Southern California River and Stream Habitats

Climate Change Vulnerability Assessment Summary

An Important Note About this Document: *This document represents an initial evaluation of vulnerability for river and stream habitats based on expert input and existing information. Specifically, the information presented below comprises habitat expert vulnerability assessment survey results and comments, peer-review comments and revisions, and relevant references from the literature. The aim of this document is to expand understanding of habitat vulnerability to changing climate conditions, and to provide a foundation for developing appropriate adaptation responses.*

Habitat Description

Rivers and streams are powerful drivers of landscape patterns and ecological communities, and provide California's most valuable forest resource: water. Rivers and streams in southern California are primarily fed by precipitation, surface runoff, and groundwater discharge; historically, peak flows and flooding occur in winter and spring, and low- or no-flow conditions often occur in the summer and fall.[1,2] This assessment includes both perennial and ephemeral systems, as well as associated riparian vegetation.

Habitat Vulnerability

Moderate Vulnerability

Low → High

High Confidence

The relative vulnerability of rivers and streams in southern California was evaluated to be moderate by habitat experts due to moderate-high sensitivity to climate and non-climate stressors, moderate exposure to future climate changes, and moderate adaptive capacity. Rivers and streams are sensitive to climate drivers that alter hydrology, water temperature, and water quality. Patterns of high and low streamflows, flooding, and drying are primarily responsible for the dynamic nature of lotic systems. Rivers and streams in southern California already reflect highly variable flow regimes; however, extreme flooding and/or drought events may magnify many processes in the system (e.g., channel incision). Extensive habitat alteration due to non-climate stressors such as dams and water diversions is likely to exacerbate the impacts of climate change. Rivers and streams are considerably degraded throughout most of the region, and hydrologic connectivity is low. This habitat type is adapted to high levels of variability and frequent disturbances, and can recover relatively quickly under natural conditions. However, highly modified streams are slow to recover and are vulnerable to impacts from additional stressors (e.g., invasive species). Overall, rivers and streams are diverse habitats and host many threatened, endangered, and endemic species. Stream improvements and restoration activities could reduce the impact of climate and non-climate stressors and enhance habitat quality.

Sensitivity

Moderate-High Sensitivity

Low → High

High Confidence

Rivers and streams are sensitive to multiple climate drivers, including precipitation, drought, and low stream flows. Rivers and streams are naturally variable systems; however, changes in climate drivers and/or disturbance patterns can alter hydrology and lead to changes in habitat structure and function.[1–5] Reduced water availability and increasingly intermittent flows also impact riparian biotic communities, affecting species composition, diversity, and distribution.[3,6] Anthropogenic stressors, such as dams, water diversions, and invasive species, make this habitat more vulnerable to negative impacts from climate changes, leading to further degradation.[3]

Habitat sensitivity factors and impacts[*]

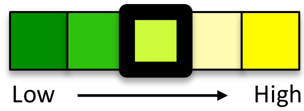
CLIMATIC DRIVERS	Moderate Sensitivity; Moderate Confidence
Precipitation & drought	Rivers and streams are primarily dependent upon precipitation to maintain flow, as well as to recharge soil moisture and groundwater systems. Although they are adapted to annual periods of summer drought, more severe and/or longer droughts can cause more significant changes that lower the ability of the habitat to recover from disturbances.[2,3] Shifts in the amount and timing of precipitation and/or increased drought may result in: • Decreased flow and prolonged duration of low- and no-flow conditions[2] • Altered stream morphology and habitat complexity[2] • Reduced water availability for riparian vegetation and a corresponding increase in drought-tolerant shrubs such as *Tamarix* spp.[3] • Shifts in the composition of macroinvertebrate communities, primarily at the genera and species level[6]
Low streamflows	Variability in annual flow regimes may be the most significant driver of dynamics in Mediterranean river and stream ecosystems.[2,7] However, over the last 20 years researchers have documented a decline in streamflow volumes throughout California,[8] which has been attributed to warmer temperatures.[9–11] Lower streamflows may cause: • Reduced water quality, including increased salinity and/or alkalinity[2] and increased concentrations of pollutants[2] • Increased water temperature[4] and associated declines in cool- and cold-water aquatic species[12,13] • Altered channel structure due to sediment and vegetation encroachment[2] • Increased isolation of pools and stream reaches[2] • Decreased extent of riparian and aquatic habitats[1,2] • Shifts in the composition of macroinvertebrate communities[6]

[*] Factors presented are those ranked highest by habitat experts. A full list of evaluated factors can be found in the River & Stream Habitats Climate Change Vulnerability Assessment Synthesis.

