Wetland Meadows

A Southern Sierra Adaptation Workshop Information Brief

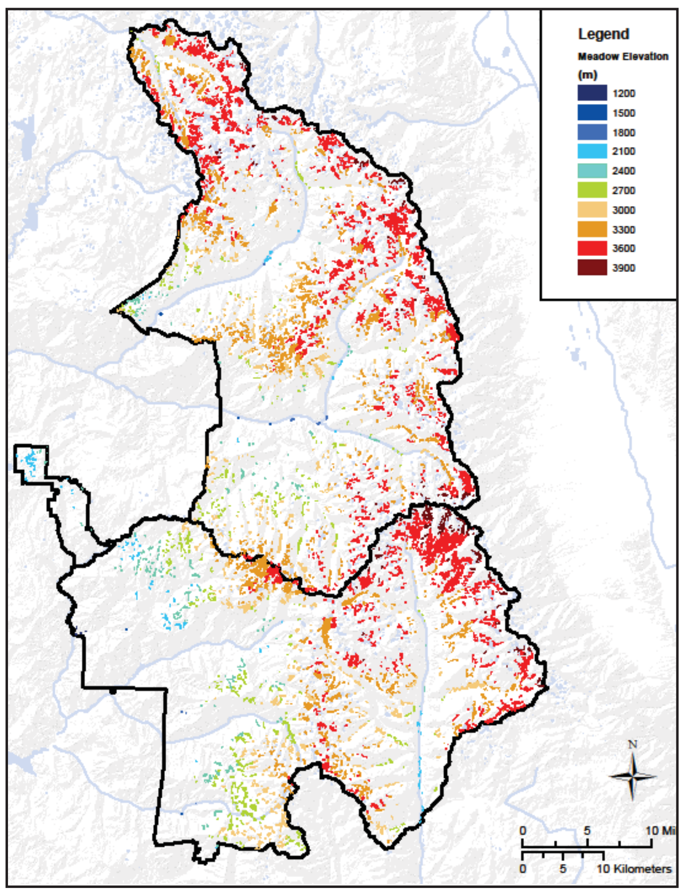
MEADOW ECOLOGY

Meadows can vary from dry/upland meadows (which are not the focus of this brief) to wet meadows and fens depending on the amount and duration of soil saturation. Most montane meadows are found in glacier-formed basins on gentle-moderate slopes in the subalpine zone, and occur down to 1,800 m (6,000 feet) in the southern Sierra Nevada[1]. Meadow size ranges from less than a hectare to larger than 100 ha, with the largest meadows found between 3,000-3,700 m (9,800-12,000feet)[2]. Vegetation in meadows is commonly dominated by sedges, rushes, grasses, and broad-leafed forbs, however woody species and bryophytes also can occur[3,4]. Wet meadows and fens cover just 1% of the land area of the Sierra[5]. Despite their relatively small area, they provide important ecosystem functions and services. Wet meadows and fens are vital habitat for invertebrates, amphibians, birds, and other wildlife. They slow down flood waters and improve water quality by storing nutrients and sediment. These wetlands also contribute to the beauty of Sierran landscapes and provide forage for wildlife as well as packstock[3,4,6].

The key physical driver influencing wetland plant and animal communities is hydrology. Spatial and temporal variability in the water table strongly influences vegetation composition and structure; ecosystem productivity, decomposition, and nutrient cycling, and hence organic matter accumulation[4]. In the Sierra Nevada, snowmelt is crucial to recharging groundwater that saturates the soil for at least part of the year in wet meadows and fens. Overland flow within the basin, surface flow from streams and springs, and direct precipitation are also important to wetland hydrology[7]. Fens and wet meadows differ mainly in the duration of high water tables that slow decomposition and allow for the accumulation of organic-rich soils (i.e., peat). Fens have more stable and higher water tables than wet meadows and have accumulated more organic soils[4].

