EcoAdapt

Freshwater Marshes, Wetlands, and Ponds

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 freshwater marshes, wetlands, and ponds 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

Freshwater marshes and wetlands are often found on the margins of lakes, creeks, and rivers[1,2]. Ponds generally occur within natural depressions or isolated channels, and can be associated with wetlands and/or riverine habitats[3,4]. Artificial ponds in the form of stock ponds, irrigation ponds, and agricultural reservoirs are also common within the study area, and are generally supplied by water diversions or instream flow[5]. Within natural wetlands and ponds, winter precipitation is the primary water source although some can receive a portion of their water supply from groundwater[5,6].

Freshwater marshes and ponds may be flooded seasonally or permanently, and plant species composition is dependent on both water depth and hydroperiod (i.e., timing and length of inundation)[1,7]. In shallow areas, plant communities are characterized by perennial herbaceous plants such as rushes (*Juncus* spp.), bulrushes (*Bolboschoenus*, *Schoenoplectus*, and *Scirpus* spp.), cattails (*Typha* spp.), common reed (*Phragmites australis*), and sedges (*Carex* spp.)[1,2]. Where water depth is over 1 m (3 ft), aquatic plants such as water lilies (*Nymphaeaceae*), duckweed (*Lemna* spp.), and pondweed (*Potamogeton* spp.) may occur[1,7]. Ponds are more likely to include areas of open water due to greater depths, and tend to have lower oxygen content compared to wetlands fed by running water[3,4].

Vulnerability Ranking

High Vulnerability

Low → High

Mod Confidence

Freshwater marshes, wetlands, and ponds are sensitive to climate stressors and disturbances that alter hydrologic and thermal regimes, including changes in patterns of precipitation and runoff, altered stream flows, increased drought, warmer water temperatures, heat waves, and sea level rise. These changes are likely to impact water levels, hydroperiods, and water quality, altering habitat suitability for many wildlife and plant species and driving changes in wetland and pond structure and function. Non-climate stressors can exacerbate habitat sensitivity by altering wetland and pond hydrology, water quality, and connectivity. Although freshwater wetlands and ponds were historically extensive within riparian floodplains in the region, many have been eliminated or degraded by historical development, agricultural activities (e.g., water diversions), and other anthropogenic factors. These fragmented and/or degraded systems are particularly vulnerable to the impacts of climate change. However, management activities such as maintaining or restoring natural hydrologic regimes, retaining water within the system, managing vegetation (e.g., through planting, mowing, disking, or grazing), reducing nutrient inputs, and protecting floodplains may increase the climate resilience of these habitats.

Copyright EcoAdapt 2021

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

Freshwater marshes, wetlands, and ponds are sensitive to climate stressors that alter hydrologic and thermal regimes, which can drive changes in wetland and pond structure, species composition, and function.

Climate Stressor	Trend Direction	Projected Future Changes
Precipitation	▲▼	• Shorter winters and longer, drier summers likely, with higher interannual variability[8,9]
Drought	▲	• Increased frequency of drought years, including periods of prolonged and/or severe drought[8,10]
Streamflow	▲▼	• Generally, wet season flows are projected to increase and dry season flows are projected to decrease[11]
Water temperature	▲	• 1.1–2.0°C (2.0–3.6°F) increase in mean summer stream temperature by the 2090s[12]
Heat waves	▲	• Significant increase in heat wave frequency and intensity[8,13]
Sea level rise	▲	• High likelihood (67% probability) of 0.2–0.3 m (0.6–1.1 ft) sea level rise by 2050[14–16]

- **Changes in precipitation patterns (e.g., amount and timing)**, **increased drought**, and **altered stream flows** impact water availability. For instance, shifts towards shorter winters with more rain falling in heavy precipitation events, coupled with prolonged dry seasons, are likely to increase surface water runoff and limit groundwater recharge[11]. Overall drier conditions are likely to reduce water levels, shorten wetland hydroperiods, and cause substantial drying of marshes, riparian edges, and ponds during the summer months[17–19]. Regional water shortages can also result in less available water to divert to irrigation ponds[5]. These changes can impact vegetation productivity, survival, and community composition in plant communities associated with freshwater wetlands and ponds, potentially allowing shifts towards more drought-adapted and upland species[17,20,21]. During severe multi-year droughts, extreme conditions can cause collapse of the food web and extirpation of many aquatic and semi-aquatic species (e.g., pond turtles)[22].
- **Warmer water temperatures** may benefit some species, potentially increasing plant and invertebrate growth, development, and productivity[17,23,24]. However, these changes are also

