

Assessing the Climate Vulnerability of the 2022 San Francisco Estuary Blueprint

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Table of Contents

Introduction	2
About the San Francisco Estuary Partnership	2
About the Estuary	2
Assessing the Vulnerability of our Work to Climate Change	3
1. Sea Level Rise	3
Trends and Projections	3
Main Impacts	4
2. Warming Temperatures	4
Trends and Projections	5
Main Impacts	6
3. Changes in Precipitation & Hydrologic Patterns	6
Trends and Projections	7
Main Impacts	9
4. Additive/Compounding Effects	9
5. Other Stressor Considerations	9
6. Evaluation of Climate Risks to Estuary Blueprint Actions	10
References	14

Introduction

About the San Francisco Estuary Partnership

The San Francisco Estuary Partnership (SFEP) was established in 1988 by the State of California and the U.S. Environmental Protection Agency under the Clean Water Act's National Estuary Program when the San Francisco Estuary was designated as an estuary of national significance. The Partnership is a collaboration of local, state, and federal agencies, NGOs, academia and business leaders working to protect and restore the San Francisco Bay-Delta Estuary. The San Francisco Estuary Partnership manages important multi-benefit projects that improve the health of the Estuary. We build partnerships and leverage federal funding with millions of dollars in state and local funds for regional-scale restoration, water quality improvement, and resilience-building projects. The Partnership's work is guided by the development and implementation of the Comprehensive Conservation and Management Plan (also known as the Estuary Blueprint), a comprehensive, collective vision for the Estuary's future.

About the Estuary

The San Francisco Estuary is the largest estuary on the west coast of North America. Its watershed extends from the ridgeline of the Sierra Nevada mountains to the strait of the Golden Gate, including almost 60,000 square miles and nearly 40% of California. Half of the state's surface water supply falls as rain or snow within this region.

The Estuary's waters and wetlands are a biological resource of tremendous importance, providing critical winter feeding habitat for over a million migratory birds, a productive nursery for many species of juvenile fish and shellfish, and a year-round home for a vast diversity of plants and animals. For thousands of years, humans have also lived and thrived along this rich hydrologic corridor, from the Ohlone, Miwok, Southern Pomo, Wappo, and Patwin peoples who first stewarded this land to the diverse international community that inhabits the region today.

San Francisco Bay is made up of four smaller bays. The farthest upstream is Suisun Bay, which includes a vast area of marshes. Suisun Bay lies just below the confluence of the Sacramento and San Joaquin Rivers. Suisun and its neighbor San Pablo Bay, sometimes called the North Bay, are surrounded mostly by rural areas, and are strongly influenced by freshwater outflows from the rivers. The Central Bay is the deepest and saltiest of the four bays. Cities and industries occupy most of its shores. The more shallow South Bay extends south into quiet backwaters surrounded by restored marshes, salt ponds, and office parks and lagoon communities.

Upstream of the Bay, the Sacramento-San Joaquin River Delta is a 1,000 square-mile triangle of diked and drained wetlands. Small remnants of once-extensive tule marshes still fringe the channels that wind between the flat, levee-rimmed farmlands of the Delta's myriad islands. Before it was diked and drained, the Delta gathered in the fresh waters of the Sacramento, San Joaquin, Mokelumne, and Cosumnes rivers and moved them all downstream through a complex array of channels into the San Francisco Bay. Today, the Delta, with its rich farmland, is the engineered junction of one of the nation's

largest plumbing systems, where much of the available fresh water is diverted to supply California's population centers and Central Valley Agriculture.

Assessing the Vulnerability of our Work to Climate Change

Increasing resilience of the Estuary's habitats, human communities, and natural resources to climate change is a central focus of the 2022 update to SFEP's Estuary Blueprint. Nonetheless, many regional goals reflected in the Blueprint are vulnerable to climate impacts. The purpose of this vulnerability assessment is to understand the extent to which climate change could impact the Partnership's ability to successfully undertake the actions laid out in the Estuary Blueprint, which reflect a plan for achieving broad habitat and living resources, resilience, water, and outreach goals by 2050.

We reviewed reports, documents, and scientific literature describing climate change stressors, impacts, and projections for the San Francisco Estuary region to inform the climate risks to Actions in SFEP's Estuary Blueprint. Two major sources that informed this background document are California's Fourth Climate Change Assessment - Bay Area Regional Report and Delta Adapts: Creating a Resilient Future. The latter is a vulnerability assessment for the Sacramento-San Joaquin Delta, and was developed by the Delta Stewardship Council using regional reports from California's Fourth Climate Change Assessment for the Sacramento Valley, San Joaquin Valley, and the San Francisco Bay Area (among other sources).

The background information presented below, in Sections 1 through 5, establishes the context for the evaluation of climate stressors on Estuary Blueprint Actions (Section 6) by identifying the most relevant stressors to include in the assessment, and informs what risks those stressors could have on the Actions.

1. Sea Level Rise

Sea levels are expected to rise due to thermal expansion of ocean waters and melting of glaciers and ice sheets. At the local level, sea level rise varies due to seismic effects on vertical land movement, sediment compaction, marsh accretion, and groundwater fluctuations (Ackerly et al. 2018). Land subsidence due to factors such as diking and draining of wetlands leads to increased rates of relative sea level rise.

Trends and Projections

Over the past 100 years, sea level in the San Francisco Estuary has risen over 0.66 feet (20 cm) according to tide data from the mouth of the Bay (OPC 2018). California's Ocean Protection Council projects a likely range of 0.6 to 1.1 feet (0.2 to 0.3 m) of sea level rise for the San Francisco Estuary by 2050, with an upper range of 1.9 feet (0.6 m). By 2100, sea levels will likely rise by 1.0 feet (0.3 m; RCP 2.6) to 3.4 feet (1.0 m; RCP 8.5), with an upper range of 6.9 feet (2.1 m; OPC 2018). At least 6.6 feet (2.0 m) of sea level rise is inevitable over the next several centuries, even if emissions are reduced drastically, due to the lag in response time of sea level rise with temperature (Ackerly et al. 2018; Clark et al. 2016). There is also a low probability of up to 10.2 feet of sea level rise by 2100 resulting from ice sheet loss (OPC 2018).