CURRENT CONDITIONS AND STRESSORS

There are a range of human impacts that have affected wetlands in the Sierra Nevada, including flow regulation, ditching, fill placement, roads, historical grazing by domestic livestock, atmospheric deposition of pollutants, and non-native species invasion[4].



Figures 1: Distribution and elevations of meadows within SEKI (Adapted from NRCA Chapter 4)[25].

Actions such as ditching and road building directly impact wetland hydrology and lead to lowered water tables, erosion of organic soils, and shifts to non-wetland plants and wildlife[8,9,10]. Changes to land cover in the surrounding watershed can indirectly alter water flow into wetlands as well[11,12]. See Table 1 for stressors affecting meadows/wetlands ecosystem.

In the Sierra Nevada, grazing of sheep and cattle at high stocking rates in the late 19th and early 20th centuries resulted in severe degradation of wet meadows and fens[3,13,14,15] and some of these wetlands still show evidence of impact, including altered plant species[9]. Sheep and cattle grazing no longer occur in many sensitive areas, including NPS lands in the S. Sierra. Packstock currently are allowed in many meadows, however, and overgrazing can have severe impacts to wet meadows and fens[9,16]. Even carefully managed packstock grazing can have subtle but detectable effects. In Sequoia and Kings Canyon National Parks (SEKI), slight differences between paired packstock grazed and ungrazed meadows were documented in terms of plant litter depth, litter cover, bare ground, and soil strength (but no difference in plant species composition); arthropods exhibited slight and very localized differences based on grazing[2,17].

High elevation wet meadows and fens in the Sierra Nevada have a low incidence of invasive non-native plant species, but lower elevation wetlands (particularly drier sites) often support dense patches of naturalized introduced pasture grasses such as Kentucky bluegrass and redtop[18]. Recently, several montane wet meadows in S. Sierra national parks have been successfully invaded by velvet grass and reed canary grass. Nitrogen pollution from atmospheric deposition has the potential to affect productivity and species composition of wetland vegetation. Additionally, atmospheric deposition of mercury and pesticides may adversely impact aquatic biota through estrogenic effects even at low concentrations, and bioaccumulates in higher trophic levels.

Changing climate has already affected meadows in the S. Sierra. Encroachment of conifers into some meadows has been observed in the past century[19], but the spatial extent and causes of this change are yet to be fully understood (see Table 1). In one study, complex interactions between minimum temperatue, precipitation, and Pacific Decadal Oscillation (PDO) were significantly correlated with lodgepole pine encroachment[19].

