



Rivers, Streams, and Floodplains

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 rivers, streams, and floodplains 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

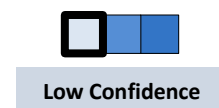
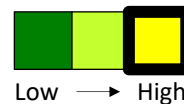
Rivers and streams in the Santa Cruz Mountains region are characterized by rain-dominated hydrological regimes, with variable flows and frequent disturbances¹. Low-lying floodplains adjacent to river and stream channels experience periodic flooding², and often include riparian vegetation such as willow (*Salix* spp.), white alder (*Alnus rhombifolia*), Fremont's cottonwood (*Populus fremontii*), western sycamore (*Platanus racemosa*), valley oak (*Quercus lobata*), and coast live oak (*Q. agrifolia*)^{1,3}. Important floodplains within the study area include those associated with Corte Madera Creek, Pajaro River, Pescadero Creek, and San Gregorio Creek⁴.

Vulnerability Ranking



Rivers, streams, and floodplains are sensitive to climate stressors (e.g., altered streamflow, changes in patterns of precipitation and runoff, increased drought, warmer water temperatures, reduced soil moisture) that impact hydrology, water quality, and the structure, composition, and distribution of riparian vegetation. Although rivers, streams, floodplains, and associated riparian areas are naturally dynamic systems, more frequent and/or severe disturbance events may impact habitat structure and ecosystem processes such as erosion and sediment transport. Non-climate stressors (e.g., development, agriculture, livestock grazing, roads/highways, dams, water diversions, pollutants, timber harvest) can exacerbate habitat sensitivity by altering habitat structure, water availability and quality, and riparian vegetation health and extent. Most rivers, streams, and floodplains within the region have been impacted by one or more of these factors, reducing their ability to recover from climate-driven changes and increasing vulnerability to sudden ecological collapse. However, societal support for the protection and management of these habitats is high, and many restoration efforts are already occurring in the region. Management practices focused on reducing vulnerability to climate change are likely to focus on strategies that enhance structural and functional integrity. These include restoring variable flow regimes and increasing flow volumes in areas impacted by dams and water diversions, reducing nutrient inputs to minimize the risk of harmful algal blooms, restoring incised stream channels, and reconnecting floodplains with mainstem rivers.

Sensitivity and Exposure



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



Rivers, streams, and floodplains are sensitive to climate stressors that impact hydrology and water quality, as well as those that alter the structure, composition, and distribution of riparian vegetation.

Climate Stressor	Trend Direction	Projected Future Changes
Streamflow	▲ ▼	<ul style="list-style-type: none"> Generally, wet season flows are projected to increase and dry season flows are projected to decrease⁵
Precipitation & runoff	▲ ▼	<ul style="list-style-type: none"> Uncertain trends in precipitation and runoff Shorter winters and longer, drier summers likely, with higher interannual variability^{6,7}
Drought	▲	<ul style="list-style-type: none"> Increased frequency of drought years, including periods of prolonged and/or severe drought^{6,8}
Water temperature	▲	<ul style="list-style-type: none"> 1.1–2.0°C (2.0–3.6°F) increase in mean summer stream temperature by the 2090s⁹
Soil moisture	▼	<ul style="list-style-type: none"> Reduced soil moisture likely due to increased evaporative demand^{6,10}

- Altered streamflow (i.e., changes in flow volume and timing)** due to **changes in patterns of precipitation and runoff** and **increased drought** are likely to influence channel geomorphology and physical processes, ultimately impacting aquatic organisms and ecosystem function^{1,11–13}. For instance, reduction or elimination of scouring flows can alter channel structure by changing patterns of sediment deposition and erosion and allowing vegetation encroachment¹⁴. During periods of low precipitation and drought, significant flow declines can disconnect floodplains and stream reaches¹⁵, creating isolated pools with high water temperatures and low dissolved oxygen¹⁶. Although most native species are adapted to periodic droughts^{1,14,17}, severe drought can reduce populations of salmonids and other aquatic organisms through increased competition, predation, and habitat loss^{15,18}. Drought can also cause changes in the composition and structure of riparian vegetation through tree mortality and/or the displacement of riparian vegetation with drought-tolerant upland species^{13,14}.
- Warmer water temperatures** directly influence the physical, chemical, and biological properties of rivers and streams, including dissolved oxygen levels, nutrient cycling, and ecosystem productivity. For aquatic organisms, increased water temperatures can impact physiological processes (e.g., food consumption, metabolic rates, cardiorespiratory performance)¹⁹ as well as

migratory behavior, disease and parasite resistance, and inter- and intra-specific competition²⁰. Warmer water temperatures in disconnected pools are also associated with harmful algal blooms, which impact water quality, alter the food web, and produce toxins^{21–24}. As a result of these changes and other interacting stressors (e.g., loss of riparian vegetation, declining flows), salmonids and many other sensitive aquatic species are likely to experience reduced habitat availability and range contractions^{15,25–27}.