In the Delta, sea level rise issues are coupled with ongoing subsidence. Much of the Delta lies below sea level due to land subsidence within Delta islands that were diked and drained (DSC 2021; Deverel et al. 2020). Continued subsidence may lead to rates of relative sea level rise that exceed general sea level rise projections for the San Francisco Estuary.

Main Impacts

Impacts of sea level rise may include coastal flooding, shoreline erosion, and saltwater intrusion (ART 2020). Sea level rise may lead to saltwater intrusion deeper into current brackish and freshwater areas, which may cause shifts in habitats and species. Saltwater intrusion is managed by releases of stored water, but may compromise freshwater quality during droughts (DSC 2021).

Frequency and magnitude of El Niño events will have a major influence on coastal hazards, including nuisance flooding, due to seasonally elevated sea levels and greater winter wave energy associated with El Niño combined with background sea level rise. Past examples have shown the severe damages that high sea levels combined with storm surge during El Niño events can have on shorelines in the Bay (Ackerly et al. 2018; Ryan et al. 1999).

Ecosystems currently protected by levees or berms are at risk of habitat loss/conversion due to levee overtopping resulting from sea level rise and storm events. While these concerns apply across the Estuary (one example in the Bay being berms/levees surrounding managed ponds), levee overtopping is a particular concern in the Delta, where large areas and segments of the population rely on a complex system of levees for flooding protection. With no change in Delta levees by 2050, about 33% of Delta land and 10% of the Delta population will be at risk of flooding due to levee overtopping during a 100-year flooding event (DSC 2021). Subsidence is another key aspect of the Delta's climate vulnerability. While subsidence rates have slowed since the early 20th century, past land management practices have resulted in areas with large elevation differences, which increase vulnerability of levees. By 2085, impacts associated with sea level rise are expected to drown or convert all remaining Delta tidal wetland ecosystems into other plant communities (DSC 2021).

2. Warming Temperatures

Average air and water temperatures are expected to increase through the end of the century, and there may be more frequent and severe extreme heat events (DSC 2021).

Trends and Projections

In the Bay Area between 1950 and 2005, average annual maximum temperature (annual average of the highest temperature on each day of the year) increased 1.7°F. Temperatures in the Bay Area are projected to increase by about 3.3°F (RCP 4.5) to 4.4°F (RCP 8.5) by mid-century (Fig. 1; Ackerly et al. 2018). Some spatial variability is expected, with inland areas warming more than coastal areas (Lebassi et al. 2009). Extreme heat events are also projected to increase. Average hottest day of the year is projected to increase by 3.9°F (RCP 4.5) to 6.3°F (RCP 8.5) in cooler coastal areas, and by 6.4°F (RCP 4.5) to 10°F (RCP 8.5) in more inland parts of the Bay (Fig. 2). Changes in fog and sea breeze will impact coastal temperature changes, but the influence of climate change on these features is not well-understood (Ackerly et al. 2018; see Other Stressor Considerations).

Average daily maximum temperature in the Delta could increase by 5.1°F (RCP 4.5) to 8.1°F (RCP 8.5) by the end of the century (Fig. 3). Similar increases are expected for average daily minimum temperatures. Delta-wide, the average number of extreme heat days is projected to increase from the historical 4-5 days per year to 24-41 days per year, depending on the emissions scenario. Yolo and San Joaquin counties may experience even greater numbers of extreme heat days (DSC 2021).

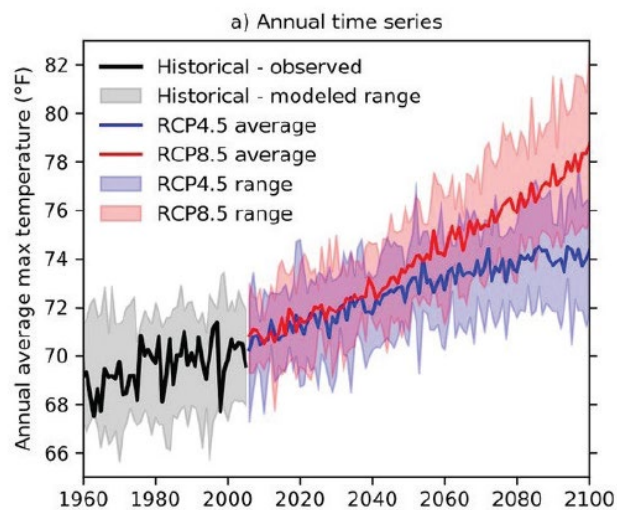


Figure 1. Observed historical (black), modeled historical (grey), and projected future (RCP 4.5 - blue, RCP 8.5 - red) annual average maximum temperature over the Bay Area. Solid black line represents observed annual average maximum temperature, while solid blue and red lines represent model averages for the RCP 4.5 and 8.5 scenarios (figure from Ackerly et al. 2018).

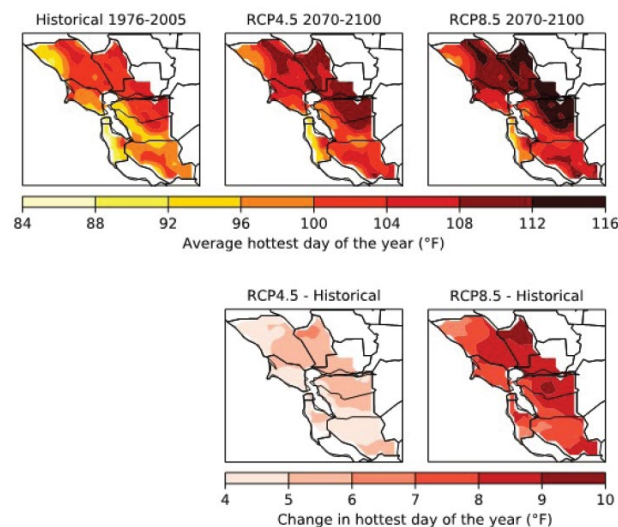


Figure 2. Average hottest day of the year in the Bay Area in the past (1976-2005) and under RCP 4.5 and 8.5 scenarios. Change in hottest day of the year is calculated as late 21st century minus historical (°F) (figure from Ackerly et al. 2018).