DISTURBANCE REGIMES	Low-Moderate Sensitivity; Moderate Confidence
Wildfire	Wildfires in surrounding upland habitat impacts rivers and streams heavily, primarily through runoff from the forest floor.[5,14] The impacts of wildfire are especially severe when coupled with early spring storms,[14] and can include: • Increased concentrations of ammonium, nitrate, dissolved organic nitrogen, phosphate, sediment, and total suspended solids[14] • Reduced riparian canopy and increased water temperature due to loss of shade[5,15] • Increased occurrence of hypoxic/anoxic conditions • Altered composition of macroinvertebrate communities, including reductions in detrivores and shredders and increases in algivores[5,16] • Altered structure and function of food web[5,16] • Possible extirpation of local fish populations[5,14]
Flooding	Intermittent flooding restores successional cycles for riparian and aquatic biota by scouring accumulated sediment and redistributing substrate and organic matter.[2] Periods of high flow may also restore channel connectivity, homogenize water quality, and alter channel morphology.[2] Shifts in flooding regimes may also impact rivers and streams by causing: • Increased flash floods, mudslides, debris flows, and extended damage[17] • Increased erosion, with episodes of more powerful sediment scour and transport[2] • Increased pollutants washed into streams[18] • Changes in riparian vegetation, including species composition, distribution, and loss[3] • Extirpation of local populations of vertebrates and invertebrates (including invasive species)[7,19,20] • Altered structure and function of food web[7,20]
NON-CLIMATE STRESSORS	Moderate-High Sensitivity and Exposure; High Confidence
Dams & water diversions	Most rivers and streams in southern California have been dammed or diverted for water supply and/or flood control at some point along their reaches.[1] Dams and diversions cause habitat loss due to changes in the volume, duration, timing, and variability of streamflows.[1] These hydrological changes may lead to channel alterations, invasive species establishment, and shifts in species composition.[1,3,21] Dams also act as barriers to migratory species that depend on upstream habitats for spawning and rearing grounds.[18,21]
Invasive & problematic species	Warming conditions, reduced high flow volumes, and extended periods of drying may contribute to increases in the presence of invasive species.[2,16,19] Increased intermittent flows and reduced flooding have been associated with reduced cover, lower species diversity, and shifts in species composition towards drought-tolerant generalist shrubs such as *Tamarix*.[3]

Exposure[†]

Moderate Exposure



High Confidence

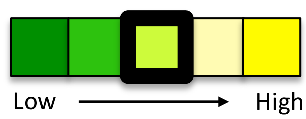
Under changing climate conditions, rivers and streams are likely to be exposed to altered streamflows, changes in the amount and/or timing of precipitation, decreased soil moisture, and increased air temperature. Over the coming century, low flow volumes are projected to decrease and periods of low-flow/no-flow conditions are expected to increase, resulting in extended periods of summer drought.[22] Less frequent but more extreme storms may also increase flash flooding by 30-40%.[23] Stream temperatures across the United States may rise 2-3°C by the end of the century,[24,25] and factors such as flow volume and urbanization can strongly influence water temperature at the watershed scale.[12,26,27] Refugia may occur in high-elevation sites and near seeps and springs, shaded areas, and deep pools that can offer shelter for cool- and cold-water organisms.[13,26,28]

Projected climate and climate-driven changes for Southern California

CLIMATIC DRIVERS	PROJECTED CHANGE
Precipitation & soil moisture	Variable annual precipitation volume and timing, with wetter winters and drier summers; decreased soil moisture
Air temperature	+2.5 to +9°C by 2100
Altered streamflows	Greater flow variability, with increased winter flood volume and frequency, reduced spring flood volume, more extreme low flows and increased duration of low- or no-flow conditions

Adaptive Capacity[‡]

Moderate Adaptive Capacity



High Confidence

Rivers and streams in southern California have been significantly degraded by anthropogenic activities, and may be one of the most disturbed habitats within the study region, especially in lower elevations.[1] Rivers and streams act as wildlife corridors and provide habitat connectivity across the landscape, but significant barriers affect both aquatic species (especially migratory fish) and terrestrial species.[1] Rivers and streams are characterized by high structural and physical diversity, as well as very high species diversity.[29] These systems offer habitat for numerous endemic, rare, and threatened/endangered species,[1,29] and are typically highly valued.

† Relevant references for regional climate projections can be found in the Southern California Climate Overview (http://ecoadapt.org/programs/adaptation-consultations/socal).

‡ Please note that the color scheme for adaptive capacity has been inverted, as those factors receiving a rank of "High" enhance adaptive capacity while those factors receiving a rank of "Low" undermine adaptive capacity.

