Seeps and Springs

Climate Change Vulnerability Assessment for the Santa Cruz Mountains Climate Adaptation Project

This document represents an initial evaluation of mid-century climate change vulnerability for seeps and springs in the Santa Cruz Mountains region based on expert input during an October 2019 vulnerability assessment workshop as well as information in the scientific literature.

Habitat Description

Springs and seeps (i.e., low-discharge springs) are the physical locations where groundwater is discharged from aquifers to the Earth's surface[1], with discharge rates varying seasonally depending on the depth and size of the supporting aquifers[2]. Deep aquifers are often confined or semi-confined, meaning that an impermeable layer of dirt, clay, and/or rock prevents water from seeping directly from the ground surface down into the aquifer below[3]. This results in longer delays in recharge and longer water residence time[4]. Shallow, unconfined aquifers experience more rapid recharge as water percolates from the surface directly into the aquifer[4].

In the Santa Cruz Mountains region, seeps and springs are abundant and productive in the middle to upper elevations of the mountain ranges, and common but less productive along the coast. They often occur naturally near landslides, faults, anticlines, and other geologic features[5]. Others are created through human intervention in areas that would not otherwise have groundwater discharge to the surface[5].

Vulnerability Ranking

High Vulnerability

Low → High

Mod Confidence

Seeps and springs are sensitive to climate stressors and disturbance regimes that alter groundwater recharge and discharge, including changes in patterns of precipitation and runoff, increased drought, altered wildfire regimes, and more frequent and intense storms and flooding. Non-climate stressors including groundwater extraction, surface water diversions, and livestock grazing can exacerbate habitat sensitivity to climate changes by altering groundwater dynamics, degrading water quality, and increasing stress on groundwater-dependent plant communities. Seeps and springs are distributed widely throughout California but are static and often isolated landscape features, reducing the potential for associated flora and fauna to shift their range in response to climate changes and disturbance. In general, seeps and springs are fairly resistant to stressors such as increased temperature, hydraulic flow changes, and drought, especially when they are connected with deep groundwater sources or large regional aquifers. However, climate-driven increases in groundwater withdrawals during dry periods can cause more rapid depletion than would otherwise occur. Multiple opportunities exist to adjust land-use practices and reduce non-climate impacts on seep and spring ecosystems, improving their ability to cope with climate impacts. These include reducing anthropogenic groundwater withdrawals and water diversions, managing grazing intensity, and mapping and monitoring seep and spring ecosystems.

Sensitivity and Exposure

High Impact

Low → High

Mod Confidence

Sensitivity is a measure of whether and how a habitat is likely to be affected by a given change in climate and climate-driven factors, changes in disturbance regimes, and non-climate stressors. **Exposure** is a measure of how much change in these factors a resource is likely to experience.

Sensitivity and future exposure to climate and climate-driven factors

Seeps and springs are sensitive to climate stressors that alter groundwater recharge and discharge, including changes in patterns of precipitation and runoff and increased drought.

Climate Stressor	Trend Direction	Projected Future Changes
Precipitation & runoff	▲ ▼	• Uncertain trends in precipitation and runoff • Shorter winters and longer, drier summers likely, with higher interannual variability[6,7]
Drought	▲	• Increased frequency of drought years, including periods of prolonged and/or severe drought[6,8]

- **Changes in patterns of precipitation and runoff** are likely to affect the magnitude and timing of groundwater recharge[9], potentially impacting spring hydrology and associated plant communities. Shifts towards shorter winters and prolonged dry seasons, coupled with increased frequency of drought, are likely to limit recharge to local groundwater systems[10]. If a greater proportion of annual rainfall occurs during heavy precipitation events, there may also be less opportunity for water to infiltrate the soil because the amount of runoff will be greater; ultimately, this may result in reduced groundwater recharge and increased flooding in low-lying areas[10]. These changes can impact vegetation productivity, survival, and community composition in plant associations adjacent to seeps and springs[11–14], which are generally comprised of facultative or obligate phreatophytes (i.e., species that access groundwater directly through their root systems)[13].
- **Increases in the severity and length of future droughts** can result in the drying of springs[15], particularly if declines in surface water supplies drive increased reliance on groundwater resources for agricultural and municipal uses[16,17]. However, changes in the discharge rate of springs generally occur more gradually and lag behind changes in systems that depend on surface runoff, especially for high-volume springs or those connected to large regional aquifers[18,19].

Sensitivity and future exposure to climate-driven changes in disturbance regimes

Seeps and springs are sensitive to changes in disturbance regimes that alter groundwater recharge and water quality, as well as those that cause direct plant mortality and/or damage from landslides.

Disturbance Regimes	Trend Direction	Projected Future Changes
Wildfire	▲	• Slight to moderate increase in wildfire risk, particularly in areas of higher rainfall[20,21]
Storms & flooding	▲	• Increased storm intensity and duration, resulting in more frequent extreme precipitation events and flooding[6,22,23]

- **Altered wildfire regimes** can influence vegetation distribution and soil properties, which in turn affects infiltration from precipitation, how plants use water, and the resulting groundwater levels and recharge rate[24,25]. Vegetation loss in burned areas exacerbates erosion and mass wasting and high-intensity fires can also make soil hydrophobic for a period of time, increasing runoff and reducing infiltration and landscape water retention[26,27]. The introduction of ash into the system can also alter water pH levels[28].
- **More intense and/or frequent storms and associated flooding** can benefit groundwater-dependent ecosystems by contributing to recharge[29]. However, storm-related runoff and severe flooding can scour seep and spring ecosystems, resulting in vegetation removal and often increasing the presence of non-native riparian plants[28]. Severe flooding is most common in and around seeps and springs associated with riverine systems and/or those located in the bottom of a gully [28], and can result in landslides that temporarily or permanently alter spring ecosystems[5].