Table 1: Current stressors affecting meadows and wetlands and their consequences

<table>
<tr><th>Stressor</th><th>Mechanism</th><th colspan="2">Effect on Wetlands/Meadows</th></tr>
<tr><td rowspan="6">Livestock and Grazing</td><td>Defoliation of vegetation</td><td rowspan="6">More erosion; loss of hydrologic function; gully formation (deep incised channel)[20]; lowered water table[14]; loss of wetland (native) plants[14,45]; altered soil structure[21]; sod/soil loss; colonization by non-wetland plants[14] and invasive plant species[3,39,40,41,42]</td><td rowspan="2">Native plant mortality; decreased biodiversity[3,37,38, 43]</td></tr>
<tr><td>Preferential grazing</td></tr>
<tr><td>Soil compaction from hooves[20]</td><td>Restricted root penetration and water flow[14]; more acidic soils[14,21]</td></tr>
<tr><td>Mineral and nutrient redistribution[22,43]</td><td>Exacerbated rodent damage to vegetation[22]</td></tr>
<tr><td>Invasive plant dispersal</td><td>See “invasive plants”</td></tr>
<tr><td>Lodgepole pine encroachment[19]</td><td>Reduced open meadow area[19]; less resources for meadow plants[3,19]</td></tr>
<tr><td rowspan="5">Human Recreational Use</td><td>Trails through wetlands[14,20]</td><td rowspan="5" colspan="2">Localized erosion[35]; gully formation[7,35]; loss of hydrologic functions[7]; altered soil structure; loss of sod/soil; soil compaction; restricted root penetration and water flow[38,43]; shift in plant and animal species[36,37,38,43,45]; more acidic soils; nutrient addition from outside sources[3]</td></tr>
<tr><td>Off-trail hiking[14,20]</td></tr>
<tr><td>Culvert and road placement[34,35]</td></tr>
<tr><td>Logging and mining[38,44]</td></tr>
<tr><td>Water diversion[34,35,36]</td></tr>
<tr><td rowspan="2">Fire Exclusion</td><td>Lodgepole pine encroachment</td><td colspan="2">See above</td></tr>
<tr><td>Increased severity of wildfires</td><td colspan="2">Plant mortality; increased runoff and sediment load; gully formation[14]</td></tr>
<tr><td rowspan="3">Invasive Plants</td><td>Competition for resources with native plants[33]</td><td colspan="2">Shift in species composition[33,37]</td></tr>
<tr><td>Altered hydrology and wetland structure[33]</td><td colspan="2">May draw down water table[33]</td></tr>
<tr><td>Altered food web dynamics for animals[33]</td><td colspan="2">Decreases native animals[33]</td></tr>
<tr><td rowspan="2">Atmospheric Pollution</td><td>Atmospheric nitrogen (N) deposition</td><td colspan="2">Increased nitrate in surface and groundwater; increased N availability may alter plant and algae species composition and productivity</td></tr>
<tr><td>Pesticides, mercury and other contaminants</td><td colspan="2">Bioaccumulation; adverse impact to aquatic biota, like amphibians</td></tr>
<tr><td>Recent climate trends</td><td>Lodgepole pine encroachment[19]</td><td colspan="2">See above</td></tr>
</table>

MEADOW VULNERABILITY IN THE FUTURE

Although predicting future climates is extremely complex, the three main IPCC emission scenarios agree that temperature in the southern Sierra Nevada will warm, with predictions between 2.6-3.9°C by 2100[23]. Less certain is the change in precipitation – of the 18 general circulation models that include California, about half predict decreases and half predict increases for the Sierra region[23]. Even with little changes in precipitation, the increased temperatures will still affect evaporation patterns, and could cause changes in wildfire regimes, snowmelt patterns, and more (Table 2).

Unless the future brings a substantial increase in precipitation, increases in evapotranspiration will reduce groundwater recharge, possibly resulting in a shift from wetland to dry vegetation types. Aquatic animals that utilize meadows for habitat may also decrease, especially cold water fishes like salmonids and sculpins[7] and amphibians. Earlier snowmelt will lead to a longer low flow duration during the dry summers, and create more thermally stressing days for aquatic life[7]. In the future, lodgepole pine invasions could become more common under certain climate futures. Based on a modelling study of 15 watersheds throughout the Sierra Nevada, meadows in watersheds in the central region are most vulnerable to longer low flow periods, and those in the central-southern region are most vulnerable to earlier runoff timing(Figure 2)[4]. However, the relative vulnerability of individual wet meadows and fens to these changes likely varies based on their specific geomorphologic and hydrologic characteristics.

The ability of wetland plants and animals to move to suitable habitat may be related to wetland connectivity. For example, low-elevation meadow plants and animals are fairly isolated, and lack connectivity to other suitable areas upslope under a warming climate[25]. It may thus be difficult for this ecosystem to shift upslope and remain within necessary environmental parameters, as the plants and animals may not be able to reach suitable areas.

