger swimmers and can consume more seawater (Haines 1964) than the Western harvest mouse (*Reithrodontomys megalotis*), a sympatric species (Smith et al. 2014).

Species group diversity

Overall species group diversity: *Moderate-high (moderate confidence)*
Diversity of life history strategies: *Moderate-high (low confidence)*
Genetic diversity: *Moderate-high (moderate confidence)*
Behavioral plasticity: *Moderate-high (high confidence)*
Phenotypic plasticity: *Moderate (low confidence)*

Most species in this group tend to be sexually mature at early age (e.g. common muskrat, 4-6 months; otters, 2 years; beaver, 3 years), have large litter sizes (e.g. beaver: 1 to 9 pups/litter, otter: 1 to 6 pups/litter, salt marsh harvest mouse, average: 3.7 – 4.0 young/litter) or can have multiple litters per year (NatureServe 2016).

The salt marsh harvest mouse has low genetic diversity (Statham et al. 2016). There is also a significant genetic differentiation between the northern (*R. v. halicoetes*) and southern (*R. v. raviventris*) subspecies, where the southern subspecies has 20% of the nucleotide diversity found on either of the northern bays (Statham et al. 2016). Such reduced genetic diversity may affect the adaptive capacity of this subspecies, especially under climate change (Statham et al. 2016).

The Suisun shrew is also an example of a subspecies with low genetic diversity, as well as high specialization on habitat use (Maldonado 2000). Genetic analyses have shown this subspecies to be distinct from other *S. ornatus* subspecies (Calsbeek et al. 2003), and it has even been questioned if it is closer to *S. vagrant* (Maldonado 2000).

Management potential

Workshop participants scored the resource's management potential.

Management Potential Component	Score
Species value	Moderate-high
Societal support	Moderate
Agriculture & rangeland practices	Moderate
Extreme events	Low
Converting retired land	Low
Managing climate change impacts	Moderate
Overall Score	**Low-moderate**

Value to people

Value to people: *Moderate-high (high confidence)*

Support for conservation

Degree of societal support for management and conservation: *Moderate (low confidence)*

Degree to which agriculture and/or rangelands can benefit/support/increase resilience: *Moderate (moderate confidence)*
Description of support: *Agricultural management can benefit these mammals; fields are better than buildings.*

Degree to which extreme events (e.g., flooding, drought) influence societal support for taking action: *Low (low confidence)*

Likelihood of converting land to support species group

Likelihood of (or support for) converting retired agriculture land to maintain or enhance species group: *Low (high confidence)*

Likelihood of managing or alleviating climate change impacts: *Moderate (moderate confidence)*
Description of likelihood: *Management potential is the same as those identified for permanent and seasonal wetland habitats. The salt marsh harvest mouse may actually get some help due to sea level rise impacts.*

In general, rodents have little societal support for their conservation (Lidicker, Jr. 2008), which makes conservation efforts for endangered species especially challenging.

Managing for beavers has the potential to benefit wetland ecosystem function and health (Pollack et al. 2015). As keystone species, beavers provide habitat for many other species, and non-lethal management strategies could be encouraged to minimize human-wildlife conflict (Pollack et al. 2015).

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