There will be subregional differences in warming, with lower elevations warming more slowly than higher elevations and areas that are more inland (DSC 2021; Lebassi et al. 2009). The Bay Area, including Suisun Bay, will remain cooler than the Delta, and the North Delta will be cooler than the South Delta. The Delta, which commonly experiences summer heat waves, may be more impacted by increases in extreme heat days than the Bay (DSC 2021).

Main Impacts

Impacts may result from warmer average air and water temperatures as well as acute events linked to temperature changes, such as extreme heat, flooding, and drought.

Temperature increases will likely lead to longer and deeper droughts (Ackerly et al. 2018). Warmer average temperatures and more extreme heat days may cause stress to species and changes in ecosystem dynamics. Of the various climate stressors, warmer temperatures pose the greatest risk to Delta water supply, because more precipitation will occur as rain rather than snow, and cannot be captured and stored due to the need to provide flood protection. Snowmelt may also occur earlier in the spring, which may decrease the freshwater flows available in summer and fall (DSC 2021).

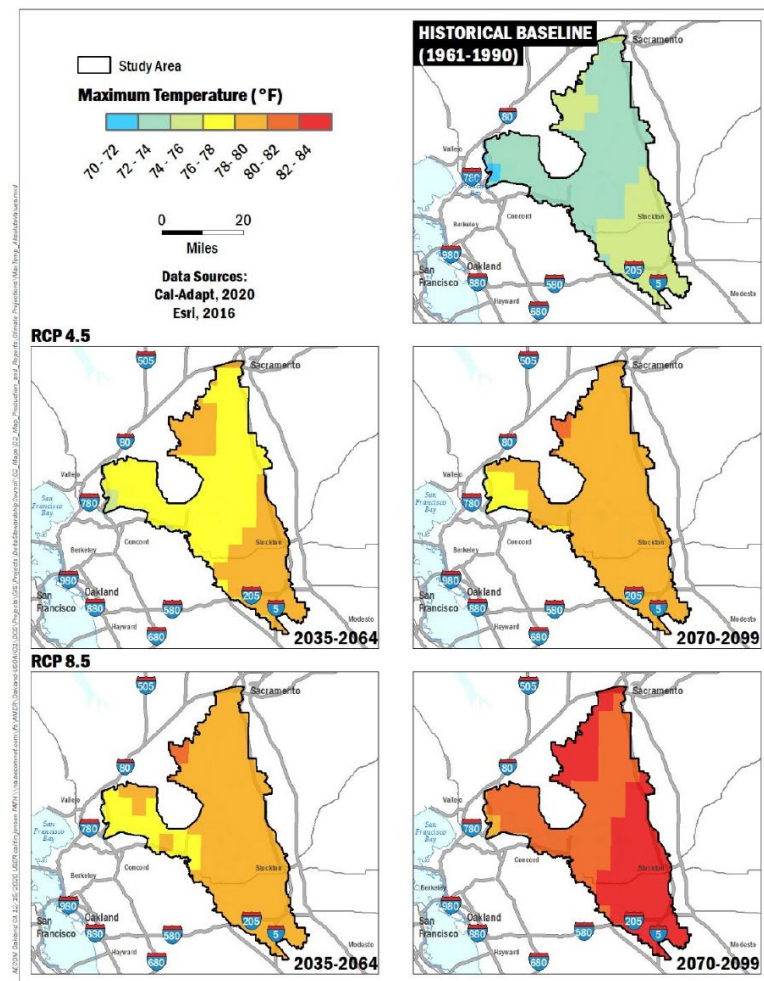


Figure 3. Average daily maximum temperature in the Delta in the past (1961-1990) and mid- and late-century projections under RCP 4.5 and 8.5 scenarios (figure from DSC 2021).

3. Changes in Precipitation & Hydrologic Patterns

Climate change is expected to affect the frequency and intensity of precipitation, as well as hydrologic patterns.

Trends and Projections

Precipitation year-to-year is highly variable in California, making it difficult to detect and project trends. Precipitation is also one of the least certain aspects of climate models (DSC 2021). While downscaled model projections show slight increases in average annual precipitation for the Bay Area and Delta, these increases are negligible in the context of the nearly 50-inch difference in rainfall between the driest and wettest years (Fig. 4; Ackerly et al. 2018; DSC 2021).

Most precipitation in California occurs from October through April, and climate change is projected to shorten this rainy season, with decreases in both fall and spring precipitation (DSC 2021; Swain et al. 2018). Large storms or atmospheric river events contribute an outsized proportion of total precipitation in the state (Dettinger 2016). Extended dry periods can be interspersed between these wet events (DSC 2021). Climate models suggest that this pattern will become more pronounced, with the wettest days representing an even greater share of total annual precipitation in the future (DSC 2021; Dettinger 2016). Very wet rainy seasons may become about 2.5 times more frequent and very dry rain seasons may become about 2 times as frequent by 2100. Frequency of “precipitation whiplash” events (rapid transitions from extremely dry to extremely wet) may increase by about 25% by 2100 (DSC 2021; Swain et al. 2018).