Table 2: Potential climate change impacts and meadows/wetlands adaptive capacity and vulnerabilities

Potential Climate Change Impacts	Potential Results	Potential Impact to Meadows/Wetlands
"Much Warmer/Much Drier" Scenario	Earlier/more rapid snowmelt[24,26]; decreased snow pack[27,28]; changes in sub/surface hydrology; increased evaporative water loss[29]	Wetlands experience longer and more severe drought conditions[7]
	Longer and more severe drought conditions during growing season[23]	Shift to dryland vegetation, non-wetland conditions
		Decrease in habitat for cold water fishes and amphibians[7]; increase likelihood of aquatic invasive species
	Change in invasive plant populations	Species composition shift
	Shift in plant species composition	Change to dryland vegetation assemblage
	Increase in fire probability at almost all elevations except foothills and alpine areas[28,30,31]; increase in area burned[32]	Mortality of wetland plants; increased erosion via gully formation, increased runoff, and sedimentation[3]
	Shift in flora and fauna range following required temp/precipitation patterns	Disappearance of low elevation meadows from lack of connectivity and suitable habitat upslope
"Moderately Warmer/ Same Precip" Scenario	Increased fire probability at almost all elevations except alpine areas[31]	Mortality of wetland plants but less than the above scenario; increased erosion via gully formation, increased runoff, and sedimentation[3]
Increased Extreme Precip. Events	Increased flooding and erosive events	Increased runoff, erosion (via gully formation), and sedimentation - especially in degraded areas; restoration of degraded sites more difficult
Vulnerabilities	**Explanation**	**Potential Impact to Meadows/Wetlands**
Water Requirements	Wetlands require groundwater at/near surface and recharge from snowmelt; wetlands operate on a watershed scale and are vulnerable to degradation of the upslope watershed as well as the wetland itself[7]	Possible state shifts to non-meadows or xeric vegetation[7]. High elevation meadows in south-central SN most susceptible to earlier runoff timing; central SN most vulnerable to longer low flow periods[24]
Connectivity	Low-elevation meadows fairly isolated, lack connectivity to other suitable areas	Low-elevation wetlands may disappear; range contraction
Synergistic Effects	Already weakened wetland/meadow ecosystems may become more vulnerable to new stressors and new combinations of stressors brought on by climate change	

POTENTIAL MANAGEMENT STRATEGIES (WORK IN PROGRESS)

- To manage for persistence (resist change and build resilience):
  - Remove unstable stream banks that promote incision cycles
  - Install snow fences to increase snowpack in meadows
  - Suppress fires that have high risk of high severity near wetlands/meadows
  - Install fuel breaks at strategic locations to limit fire spread
  - Restore meadow hydrologic function and plant communities to increase their resilience to climate change
  - Remove exotic/invasive vegetation to increase resilience, avoid water table drawdown, and buildup of wildfire fuels
  - Thin forests around meadows to maximize water availability for meadow
  - Prohibit/restrict grazing; manipulate livestock distribution to deter detrimental effects to meadows
- To manage for change (facilitate transformation):
  - Assist migration of wetland meadow plants to higher elevations following desired environmental parameters
  - Replant desiccated areas with native upland species
  - Replant higher elevation meadows with species and genotypes from lower elevations and latitudes
  - Assisted migration/captive breeding of meadow biota (amphibians)
- Delay deciding (monitor and research):
  - Invasive plant monitoring
  - Grazing effects monitoring to ensure critical thresholds are not passed
  - Monitor size/distribution of wetlands
  - Monitor lodgepole pine invasions and possible causes
  - Monitor groundwater level and soil moisture
  - Monitor phenology of keystone species
  - Conduct before-and-after experiments to see affects of wildfire, grazing, and other disturbances have on meadows