Copyright EcoAdapt 2021

likely to alter community composition and structure, and altered food webs may ultimately lead to a decline in ecosystem functioning[23]. For instance, warmer water temperatures are associated with increased growth of harmful algal blooms in nutrient-rich waters, which deplete dissolved oxygen, reduce water clarity, alter the food web, and produce toxins[25–27].

- **More frequent and/or intense heat waves** are likely to exacerbate thermal stress in aquatic species, potentially leading to direct mortality and facilitating the establishment of non-native species more tolerant of high temperatures[28].
- **Sea level rise** is likely to increase salinity within tidal freshwater marshes directly (i.e., through increased mixing of saltwater and fresh water), but it may also impact salinity in groundwater-fed wetlands where saltwater intrudes into coastal aquifers[29,30]. Increased salinity associated with sea level rise is likely to result in reduced wetland productivity, shifts in species composition towards salt-tolerant species, and potentially the loss of freshwater marsh areas[5,30]. Increasing salinity may be further exacerbated by drought and water diversions that reduce inflow of fresh water into the system[30].

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

Storms are the key disturbance in freshwater marshes, wetlands, and ponds within the Santa Cruz Mountains region due their impact on habitat structure and functioning.

Disturbance Regimes	Trend Direction	Projected Future Changes
Storms & flooding	▲	• Increased storm intensity and duration, resulting in more frequent extreme precipitation events and flooding[8,31,32]

- While freshwater marshes, wetlands, and ponds are well-adapted to seasonal flooding and can benefit from scouring and increased surface water runoff[5,33,34], **more frequent and/or intense storms and associated flooding** may damage habitats by altering structure and community composition[5]. For instance, flash floods can be associated with landslides and debris flows[35]. Floods also increase the amount of silt and pollutants carried into wetlands and ponds, affecting water quality and biological communities[17].

Sensitivity and current exposure to non-climate stressors

Non-climate stressors can exacerbate habitat sensitivity to changes in climate factors and disturbance regimes by altering wetland and pond hydrology, water quality, and connectivity.

- **Land-use conversion to residential and commercial development** damages and fragments wetlands directly through draining, vegetation removal, channel incision, and loss of floodplain connectivity[5,6]. Although continued development of freshwater wetlands and ponds is now limited in the region, historic floodplain development resulted in significant habitat loss[5].
- **Roads, highways, and trails** increase runoff of stormwater and pollutants, deliver large amounts of sediment into waterways, and facilitate the spread of invasive species[36–38]. Roads frequently reduce or eliminate connections between floodplains and creeks or rivers, altering wetland hydrology[36–38].
- **Water diversions** significantly reduce summer stream flows[39], decreasing surface water supplied to wetlands within riparian areas and potentially resulting in habitat drying and loss[2].

Copyright EcoAdapt 2021

- **Invasive plants** can degrade freshwater marshes by displacing native species, altering nutrient cycles, and reducing water quality, particularly where they form dense stands[6,40]. While hydrologically-intact wetlands are resistant to terrestrial invasives, degraded systems are vulnerable to invasion by drought-tolerant species such as giant reed (*Arundo donax*), which drive further changes in hydrology and biodiversity as well as increased fire risk[6].
- **Introduced fish, invertebrates, and amphibians** can also alter the abundance and diversity of native species through competition for resources, increased predation risk, and/or disease spread[41,42].
- **Pollutants** such as pesticides, excess nutrients, and heavy metals (e.g., mercury associated with historical mining) can significantly degrade wetland and pond water quality, with potentially severe impacts on aquatic organisms due to direct toxicity or indirectly through effects on the food chain[26,27,43]. Excess nutrients (especially phosphorus) have been identified as a major driver of harmful algae blooms, and are likely to be exacerbated by climate-driven increases in water temperature[26,27].