- **Reduced soil moisture** is likely to decrease plant growth and increase mortality, potentially altering riparian vegetation composition and structure¹³. For instance, increased moisture stress within riparian areas could contribute to shifts towards more drought-tolerant and/or non-native species, with riparian species such as cottonwoods and willows likely declining¹³.

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



Although rivers, streams, and floodplains are naturally dynamic systems, more frequent and/or severe disturbance events may impact habitat structure and ecosystem processes (e.g., erosion and sediment transport).

Disturbance Regimes	Trend Direction	Projected Future Changes
Storms & flooding	▲	<ul style="list-style-type: none"> • Increased storm intensity and duration, resulting in more frequent extreme precipitation events and flooding^{6,28,29}
Wildfire	▲	<ul style="list-style-type: none"> • Slight to moderate increase in wildfire risk, particularly in areas of higher rainfall^{30,31}

- Flooding is a key disturbance regime that maintains riparian plant communities and riverine habitat features over the long term^{12,14,17}. However, changes in the **intensity and/or frequency of storms and associated flooding** may slow or stop natural recovery in systems where hydrology and water quality has already been altered by climate and/or non-climate stressors. Severe flooding removes riparian vegetation and alters stream channel morphology by causing erosion and changing patterns of sediment transport^{1,13}. Water quality also declines where large storms transport nutrients and suspended sediments into stream channels, especially when they occur at the start of the rainy season³². Aquatic organisms whose life cycles are adapted to seasonal high flows are likely to be significantly impacted by shifts in the timing of floods that cause mismatches between peak flows and important life history events, such as breeding and migration^{17,33}. This is likely to result in reduced survival and recruitment for these species, impacting food webs and potentially causing extirpation in small and/or isolated populations^{17,33}.
- **Altered wildfire regimes** (e.g., increased extent and/or frequency of high-severity fire) are likely to degrade habitat quality, contributing to greater loss of riparian and aquatic species and preventing population recovery^{34–36}. The loss of riparian vegetation following high-severity fires can significantly increase water temperatures^{35–38} and increase the risk of large landslides and debris flows during post-fire rain events³⁹. Landslides and debris flows also wash ash, sediment, nutrients, and contaminants into rivers and streams^{32,40,41}. Sediment and debris can alter channel structure^{42,43}, while nutrients and toxins can impact the food web and/or directly affect invertebrates, fish, amphibians, and other species^{40,44}. However, wildfire at low to moderate intensities can have positive influences on the ecology and geomorphology of rivers and

streams. For instance, fire can enhance stream productivity as nutrients enter the food web^{34,44} and maintains instream habitat complexity over longer time scales^{36,45}. Fire within riparian areas also enhances wildlife habitat by maintaining early-successional vegetation^{46,47} and can reduce water use by high-density riparian vegetation, increasing runoff into streams⁴⁸.

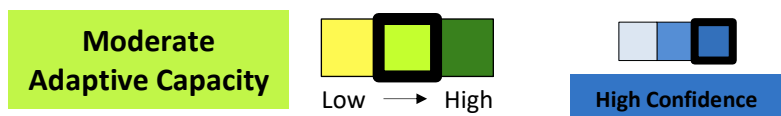
Sensitivity and current exposure to non-climate stressors



Non-climate stressors can exacerbate habitat sensitivity to changes in climate factors and disturbance regimes by altering habitat structure, hydrology, water quality, and riparian vegetation.