Habitat adaptive capacity factors and characteristics[§]

FACTORS	HABITAT CHARACTERISTICS
Habitat extent, integrity, & continuity Moderate High Confidence	+ High-elevation mountain streams and headwaters are less degraded, in part because they are not easily accessible[1] - Anthropogenic activities have affected the majority of rivers and streams in southern California[1] - Streambank terraces and riparian areas are in high demand for development and conversion to agriculture[1]
Landscape permeability Low-Moderate High Confidence	- Dams and water diversions are the primary barrier to habitat continuity and dispersal in rivers and streams. - Movement and dispersal of aquatic organisms (especially fish) is also limited by: land use conversion, agriculture, and transportation corridors
Resistance & recovery Low-Moderate Moderate Confidence	+ Rivers and streams are adapted to disturbance and recover quickly from conditions within the natural range of variability[29] +/- Native plants may not be able to withstand increasingly powerful or frequent flash floods - Anthropogenic disturbances may slow natural recovery
Habitat diversity Moderate-High High Confidence	+ High structural diversity, with variable flows and heterogeneous site conditions based on factors such as gradient, substrate, water quality, temperature, and frequent disturbance[2] + Rivers and streams have extremely high species diversity, support hundreds of endemic and threatened/endangered aquatic species state-wide[30] + Rivers and streams also support a wide range of terrestrial birds, mammals, and amphibians because they are adjacent to a variety of terrestrial habitats[31] - Many species have not been evaluated for risk of extinction (especially invertebrates), and most at-risk species do not have federal or state protection[30]
Management potential Moderate-High Moderate Confidence	+ High societal value: Valued for recreational purposes and as a water source for urban and agricultural needs + Rivers and streams provide a variety of ecosystem services: biodiversity, flood and erosion protection, water supply/quality/sediment transport, recreation, grazing, carbon sequestration, air quality, nitrogen retention, fire regime controls,

[§] Characteristics with a green plus sign contribute positively to habitat adaptive capacity, while characteristics with a red minus sign contribute negatively to habitat adaptive capacity.

FACTORS	HABITAT CHARACTERISTICS
	and public health +/- While management actions can help alleviate the impacts of climate change, effective actions will depend on the magnitude and direction of climate changes

Recommended Citation

Hilberg, L.E., W.A. Reynier, and J.M. Kershner. 2017. Southern California River and Stream Habitats: Climate Change Vulnerability Assessment Summary. Version 1.0. EcoAdapt, Bainbridge Island, WA.

This document is available online at the EcoAdapt website (http://ecoadapt.org/programs/adaptation-consultations/socal).

Literature Cited

[1] Stephenson, J. R., & Calcarone, G. M. (1999). *Southern California mountains and foothills assessment: Habitat and species conservation issues* (p. 402). Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. Retrieved from http://www.treesearch.fs.fed.us/pubs/6778

[2] Gasith, A., & Resh, V. H. (1999). Streams in Mediterranean climate regions: Abiotic influences and biotic responses to predictable seasonal events. *Annual Review of Ecology and Systematics*, *30*, 51–81.

[3] Stromberg, J. C., Beauchamp, V. B., Dixon, M. D., Lite, S. J., & Paradzick, C. (2007). Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in arid south-western United States. *Freshwater Biology*, *52*, 651–679.

[4] Webb, B. W., & Nobilis, F. (2007). Long-term changes in river temperature and the influence of climatic and hydrological factors. *Hydrological Sciences Journal*, *52*(1), 74–85.

[5] Cooper, S. D., Page, H. M., Wiseman, S. W., Klose, K., Bennett, D., Even, T., … Dudley, T. L. (2014). Physicochemical and biological responses of streams to wildfire severity in riparian zones. *Freshwater Biology, 60*(12), 2600-2619.

[6] Lawrence, J. E., Lunde, K. B., Mazor, R. D., Bêche, L. A., McElravy, E. P., & Resh, V. H. (2010). Long-term macroinvertebrate responses to climate change: Implications for biological assessment in Mediterranean-climate streams. *Journal of the North American Benthological Society*, *29*(4), 1424–1440.

[7] Meffe, G. K. (1984). Effects of abiotic disturbance on coexistence of predator-prey fish species. *Ecology*, *65*(5), 1525–1534.

[8] Vicuna, S., & Dracup, J. A. (2007). The evolution of climate change impact studies on hydrology and water resources in California. *Climatic Change*, *82*(3-4), 327–350.

[9] Hayhoe, K., Cayan, D. R., Field, C. B., Frumhoff, P. C., Maurer, E. P., Miller, N. L., … Verville, J. H. (2004). Emissions pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences*, *101*(34), 12422–12427.

[10] Hamlet, A. F., Mote, P. W., Clark, M. P., & Lettenmaier, D. P. (2007). Twentieth-century trends in runoff, evapotranspiration, and soil moisture in the western United States. *Journal of Climate*, *20*(8), 1468–1486.

[11] Stewart, I. T., Cayan, D. R., & Dettinger, M. D. (2005). Changes toward earlier streamflow timing across western North America. *Journal of Climate*, *18*(8), 1136–1155.