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

Freshwater wetlands and ponds were historically extensive within riparian floodplains, but the expansion of urban development resulted in the loss of many of these areas over the past century[6,44]. Infrastructure associated with development (e.g., roads, flood protection and water storage/delivery systems) can further fragment wetland habitats, hindering the movement and dispersal of native plants and animals[17,45,46]. Altered hydrology and changes in sedimentation/erosion processes due to climate change or anthropogenic causes can also reduce the structural and functional integrity of freshwater marshes by contributing to floodplain disconnection, channel incision, lowered groundwater tables, and reduced wetland area[2,5,17,44].

Habitat diversity

Freshwater wetlands are unique because of their role as transitional ecotones between aquatic and terrestrial ecosystems, and both wetlands and ponds are dynamic and productive ecosystems with diverse structural characteristics and biological communities[1,6,17]. These systems provide food, water, and cover for numerous species of fish, invertebrates, amphibians, reptiles, and mammals, including many rare species such as the California red-legged frog (*Rana draytonii*), western pond turtle (*Actinemys marmorata*), and San Francisco garter snake (*Thamnophis sirtalis tetrataenia*)[2,6,47].

Resistance and recovery

In general, wetlands and ponds supported primarily by surface water inputs are less resistant to precipitation declines and warming temperatures compared to groundwater-supplied systems[17,48].

Copyright EcoAdapt 2021

Management potential

Freshwater wetlands and ponds are critically-important ecosystems that provide water filtration, flood protection, groundwater recharge, and habitat for resident and migratory birds, fish, amphibians, and mammals[17,49,50]. These habitats are also valued by the public for their recreational opportunities, including swimming and bird watching[5]. Regulatory support for wetland habitats exists through the Federal Clean Water Act of 1972 (33 U.S.C. §§1251-1387), though this legislation does not fully protect these habitats from non-point source pollution that can lead to eutrophication and harmful algal blooms[51]. There is generally ample grant funding available for wetland restoration, although environmental regulations, permitting requirements, and competing land use can make restoration and management of freshwater wetlands and ponds complex[5].

Management activities designed to reduce climate vulnerability in freshwater marshes, wetlands, and ponds often focus on restoring natural hydrology, retaining water within the system, and managing vegetation through planting, burning, mowing, disking, or grazing[49]. Reducing nutrient inputs to wetlands and ponds would also minimize eutrophication and limit the risk of harmful algal blooms, particularly during periods of drought[27]. Finally, acquiring and restoring modified historic floodplains adjacent to creeks will prevent continued habitat loss, protecting potential refugia and enabling aquatic systems to recover from disturbances[5]. In addition to reducing the impacts of climate stressors and disturbances (e.g., warmer water temperatures, changing precipitation patterns, drought), climate-informed management of these habitats would also benefit conservation target species (i.e., frogs, fish), maintain high biodiversity across the landscape, and provide the public with important water resources and recreational benefits[49].

Recommended Citation

EcoAdapt. 2021. Freshwater Marshes, Wetlands, and Ponds: 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).

Literature Cited

1. Kramer, G. *Fresh emergent wetland*. https://www.wildlife.ca.gov/Data/CWHR/Wildlife-Habitats (1988).
2. CDFW. *California State Wildlife Action Plan, 2015 Update: a conservation legacy for Californians*. (2015).
3. Cowardin, L. M., Carter, V., Golet, F. C. & LaRoe, E. T. *Classification of wetlands and deepwater habitats of the United States*. (1979).
4. Grenfell, W. E., Jr. *Lacustrine*. https://www.wildlife.ca.gov/Data/CWHR/Wildlife-Habitats (1988).
5. Vuln. Assessment Workshop. Personal communication. (2019).
6. Duffy, W. G. *et al.* Wetlands. in *Ecosystems of California* (eds. Mooney, H. A. & Zavaleta, E. S.) 669–692 (University of California Press, 2016).
7. Thorne, J. H., Boynton, R. M., Holguin, A. J., Stewart, J. A. E. & Bjorkman, J. *A climate change vulnerability assessment of California's terrestrial vegetation*. (2016).
8. Pierce, D. W., Kalansky, J. F. & Cayan, D. R. *Climate, drought, and sea level rise scenarios for the Fourth California Climate Assessment*. (2018).