The degree to which precipitation extremes will be enhanced is a current research area (Ackerly et al. 2018). Due to a link with warming temperatures (see Additive/Compounding Effects), atmospheric rivers may become more intense. There may

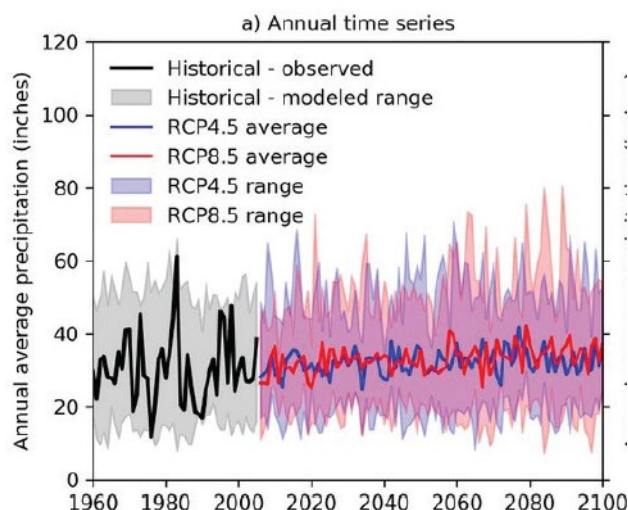


Figure 4. Observed historical (black), modeled historical (grey), and projected future (RCP 4.5 - blue, RCP 8.5 - red) annual average precipitation (inches) over the Bay Area. Solid black line represents observed annual mean precipitation, while solid blue and red lines represent model averages for the RCP 4.5 and 8.5 scenarios (figure from Ackerly et al. 2018).

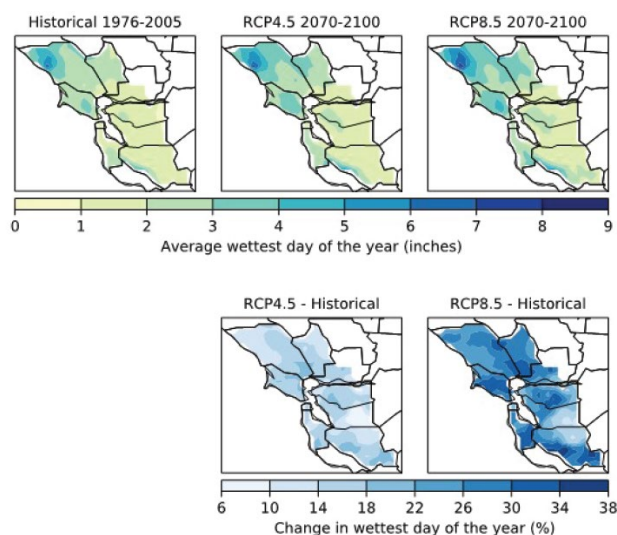


Figure 5. Average wettest day of the year in the Bay Area in the past (1976-2005) and under RCP 4.5 and 8.5 scenarios. Change in wettest day of the year is calculated as late 21st century minus historical, as a percent (figure from Ackerly et al. 2018).

also be a greater number and longer peak season of these events (DSC 2021). Extreme prolonged precipitation events may also become about 3-5 times more frequent by 2100 (DSC 2021; Swain et al. 2018).

Average annual precipitation in the Bay Area is projected to increase by 2.5 inches/year (RCP 4.5) to 4.6 inches/year (RCP 8.5) by 2100 (Ackerly et al. 2018). Given interannual variability, there is very high confidence in “reoccurring and persistent hydrological drought” unless adaptation measures are put in place, such as improved water-use efficiency and water storage (Ackerly et al. 2018; Wehner et al. 2017). The North Bay generally receives the most rainfall, and this trend is expected to continue with climate change (Fig. 5).

Average annual precipitation within the Delta is projected to increase by approximately 1.5 inches (RCP 4.5) to 3.0 inches (RCP 8.5) by 2100 (DSC 2021; Ackerly et al. 2018). Precipitation also varies geographically within the Delta. Suisun Bay and the North Delta experience an average of 22 inches/year, while the South Delta experiences an average of 8 inches/year (DSC 2021). Taking into account the regional differences, Suisun Bay and the North Delta will likely experience the largest increases, while the Central and South Delta may see little to no change in precipitation on average (Fig. 6; DSC 2021).

Precipitation in the greater Sacramento-San Joaquin watershed, which is primarily snowfall in the Sierra Nevada, has a major impact on hydrology in the Delta. Given projected temperature increases, it is very likely that Sierra snowpack will continue to decline due to climate change, with impacts on water supplies (see Additive/Compounding Effects; Ackerly et al. 2018; Mote et al. 2018; Wehner et al. 2017).