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate seep and spring habitat sensitivity to changes in climate factors and disturbance regimes by altering groundwater dynamics, degrading water quality, and increasing stress on groundwater-dependent plant communities.

- **Groundwater extraction** (e.g., pumping) and **surface water diversions** for municipal, industrial, and agricultural use have been associated with declines in spring discharge[30–33], decreasing vigor in seep and spring plant communities[13] and limiting water availability for wildlife. Increases in both groundwater extraction and surface water diversions occur during periods of low precipitation and drought[32,33], and are likely to be further exacerbated by growing human populations in the state[34].
- **Land-use conversion for residential/commercial development** additionally impacts soil infiltration, runoff, and water quality[3,35]. For instance, runoff from impervious surfaces and/or compacted soils in developed areas can introduce contaminants into shallow aquifers connected to springs[3].
- **Livestock grazing** can degrade seep and spring ecosystems by compacting soils, removing vegetation, and increasing nutrient inputs, depending on grazing intensity. Soil compaction decreases groundwater recharge and increases runoff, potentially impacting water supplies for seeps and springs[36]. Grazing can reduce vegetation height and cover[37,38], and is associated with changes in herbaceous species composition and diversity[37]. The abundance of aquatic fauna, such as springsnails (*Pyrgulopsis* spp.), can also be reduced by livestock grazing around springs[39]. In addition, concentrated livestock feeding operations increase nutrient pollution that affects water quality in groundwater-dependent systems[40].

Adaptive Capacity

Moderate Adaptive Capacity

Low → High

High Confidence

Adaptive capacity is the ability of a habitat to accommodate or cope with climate change impacts with minimal disruption.

Habitat extent, integrity, continuity, and barriers to dispersal

Seeps and springs are distributed widely but unevenly throughout California[2]. They are static and often isolated landscape features[2], reducing the potential for associated flora and fauna to shift their range in response to climate changes and disturbance[41]. Additionally, the integrity of some systems has been threatened by groundwater depletion, pollution, and other anthropogenic impacts[1].

Habitat diversity

Seeps and springs support biologically rich ecosystems and can include aquatic, wetland, and terrestrial species that are dependent on or benefit from groundwater for persistence[2]. Due to their high environmental stability and varied chemical composition, seep and spring ecosystems often include many rare/endemic species and unique assemblages[42,43]. Within the Santa Cruz Mountains study area, this includes the state-listed fountain thistle (*Cirsium fontanale* var. *fontanale*), which is associated with spring-fed serpentine soils in parts of San Mateo County[44]. Cold spring waters also support breeding California red-legged frogs (*Rana aurora draytonii*)[45], a federally-listed threatened species[46].

Resistance and recovery

In general, seeps and springs are fairly resistant to stressors such as increased temperature, hydraulic flow changes, and drought, especially when they are connected with deep groundwater sources or large regional aquifers[4,12,13,19,47]. However, climate-driven increases in groundwater withdrawals during dry periods can cause more rapid depletion than would otherwise occur[13,32]. Additionally, deep and/or confined aquifers are more likely to contain non-renewable groundwater, which is particularly vulnerable to anthropogenic withdrawals[48,49]. Seep and spring ecosystems likely have strong recovery potential following disturbances such as drought, although prolonged drought may alter vegetation types by favoring more upland species[5].

Management potential

Although seeps and springs are often not well-recognized or understood[5], they are highly valued and represent critical resources for human communities and wildlife[2]. They are also likely to provide hydrological refugia for plants and animals as surrounding habitats become progressively warmer and drier[50]. Despite these critical ecosystem services, relatively little societal support for management exists[5]. For instance, springs are exempt from regulation under the federal Clean Water Act because they are considered "isolated waters of the state"[51]. However, the 2014 Sustainable Groundwater Management Act (Cal. Code Regs. 23 § 350–358) supports efforts to preserve groundwater-dependent ecosystems by decreasing groundwater withdrawals and relocating wells that affect aquifer recharge[48]. Springs are also protected by the Porter-Cologne act in California[5].

Protection and management of seeps and springs are hindered by significant knowledge gaps (e.g., lack of comprehensive mapping efforts)[2], though the scientific literature documents multiple opportunities to adjust land-use practices and reduce non-climate impacts on seep and spring ecosystems. These include reducing anthropogenic groundwater withdrawals[32,33,52] and water diversions[5], managing grazing intensity through fencing or alternative grazing approaches[14,53,54], and providing guidance for land management (e.g., fuel reduction, restoration) activities to lessen impacts on ecosystems associated with seeps and springs[55,56]. Mapping and monitoring seep and spring ecosystems would also allow the use of adaptive management strategies designed to protect groundwater supplies and critical habitat for the many rare and endemic species that utilize these areas[2,33].

Recommended Citation

EcoAdapt. 2021. Seeps and Springs: Climate Change Vulnerability Assessment Summary for the Santa Cruz Mountains Climate Adaptation Project. Version 1.0. EcoAdapt, Bainbridge Island, WA.

Further information on the Santa Cruz Mountains Climate Adaptation Project is available on the project page (http://ecoadapt.org/programs/awareness-to-action/santa-cruz-mountains).

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