Copyright EcoAdapt 2021

9. Swain, D. L., Langenbrunner, B., Neelin, J. D. & Hall, A. Increasing precipitation volatility in twenty-first-century California. *Nature Climate Change* **8**, 427 (2018).
10. Cook, B. I., Ault, T. R. & Smerdon, J. E. Unprecedented 21st century drought risk in the American Southwest and Central Plains. *Science Advances* **1**, e1400082 (2015).
11. Grantham, T. E. W., Carlisle, D. M., McCabe, G. J. & Howard, J. K. Sensitivity of streamflow to climate change in California. *Climatic Change* **149**, 427–441 (2018).
12. Hill, R. A., Hawkins, C. P. & Jin, J. Predicting thermal vulnerability of stream and river ecosystems to climate change. *Climatic Change* **125**, 399–412 (2014).
13. Gershunov, A. & Guirguis, K. California heat waves in the present and future. *Geophys. Res. Lett.* **39**, L18710 (2012).
14. Kopp, R. E. *et al.* Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future* **2**, 2014EF000239 (2014).
15. Sweet, W. V. *et al. Global and regional sea level rise scenarios for the United States*. (2017).
16. Griggs, G. *et al. Rising seas in California: an update on sea-level rise science*. (2017).
17. Poff, N. L., Brinson, M. M. & Day, J. W., Jr. *Aquatic ecosystems and global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States*. (2002).
18. Purcell, K. L., McGregor, E. L. & Calderala, K. Effects of drought on western pond turtle survival and movement patterns. *Journal of Fish and Wildlife Management* **8**, 15–27 (2017).
19. Reiter, M. E., Elliott, N. K., Jongsomjit, D., Golet, G. H. & Reynolds, M. D. Impact of extreme drought and incentive programs on flooded agriculture and wetlands in California's Central Valley. *PeerJ* **6**, e5147 (2018).
20. Perry, L. G., Andersen, D. C., Reynolds, L. V., Nelson, S. M. & Shafroth, P. B. Vulnerability of riparian ecosystems to elevated CO_2 and climate change in arid and semiarid western North America. *Glob Change Biol* **18**, 821–842 (2012).
21. Stromberg, J. C., Lite, S. J. & Dixon, M. D. Effects of stream flow patterns on riparian vegetation of a semiarid river: implications for a changing climate. *River Research and Applications* **26**, 712–729 (2010).
22. Lovich, J. E. *et al.* The effects of drought and fire in the extirpation of an abundant semi-aquatic turtle from a lacustrine environment in the southwestern USA. *Knowledge & Management of Aquatic Ecosystems* **418**, 18 (2017).
23. Greig, H. S. *et al.* Warming, eutrophication, and predator loss amplify subsidies between aquatic and terrestrial ecosystems. *Global Change Biology* **18**, 504–514 (2012).
24. Petchey, O. L., McPhearson, P. T., Casey, T. M. & Morin, P. J. Environmental warming alters food-web structure and ecosystem function. *Nature* **402**, 69–72 (1999).
25. Visser, P. M. *et al.* How rising CO_2 and global warming may stimulate harmful cyanobacterial blooms. *Harmful Algae* **54**, 145–159 (2016).
26. Coffey, R., Paul, M. J., Stamp, J., Hamilton, A. & Johnson, T. A review of water quality responses to air temperature and precipitation changes 2: nutrients, algal blooms, sediment, pathogens. *JAWRA Journal of the American Water Resources Association* **55**, 844–868 (2019).
27. Paerl, H. W. *et al.* Mitigating a global expansion of toxic cyanobacterial blooms: confounding effects and challenges posed by climate change. *Mar. Freshwater Res.* (2019) doi:10.1071/MF18392.
28. Diez, J. M. *et al.* Will extreme climatic events facilitate biological invasions? *Frontiers in Ecology and the Environment* **10**, 249–257 (2012).
29. Cloern, J. E. *et al.* Projected evolution of California's San Francisco Bay-Delta-River System in a century of climate change. *PLOS ONE* **6**, e24465 (2011).
30. Herbert, E. R. *et al.* A global perspective on wetland salinization: ecological consequences of a growing threat to freshwater wetlands. *Ecosphere* **6**, art206 (2015).
31. Dettinger, M. Climate change, atmospheric rivers, and floods in California – a multimodel analysis of storm frequency and magnitude changes. *Journal of the American Water Resources Association* **47**, 514–523 (2011).
32. Shields, C. A. & Kiehl, J. T. Simulating the Pineapple Express in the half degree Community Climate System Model, CCSM4. *Geophysical Research Letters* **43**, 7767–7773 (2016).
33. Gasith, A. & Resh, V. H. Streams in Mediterranean climate regions: abiotic influences and biotic responses to predictable seasonal events. *Annual Review of Ecology and Systematics* **30**, 51–81 (1999).
34. Doble, R. C., Crosbie, R. S., Smerdon, B. D., Peeters, L. & Cook, F. J. Groundwater recharge from overbank floods. *Water Resources Research* **48**, (2012).
35. Coats, R., Collins, L., Florsheim, J. & Kaufman, D. Channel change, sediment transport, and fish habitat in a coastal stream: Effects of an extreme event. *Environmental Management* **9**, 35–48 (1985).