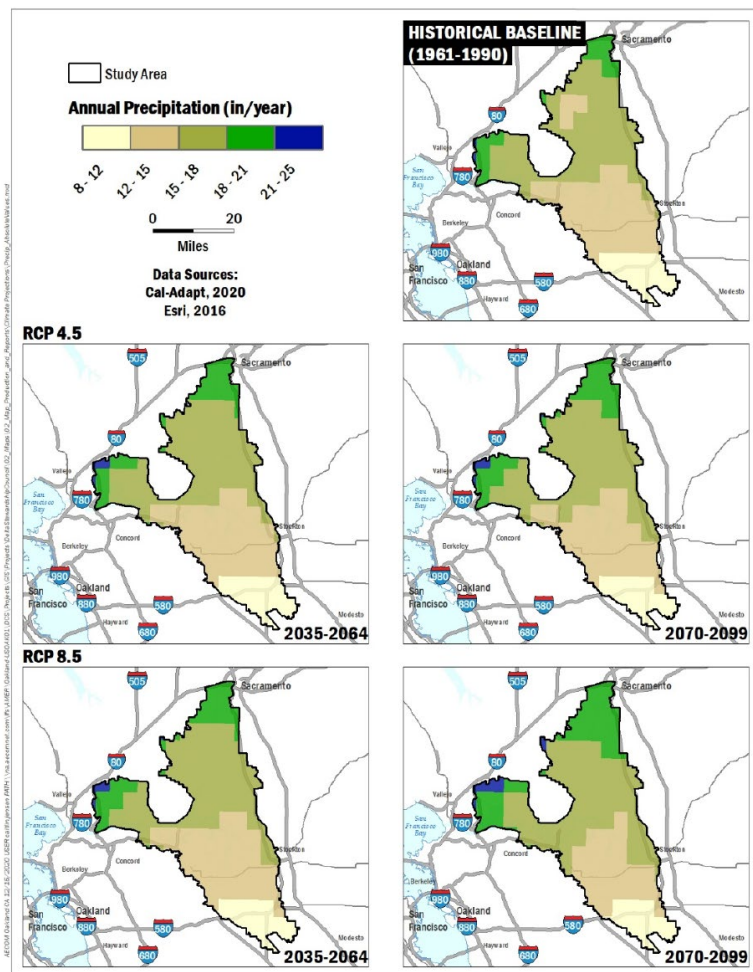


Figure 6. Changes in annual average precipitation in the Delta from the past (1961-1990) to mid- and late-century projections under RCP 4.5 and 8.5 scenarios (figure from DSC 2021).

Main Impacts

Flooding is a major hazard associated with precipitation changes. Winter storms will likely become more intense, and can lead to heavy rainfall and high flood risk (Ackerly et al. 2018). Increases in winter/early spring rainfall in the Sierra Nevada, due to warming temperatures that result in an increasing proportion of precipitation falling as rain rather than snow, may lead to more frequent and extreme high runoff events in the Delta. Peak freshwater inflows to the Delta may increase by about 45% by mid-century and by 80% by end of century as a result of increases in frequency and magnitude of high streamflow discharge. Future runoff behavior across the Delta watershed is an area of active research (DSC 2021).

Other changes in precipitation and hydrologic patterns, such as reduced spring and fall precipitation and increased interannual variability, will also impact freshwater supplies and the species and habitats that depend on them. Reduction of reservoir storage & exports of water from the Delta is expected in all years, leading to greater water shortages (especially in dry years) and lower reliability of water exports. Precipitation changes may stress species, favor less diverse assemblages, and lead to increases in non-native species (DSC 2021). Changes in precipitation and hydrologic patterns will also affect sediment transport, and in turn, the habitats that rely on sediment supply from rivers and the Delta (Dusterhoff et al. 2021).

4. Additive/Compounding Effects

The climate stressors described in Sections 1-3 will have several additive and compounding effects.

Warming temperatures will interact with precipitation by causing more precipitation in the Sierra Nevada to fall as rain rather than snow. Reduction of Sierra snowpack (particularly in the spring) has been observed and is projected to continue (Mote et al. 2018). This will result in earlier peak runoff, with less freshwater flowing into the Delta and Bay during summer and fall. Combined with potential increases in interannual variability in precipitation amount, this change in runoff timing may lead to increasing frequency and intensity of high runoff events in the Delta during the rainy season. Increasing air and sea surface temperatures have also been linked to increasing intensity of atmospheric rivers (wetter, longer, wider) that can lead to higher precipitation rates (DSC 2021).

Sea level rise will also interact with precipitation changes. Sea level rise may impede drainage or cause back-up into storm drain systems when increased precipitation discharges to tidally-influenced areas. Peak water level events will also increase in frequency and magnitude in the Delta (DSC 2021).

5. Other Stressor Considerations

Other stressors that may impact the San Francisco Estuary include wind, fog, acidification, and wildfire, though this list is not exhaustive.

Wind patterns will likely be impacted by temperature changes, and wind is considered a secondary stressor in the Delta Adapts vulnerability assessment (DSC 2021). Warming summer air temperatures inland may enhance sea breezes driven by temperature differences between inland and coastal areas.

These wind patterns may offset local summer temperatures in some areas (DSC 2021; Lebassi et al. 2009).

Fog is a well-known characteristic of the Bay Area, and ground fog (“tule fog”) also commonly occurs in the Delta. Studies suggest that coastal fog has become less frequent, but the link to climate change is unclear because of the complex interactions between temperature and humidity that lead to fog formation (Ackerly et al. 2018). Changes in air pollution levels may also impact fog formation (DSC 2021). One model predicts a 12-20% reduction in California coastal fog from 1900 to 2070 (O'Brien et al. 2013). Fog is important for cooling, shading, and water supply. The effects of climate change on fog, and resulting impacts on ecosystems, is a growing area of study (Ackerly et al. 2018).

Acidification is commonly included as a stressor in vulnerability assessments. Acidification affects some sensitive organisms and habitats. However, less is known about acidification in the San Francisco Estuary than about changes in sea level rise, temperature, and precipitation and hydrologic patterns. In SFEP’s previous Comprehensive Conservation and Management Plan, the 2016 Estuary Blueprint, status and impacts of ocean acidification in the San Francisco Estuary were identified as information gaps that make prioritization for this issue unclear.

Fire risk is projected to increase in most of the Bay Area as a result of warming temperatures and expansion of the urban-wildland interface. Fire risk may decline in areas that become more heavily urbanized. Studies show evidence that climate change (warming temperatures, drought) has increased the area burned by fires in the Western U.S. However, as with storms and hurricanes, the contributions of climate change to individual fires cannot be clearly pinpointed. Urban fires can release toxins that directly impact invertebrates, fish, amphibians, and other species. Fine sediments can impact spawning habitat for threatened & endangered salmonids (Ackerly et al. 2018).