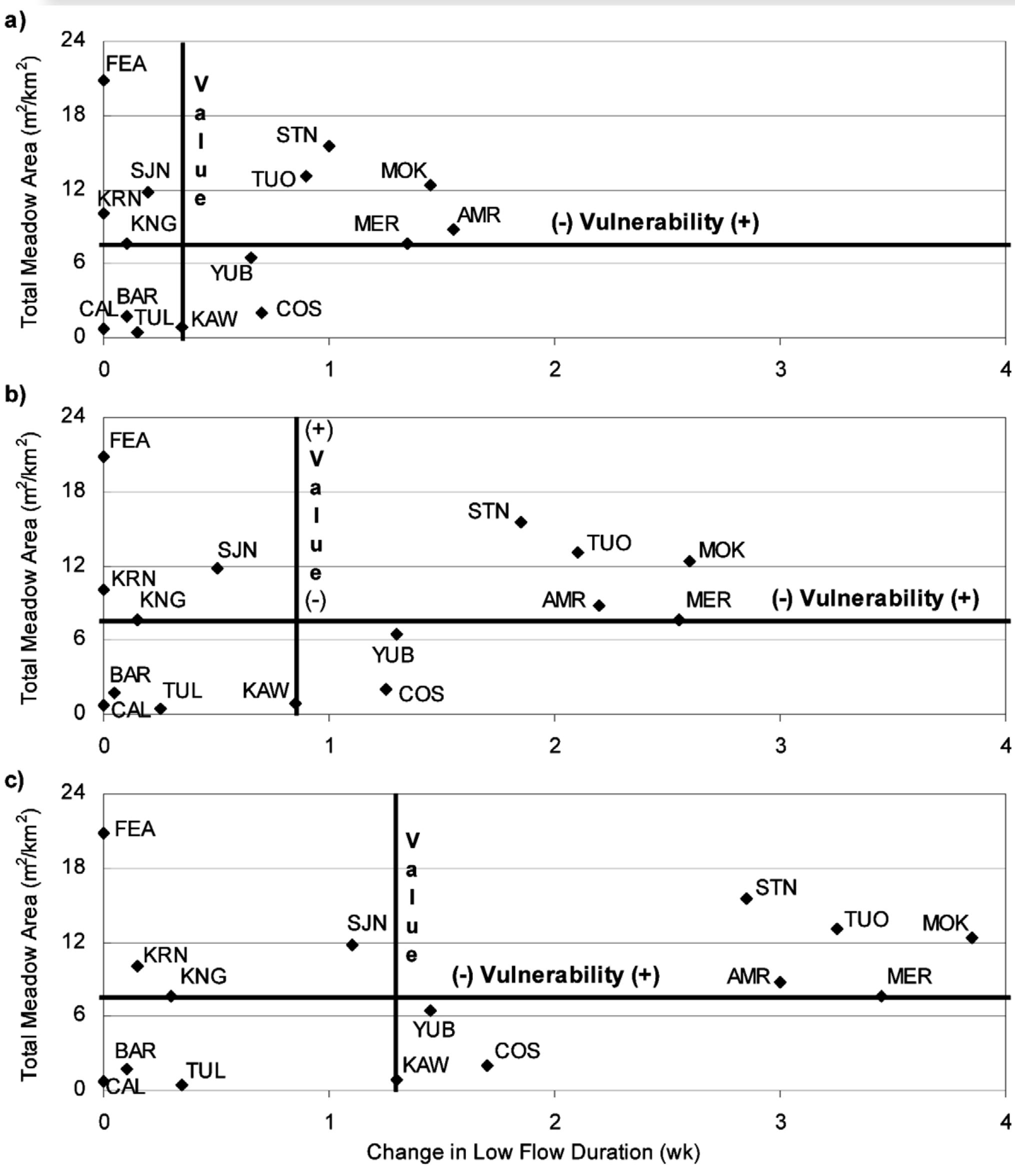


Figure 2: The relative vulnerability of watersheds based on meadow area and low flow durations for a) a 2°C warming, b) a 4°C warming, and c) a 6°C warming. Abbreviations for watersheds are as follows: FEA (Feather); YUB (Yuba); BAR (Bear); AMR (American); COS (Cosumnes); MOK (Mokelumne); CAL (Calaveras); STN (Stanislaus); TUO (Tuolumne); MER (Merced); SJB (San Joaquin); KNG (Kings); KAW (Kaweah); TUL (Tule); KRN (Kern). Adapted from Null et al. 2010[24].

Authorship Note

This information brief was created by Katy Cummings (NPS), Koren Nydick (NPS) with review and contributions from and Sylvia Haultain (NPS) and Eric Winford (NPS). Additional thanks to Erika Williams (NPS) for graphic design assistance.

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