Copyright EcoAdapt 2021

36. Trombulak, S. C. & Frissell, C. A. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* **14**, 18–30 (2000).
37. Coffin, A. W. From roadkill to road ecology: a review of the ecological effects of roads. *Journal of Transport Geography* **15**, 396–406 (2007).
38. Forman, R. T. T. & Alexander, L. E. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* **29**, 207–231 (1998).
39. Bauer, S. *et al.* Impacts of surface water diversions for marijuana cultivation on aquatic habitat in four northwestern California watersheds. *PLOS ONE* **10**, e0120016 (2015).
40. Okada, M., Grewell, B. J. & Jasieniuk, M. Clonal spread of invasive *Ludwigia hexapetala* and *L. grandiflora* in freshwater wetlands of California. *Aquatic Botany* **91**, 123–129 (2009).
41. Anderson, R. B. & Lawler, S. P. Behavioral changes in tadpoles after multigenerational exposure to an invasive intraguild predator. *Behav Ecol* **27**, 1790–1796 (2016).
42. Olimpi, E. M., Pasari, J. R., Skikne, S. A., Quadri Barba, P. & Ennis, K. K. Biological invasions. in *Ecosystems of California* (eds. Mooney, H. & Zavaleta, E.) 229–249 (University of California Press, 2016).
43. Aguilera, R. & Melack, J. M. Relationships among nutrient and sediment fluxes, hydrological variability, fire, and land cover in coastal California catchments. *Journal of Geophysical Research: Biogeosciences* **123**, 2568–2589 (2018).
44. Potter, C. Ten years of land cover change on the California coast detected using Landsat satellite image analysis: Part 2—San Mateo and Santa Cruz counties. *J Coast Conserv* **17**, 709–718 (2013).
45. Gilmer, D. S., Miller, M. R., Bauer, R. D. & LeDonne, J. R. California's Central Valley wintering waterfowl: concerns and challenges. in *Transactions of the Forty-seventh North American Wildlife and Natural Resources Conference* (ed. Sabol, K.) 441–452 (U.S. Fish and Wildlife Service, 1982).
46. Dudgeon, D. *et al.* Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* **81**, 163 (2006).
47. Howard, J. K. *et al.* Patterns of freshwater species richness, endemism, and vulnerability in California. *PLOS ONE* **10**, e0130710 (2015).
48. Winter, T. C. The vulnerability of wetlands to climate change: a hydrologic landscape perspective. *Journal of the American Water Resources Association* **36**, 305–311 (2000).
49. Duffy, W. G. & Kahara, S. N. Wetland ecosystem services in California's Central Valley and implications for the Wetland Reserve Program. *Ecological Applications* **21**, S18–S30 (2011).
50. Colloff, M. J. *et al.* Adaptation services of floodplains and wetlands under transformational climate change. *Ecol Appl* **26**, 1003–1017 (2016).
51. Carpenter, S. R. Eutrophication of aquatic ecosystems: bistability and soil phosphorus. *Proceedings of the National Academy of Sciences* **102**, 10002–10005 (2005).

Copyright EcoAdapt 2021