6. Evaluation of Climate Risks to Estuary Blueprint Actions

The following spreadsheet evaluates the risks that the following climate stressors pose to the Actions in the San Francisco Estuary Partnership’s Estuary Blueprint (2022 Update): sea level rise, warming temperatures, and changes in precipitation & hydrologic patterns. The 25 Actions represent regional priorities to achieve a healthy, resilient Estuary by 2050. SFEP and partners carry out discrete Tasks over a five-year period to advance the Actions. This vulnerability assessment was developed concurrently with the 2022 Estuary Blueprint update, and many Tasks and Actions represent initiatives to directly address climate vulnerabilities (as reflected in the “Near-Term Adaptation Strategy” column).

Action #	Action	Climate Stressors	Risks	Near-Term Likelihood (5-Year)	Long-Term Likelihood (by 2050)	Consequences	Near-Term Adaptation Strategy (supplemental)
1	Plan for increased climate resiliency that incorporates natural resource protection	No direct stressors (planning-level activity)	No direct risks	N/A	N/A	N/A: This Action is focused on planning, capacity-building, and science.	Tasks within this Action reflect regional adaptation efforts to address climate risks to the Estuary.
2	Elevate frontline and Indigenous communities in planning for and benefiting from a healthy, resilient Estuary	No direct stressors (planning-level activity)	No direct risks	N/A	N/A	N/A: This Action is focused on partnerships, capacity-building, and advancing equity in planning and projects.	Tasks within this Action reflect regional efforts to address equity issues, including climate adaptation.
3	Overcome challenges to accelerate implementation of climate adaptation projects that prioritize natural and nature-based strategies	No direct stressors (planning-level activity)	No direct risks	N/A	N/A	N/A: This Action is focused on funding, capacity-building, planning, and regulatory policies and processes.	Tasks within this Action reflect regional efforts to overcome financial, capacity, and regulatory barriers to natural and nature-based resilience strategies.
4	Implement climate adaptation projects that prioritize natural and nature-based strategies	Sea level rise; Warming temperatures; Changes in precipitation & hydrologic patterns	Several habitat types may be included in the adaptation projects that are the focus of this Action. See Risks for Actions 9, 11	LOW	LOW	MEDIUM: Projects designed specifically for climate adaptation, such as gently sloping horizontal levees, may still face some of the same consequences as the naturally-occurring habitat types they emulate (see Actions 9, 11).	Tasks within this Action reflect regional efforts to advance shoreline climate adaptation strategies that provide multiple benefits.
5	Restore watershed connections to the Estuary to improve habitat, flood protection, and water quality	Changes in precipitation & hydrologic patterns	Drought may limit water supplies that flow into the Estuary	MEDIUM	HIGH	MEDIUM: Water supply limitations due to severe droughts have the potential to limit reconnections of watersheds to the Estuary.	While climate stressors may make it more difficult to reconnect watersheds to the Estuary, this Action will help increase resilience of habitats to sediment supply issues associated with climate change (see Action 6).
6	Manage sediment and soil on a regional scale and advance beneficial use	Changes in precipitation & hydrologic patterns	Sediment supply limitations. Changes in precipitation & hydrologic patterns will have impacts on natural sediment supply from rivers and the Delta	LOW	HIGH	HIGH: Shifts in sediment supply may include increases in supply from some sources and decreases from others. The ability to maintain and enhance Estuary habitats will be impaired for areas where sediment supply does not meet the needs of habitats.	The vulnerability of Estuary habitats to reduced sediment supplies highlights the importance of this Action, which focuses on advancing beneficial reuse and exploring other opportunities to supplement natural sediment supplies. Other Actions (e.g. Action 5) also address sediment supply issues resulting from climate stressors.
7	Decrease carbon emissions and subsidence in the Delta and increase carbon sequestration on natural and agricultural lands	Changes in precipitation & hydrologic patterns	Drought may reduce primary productivity or lead to mortality of plants	MEDIUM	HIGH	MEDIUM: Reduced primary productivity or plant mortality during drought could result in net carbon loss to the atmosphere from some land cover types, though some management practices can reduce these losses.	Tasks within this Action focus on exploring economic incentives and understanding carbon storage in different habitats to prioritize management, such as restoration of specific habitat types, that enhances carbon storage.
8	Implement a Wetlands Regional Monitoring Program	No direct stressors (planning-level activity)	No direct risks	N/A	N/A	LOW: Large-scale loss of tidal marsh and/or loss of funding for protection, restoration, and enhancement may reduce support for the Wetlands Regional Monitoring Program.	Climate stressors will not directly affect the ability to establish the Wetlands Regional Monitoring Program. Rather, the vulnerability of tidal wetlands to climate stressors (see Action 10) makes the role of the WRMP in evaluating changes and recommending management actions more essential.
9	Protect, restore, and enhance intertidal, tidal flat, and subtidal habitats	Sea level rise; Warming temperatures; Changes in precipitation & hydrologic patterns	Increased inundation depth. Increases in inundation depth and time due to SLR may be intolerable for the ecosystem engineers associated with these habitats in their current locations Heat stress. Warming temperatures may have physiological impacts on organisms and change species distributions, including local extinctions and species introductions Sediment supply limitations. Sediment supply, crucial for maintaining mudflats, is affected by changes in precipitation & hydrological patterns and may not be sufficient to meet sediment needs of mudflats Erosion. More extreme precipitation events and increased tidal range may increase erosion and alter shorelines and mudflats	LOW	HIGH	MEDIUM: Intertidal and subtidal habitat types may not persist in their current locations due to changes in inundation depth, temperature, sediment supply, and erosion. Habitats requiring continual sediment supply, such as intertidal mudflats, may be particularly at risk. However, tidal marshes drowning due to SLR will provide migration opportunities for mudflats. The effects of climate stressors on these habitats are hard to predict given limited understanding of the drivers of some current habitat distributions, like eelgrass beds.	Tasks within this Action focus on understanding habitat suitability for eelgrass in the context of climate change and increasing the pace and scale of habitat restoration for multiple intertidal and subtidal habitat types. Other Actions reduce climate risks to this Action by addressing sediment supply issues (Action 6) and monitoring species introductions (Action 15)
			Tidal marsh drowning. Tidal marshes at elevations that currently support marsh vegetation may drown due to SLR	LOW	HIGH		