[12] Nelson, K. C., & Palmer, M. A. (2007). Stream temperature surges under urbanization and climate change: Data, models, and responses. *Journal of the American Water Resources Association*, *43*(2), 440–452.

[13] Ebersole, J. L., Liss, W. J., & Frissell, C. A. (2003). Cold water patches in warm streams: Physicochemical characteristics and the influence of shading. *Journal of the American Water Resources Association*, *39*(2), 355–368.

[14] Morrison, K. D., & Kolden, C. A. (2015). Modeling the impacts of wildfire on runoff and pollutant transport from coastal watersheds to the nearshore environment. *Journal of Environmental Management*, *151*, 113–123.

[15] Beakes, M. P., Moore, J. W., Hayes, S. A., & Sogard, S. M. (2014). Wildfire and the effects of shifting stream temperature on salmonids. *Ecosphere*, *5*(5), 63.

[16] Klose, K., & Cooper, S. D. (2012). Complex impacts of an invasive omnivore and native consumers on stream communities in California and Hawaii. *Oecologia*, *171*(4), 945–60.

[17] Carpenter, T. M., Wang, J., Taylor, S. V., Shamir, E., Sperfslage, J. A., & Georgakakos, K. P. (2007). Surveying flash flood response in mountain streams. *Eos*, *88*(6), 69–72.

[18] Poff, N. L., Brinson, M. M., & Day, J. W. J. (2002). *Aquatic ecosystems & global climate change: Potential impacts on inland freshwater and coastal wetland ecosystems in the United States* (p. 44). Prepared for the Pew Center on Global Climate Change.

[19] Doubledee, R. A., Muller, E. B., & Nisbet, R. M. (2003). Bullfrogs, disturbance regimes, and the persistence of California red-legged frogs. *Journal of Wildlife Management*, *67*(2), 424–438.

[20] Gamradt, S. C., & Kats, L. B. (1996). Effect of introduced crayfish and mosquitofish on California newts. *Conservation Biology*, *10*(4), 1155–1162.

[21] Beechie, T., Imaki, H., Greene, J., Wade, A., Wu, H., Pess, G., … Mantua, N. (2012). Restoring salmon habitat for a changing climate. *River Research and Applications*, *29*(8), 939–960.

[22] Perry, L. G., Andersen, D. C., Reynolds, L. V., Nelson, S. M., & Shafroth, P. B. (2012). Vulnerability of riparian ecosystems to elevated CO2 and climate change in arid and semiarid western North America. *Global Change Biology*, *18*, 821–842.

[23] Modrick, T. M., & Georgakakos, K. P. (2015). The character and causes of flash flood occurrence changes in mountainous small basins of Southern California under projected climatic change. *Journal of Hydrology: Regional Studies*, *3*, 312–336.

[24] Hill, R. A., Hawkins, C. P., & Jin, J. (2014). Predicting thermal vulnerability of stream and river ecosystems to climate change. *Climatic Change*, *125*(3-4), 399–412.

[25] Morrill, J. C., Bales, R. C., & Conklin, M. H. (2005). Estimating stream temperature from air temperature: Implications for future water quality. *Journal of Environmental Engineering*, *131*(1), 139–146.

[26] Webb, B. W., Hannah, D. M., Moore, R. D., Brown, L. E., & Nobilis, F. (2008). Recent advances in stream and river temperature research. *Hydrological Processes*, *22*, 902–918.

[27] van Vliet, M. T. H., Ludwig, F., Zwolsman, J. J. G., Weedon, G. P., & Kabat, P. (2011). Global river temperatures and sensitivity to atmospheric warming and changes in river flow. *Water Resources Research*, *47*(2), W02544.

[28] Matthews, K. R., & Berg, N. H. (1997). Rainbow trout responses to water temperature and dissolved oxygen stress in two southern California stream pools. *Journal of Fish Biology*, *50*, 50–67.

[29] Seavy, N. E., Gardali, T., Golet, G. H., Griggs, F. T., Howell, C. A., Kelsey, R., … Weigand, J. F. (2009). Why climate change makes riparian restoration more important than ever: Recommendations for practice and research. *Ecological Restoration*, *27*(3), 330–338. http://doi.org/10.3368/er.27.3.330

[30] Howard, J. K., Klausmeyer, K. R., Fesenmyer, K. A., Furnish, J., Gardali, T., Grantham, T., … Morrison, S. A. (2015). Patterns of freshwater species richness, endemism, and vulnerability in California. *PloS ONE*, *10*(7), e0130710.

[31] Grenfell, W. E. J. (1988). Riverine. In K. E. Mayer & W. F. Laudenslayer, Jr. (Eds.), *A Guide to Wildlife Habitats of California*. Sacramento, CA: Resources Agency, California Department of Fish and Game.