- **Pollutants** such as pesticides, excess nutrients, and heavy metals (e.g., mercury associated with historical mining) reduce water quality, with potentially severe impacts on aquatic organisms due to direct toxicity or indirectly through effects on the food chain^{23,24,32}. Excess nutrients have been identified as a major driver of harmful algae blooms, and are likely to be exacerbated by climate-driven increases in water temperature^{23,24}.
- **Roads, highways, and trails** increase runoff of stormwater and pollutants, deliver large amounts of sediment into waterways, and facilitate the spread of invasive species⁴⁹⁻⁵¹. Roads and associated culverts also contribute to channel incision and floodplain disconnection by restricting the movement of sediment and debris as well as that of fish and other aquatic organisms⁴⁹⁻⁵¹.
- **Dams and water diversions** impact flow volume and timing in rivers and streams, which alters thermal regimes, erosion and sediment transport processes, and habitat continuity (e.g., by disconnecting floodplains or preventing upstream movement of anadromous fish)⁵²⁻⁵⁴.
- **Residential and commercial development** within floodplains has resulted in significant habitat loss and fragmentation through draining of floodplains, vegetation removal, channel incision, and loss of floodplain connectivity^{4,55}.
- **Agriculture and livestock grazing** increase water demand for irrigation and livestock, contributing to water withdrawals that reduce flow volume⁵⁶. Where livestock congregate along streambanks and in riparian areas, soil trampling and the loss of riparian vegetation can also increase bank erosion and channel incision⁵⁷.
- **Timber harvest** within riparian areas can increase water temperatures, affecting the growth, development, and survival of fish and invertebrates^{58,59}. Increased erosion and debris slides are associated with logged slopes, and declines in water quality occur where sediment and debris enters streams^{60,61}.

Adaptive Capacity



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



Within the Santa Cruz Mountains region, the San Gregorio and Pescadero Rivers are the only large rivers that remain relatively undeveloped by humans⁴. Most others have been degraded by land-use

conversion to development and agriculture, dams, water diversions, and other anthropogenic changes that alter flow regimes and water quality. Additionally, many areas of floodplains and riparian habitat have been disconnected from mainstem rivers by culverts, water diversions, flood control structures (e.g., dikes and levees), stream channelization, and agricultural use^{62–65}.

Habitat diversity



Geomorphic features and structural elements comprised of sediment, woody debris, and other materials transported by stream flows create diverse physical habitats within rivers, streams, and floodplains¹². Additionally, varied flow depth and velocity alter conditions within a single river on seasonal and annual time scales, contributing to diverse aquatic communities well-adapted to these conditions¹². These include protected species such as steelhead (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), and California red-legged frogs (*Rana draytonii*).

Resistance and recovery



Rivers, streams, and floodplains with intact hydrological regimes are dynamic systems adapted to recovery from a variety of disturbance regimes over time^{14,65}. However, degraded rivers and streams are less able to recover from both climate-driven changes and non-climate stressors⁴³. Altered hydrological regimes, loss of riparian vegetation, and other changes that impact the structure and functioning of these systems may prevent post-disturbance recovery and/or lead to sudden ecological collapse^{1,18,65}.

Many aquatic organisms are well-adapted to the variable flow regimes typical of the region^{1,14,17,33}. For instance, fish, frogs, and other longer-lived species generally exhibit behavioral, morphological, and physiological responses to flooding and low flows¹⁴. Areas of refugia may buffer aquatic species from some environmental stress and/or allow population recovery following episodic disturbances; these include microhabitats within the channel (e.g., gravel, pool-riffle, large woody debris), systems with higher groundwater inputs, and areas shaded by riparian vegetation^{4,66–68}. Floodplains can also act as refugia from disturbances, providing access to additional habitat with low-velocity flows for foraging and spawning^{69,70}.

Management potential



Rivers, streams, and floodplains are critically-important ecosystems that provide water supplies and filtration, flood protection, and habitat for resident and migratory birds, fish, amphibians, and mammals^{1,11,71,72}. These habitats are also valued by the public for the provision of fresh water as well as for recreational opportunities (e.g., swimming, boating, fishing)¹. Generally, societal support (e.g., funding, regulatory mechanisms) for the protection and management of these habitats is high, and many constituency groups are involved in restoration efforts within the region⁴.

Management practices that enhance the structural and functional integrity of rivers, streams, and floodplains may limit climate impacts to some extent, increasing the likelihood of habitat recovery following disturbances⁴. In particular, management efforts may focus on restoring variable flow regimes in areas impacted by dams and water diversions^{53,73} and reducing water withdrawals to maintain or increase stream flows, particularly during the summer months and during periods of drought⁷⁴. Reducing nutrient inputs to lakes and ponds would also minimize eutrophication and limit the risk of harmful algal blooms, particularly during periods of drought²⁴. Restoring incised stream channels generally increases habitat complexity, enhances baseflow, and can reduce water

temperatures^{75,76}. Similarly, restoring connections between floodplains and mainstem rivers increases groundwater recharge and floodwater storage, and provides seasonal habitat for native fish^{63,69,70}.

Recommended Citation

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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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