Action #	Action	Climate Stressors	Risks	Near-Term Likelihood (5-Year)	Long-Term Likelihood (by 2050)	Consequences	Near-Term Adaptation Strategy (supplemental)
10	Protect, restore, and enhance tidal marsh habitat	Sea level rise; Changes in precipitation & hydrologic patterns	Sediment supply limitations. Sediment accretion is crucial for wetland vegetation establishment and adaptation to SLR, and natural sediment supply is impacted by changes in precipitation & hydrological patterns and may not be sufficient to meet sediment needs of marshes Shoreline erosion. More extreme precipitation events may lead to shoreline erosion and wetland loss	LOW MEDIUM	HIGH HIGH	HIGH: Long-term projections for SLR & sediment supply indicate large-scale loss of tidal marsh without changes in management. Shoreline erosion over time will be a source of additional losses. Regional differences in sediment supply indicate that some marshes may be more able to adapt to SLR than others.	Tasks within this Action focus on increasing the pace and scale of tidal marsh restoration to keep pace with SLR. Other Actions reduce climate risks to this Action by developing information to improve restoration in the face of climate change (Action 8), address sediment supply issues (Action 6), and protect migration space for wetlands (Action 11).
11	Protect, restore, and enhance estuarine-upland transition zones and adjacent upland ecosystems	Sea level rise	Transition zone narrowing. Transition zones will be compressed between wetlands and developed areas as sea levels rise	LOW	HIGH	HIGH: Already-narrow transition zones in areas of steep land and/or smaller tidal range are not expected to persist under SLR over the long term. Wide, gently sloping transition zones will last longer. Abandonment of developed areas due to SLR may provide accommodation space for transition zones.	Tasks within this Action focus on increasing the pace and scale of transition zone restoration and protection, including connecting transition zone projects to tidal marsh, uplands, and diked historic baylands where feasible to increase future marsh and transition zone migration opportunities.
12	Maximize habitat benefits of managed ponds and wetlands	Sea level rise; Changes in precipitation & hydrologic patterns	Managed pond flooding. SLR and erosion from large wind-waves may result in overtopping and/or failure of levees surrounding managed ponds. Intense storm events and SLR may also put additional stress on water control structures and pose maintenance challenges, such as hindering the ability to drain ponds as needed for management.	LOW	HIGH	HIGH: Long-term viability of managed ponds is uncertain due to these climate change risks.	Tasks within this Action will help evaluate the costs and benefits of maintaining managed ponds under climate change scenarios to inform future management.
13	Protect, restore, and enhance seasonal wetlands	Warming temperatures; Changes in precipitation & hydrologic patterns	Shorter inundation period. Warmer temperatures and increases in drought frequency and severity may result in a shorter period of inundation in seasonal wetlands, causing stress for species that depend on them.	MEDIUM	HIGH	MEDIUM: Heat and drought stress may have long-lasting impacts on persistence of existing seasonal wetlands.	Actions that protect other habitat types and improve habitat connectivity may reduce the consequences that climate risks pose to seasonal wetlands.
14	Conserve and enhance riparian and in-stream habitats throughout the Estuary's watersheds	Sea level rise; Warming temperatures; Changes in precipitation & hydrologic patterns	Heat and drought stress. Warmer temperatures and increases in drought frequency and severity can affect stream flows and temperatures, causing physiological stress, disease, and other impacts Exotic species. There is a potential for shifts in community composition towards exotic fish species with greater thermal tolerance Erosion. More extreme precipitation events may lead to erosion Flooding. More extreme precipitation events, particularly combined with SLR and groundwater rise, may lead to flooding of riparian areas. SLR/groundwater rise may push "head of tides" deeper into watersheds, leading to increased risk of overbank, riverine flooding where floodplains are not available.	MEDIUM LOW MEDIUM MEDIUM	HIGH HIGH HIGH HIGH	MEDIUM: Heat and drought stress, exotic species, erosion, and flooding may have additive/compounding effects on existing riparian habitats and species. In particular, "heads of tides" moving deeper into watersheds and intersecting with other risks may cause permanent changes to riparian habitat projects.	Accelerating the pace and scale of in-stream and riparian habitat restoration through this Action will play a critical role in climate adaptation, including flood reduction and temperature management.
15	Minimize the impact of invasive species	Warming temperatures; Changes in precipitation & hydrologic patterns	Habitat suitability. Warming temperatures and changes in precipitation & hydrologic patterns may make new areas suitable for invasive species establishment and enable existing invasive species to proliferate. New pathways of spread. Warming and more extreme weather conditions can create new pathways of spread (e.g. travel, trade, and extreme weather events may influence invasive species dispersal). If the Arctic shipping routes open up and are heavily used, that will open up a new pathway. Flooding or tornados can move species between waterways that were not closely connected previously.	MEDIUM MEDIUM MEDIUM	HIGH HIGH HIGH	HIGH: The San Francisco Estuary is already highly invaded, and changes in habitat suitability and new pathways for spread may result in increases in abundance and distribution of existing invasive species, as well as new invasive species establishment, despite efforts to minimize invasive species impact.	Ecological resilience to climate change can be improved by preventing the adverse impacts of invasive species, making it even more urgent to implement the prevention and Early Detection and Rapid Response tasks in this Action.
16	Improve the timing, amount, and duration of freshwater flows critical to Estuary health	Sea level rise; Warming temperatures; Changes in precipitation & hydrologic patterns	Salinity intrusion may impair freshwater sources Drought. Longer dry seasons and more frequent and severe droughts as a result of climate stressors may reduce the quantity and quality of freshwater available for flow, while also increasing demand for freshwater	LOW MEDIUM	HIGH HIGH	MEDIUM: Frequent, severe drought combined with salinity intrusion may preclude improvements in timing, amount, and duration of freshwater flows.	Tasks within this Action will improve understanding of the values, ecological connections, and stakeholder priorities associated with freshwater flows. Information-sharing and capacity-building tasks will improve the ability of management to achieve the identified priorities under current and future scenarios. Tasks may improve regulations regarding management of flows for ecological protection.
17	Reduce water use around the Estuary	Warming temperatures	Increased demand. Warmer temperatures may drive greater water demand	LOW	MEDIUM	LOW: While there may be some increases in water demand, they are not expected to exceed the potential reduction opportunities pursued through this Action.	Tasks within this Action explore various avenues for reducing water demand to help deal with future droughts and other freshwater impacts associated with climate change.

Action #	Action	Climate Stressors	Risks	Near-Term Likelihood (5-Year)	Long-Term Likelihood (by 2050)	Consequences	Near-Term Adaptation Strategy (supplemental)
18	Expand the use of recycled water	Sea level rise; Warming temperatures; Changes in precipitation & hydrologic patterns	<p>Unpredictable supply. Changes in water use in response to drought may result in an inconsistent and unpredictable supply of recycled water</p> <p>Flooding and salinity intrusion. Wastewater treatment infrastructure located along the shoreline may be vulnerable to flooding and salinity intrusion from rising sea levels and groundwater</p>	LOW	MEDIUM	HIGH: Numerous wastewater treatment plants are projected to be impacted by rising bay and groundwater levels by 2050, with consequences including costly protection, retrofitting, or relocation measures. If salinity intrusion impacts sewer systems, there will be even greater cost increases associated with water recycling.	This Action addresses water supply issues that will be exacerbated by climate change.
19	Manage stormwater with low impact development and green stormwater infrastructure	Changes in precipitation & hydrologic patterns	Drought may impact vegetation in low impact development/green stormwater infrastructure installations	MEDIUM	MEDIUM	LOW: While some loss of vegetation or increased maintenance requirements may occur, they are not expected to outweigh the benefits or preclude the use of low impact development/green stormwater infrastructure	Green stormwater infrastructure/low impact development (GI/LID) help reduce flooding and runoff during storm events, which are expected to increase in frequency and severity with climate change. Tasks within this Action will expand the use of GI/LID through developing planning & tracking tools, technical materials, policy recommendations, and financing strategy guidance.
20	Advance nutrient management in the Estuary	Warming temperatures; Changes in precipitation & hydrologic patterns	<p>Dissolved oxygen capacity. Warming temperatures may reduce the amount of dissolved oxygen in water</p> <p>Stratification. Longer heat waves or intense precipitation events may lead to stratification of the Estuary's waters</p>	LOW	MEDIUM	MEDIUM: Fish in shallower areas may be adversely impacted by low dissolved oxygen in warmer waters. Stratification resulting from climate stressors may make algal blooms a more persistent problem, requiring changes to nutrient management strategy.	Tasks under this Action focus on understanding nutrient loading and algal blooms in the Estuary to inform management in response to climate change.
21	Address emerging contaminants in the Estuary's waters	Sea level rise; Changes in precipitation & hydrologic patterns	Contaminant mobilization. Sea level rise, and associated groundwater rise, may mobilize new sources of contaminants	LOW	MEDIUM	HIGH: Dozens of hazardous waste sites in the region are at risk of nuisance flooding due to sea level rise, potentially resulting in mobilization of new contaminants.	Task 1-8 will be a first step in studying the potential influence of rising sea level on contaminated sites around the Estuary.
22	Reduce human health risks due to legacy contaminants and contaminants in fish	Sea level rise	Contaminant mobilization. Sea level rise, and associated groundwater rise, may mobilize new sources of contaminants	LOW	MEDIUM	HIGH: Dozens of hazardous waste sites in the region are at risk of nuisance flooding due to sea level rise, potentially resulting in mobilization of new contaminants and associated health impacts for people who are exposed.	Task 1-8 will be a first step in studying the potential influence of rising sea level on contaminated sites around the Estuary.
23	Reduce trash input into the Estuary	Changes in precipitation & hydrologic patterns	Extreme storm events associated with climate change may bring greater volumes of trash into the Estuary	MEDIUM	HIGH	MEDIUM: As climate change creates more extreme and unpredictable storms, trash input to the Estuary via storm drains and waterways may increase.	Tasks under this Action will improve monitoring and understanding of effective strategies to reduce this risk. Tasks focus on reducing trash at the source, which will not be directly impacted by climate change.
24	Provide equitable public access and recreational opportunities compatible with wildlife	Sea level rise; Warming temperatures; Changes in precipitation & hydrologic patterns	<p>Harmful algal blooms (HABs) associated with warming temperatures and drought may become more frequent</p> <p>Invasive plants may spread with warmer temperatures</p> <p>Erosion and flooding may increase due to extreme precipitation events</p> <p>Open space availability. Sea level rise and other climate impacts may change the quantity, quality, and location of open space</p>	LOW	MEDIUM	MEDIUM: HABs and proliferation of invasive vegetation have impacted recreation in the past, and could impact the Bay Area Water Trail (and potentially beaches). Frequent or severe erosion and flooding may impair recreation access such as creekside trails and the Bay Trail, possibly requiring adjustments to trail alignment or elevation. Changes in open space may result in increased conflicts between public access and wildlife habitat protection.	Advancing tools and metrics to track open space through Tasks under this Action will facilitate future planning and adaptation efforts. Increasing public access today can garner support for future protection efforts to address climate impacts.
25	Champion the Estuary	No direct stressors (communications-focused activity)	No direct risks	N/A	N/A	N/A: This Action is focused on education and information-sharing.	Communicating the urgency of the climate crisis to current and future audiences through Tasks under this Action can garner support for a healthy, resilient Estuary and foster greater participation in Estuary Blueprint priorities.

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