Climate Impacts Table for the North-central California coast and ocean region.

Content excerpted from Largier et al. 2010[1].

Climate Variable	Historical Changes	Direction and Range of Change Expected in the Future	Seasonal Pattern of Change	Confidence
Sea Level	Documented 19.5 cm rise in sea level from 1870 to 2004. Rate of rise increased from .018 cm/yr in 1900s to .31 cm/year between 1993 and 2003. The trend in San Francisco is 2.01 mm per year.	According to the National Research Council's 2012 SLR projections[2], **28 (± 9.2) cm of SLR is expected by 2050 and 91.9 (± 25.5) cm by 2100**. Other projections suggest a rise of up to 176 cm by 2100.	El Nino events, storm surges, and strong onshore wind can raise sea levels up to 30 cm above the predicted tides. A transition back to the warm state of the PDO (Pacific Decadal Oscillation) will result in accelerated SLR.	Medium-high
Coastal Erosion	A majority of the sandy beach and seacliff in the study region is classified as eroding.	An **enhanced potential for coastal erosion** is expected across the region. Mendocino county is projected to lose the largest area of land to coastal erosion. Marin county will feel the greatest impact of dune erosion.	Erosion will more likely occur in association with increased storm surge, typically over fall and winter.	Medium-high
Freshwater Runoff	Increase since early 1900s due to increased extreme precipitation during single-day events.	Rising temperatures expected to **decrease snowpack and decrease precitipation ratio of snowfall to rainfall**. Higher annual peak runoff. Anticipated increase in intensity and occurence of fire may also increase run-off.	Expected increase in runoff in winter and decrease in spring/summer.	Medium

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Precipitation	Increase since early 1900s. 10% increase in precipitation for all of North America since 1910.	**Varied**. Some models suggest increased precipitation across CA, with greatest increase in northern CA. Others suggest no change, or only slight increase for northern CA and slight decrease for central CA. Increased frequency of extreme events is expected, as is increased variability (drier dry years, wetter wet years).	The majority of rainfall occurs between November and April. Wet winters are expected to get wetter; dry winters are expected to get drier.	Low
Surface Ocean Temperature	Globally, an increase of 0.10˚C from 1961-2003. Coastal measurements along the US West coast indicate warming offshore and along the coast. Over the continental shelf off central CA, cooling has been documented over the last 30 years, consistent with an increase in coastal upwelling.	Cross-shore differences are expected with a **warming of nearshore** and enclosed bay waters, while enhanced upwelling can be expected to **cool waters over the shelf**. Futher offshore, beyond the active upwelling area, surface waters are expected to warm.	During the upwelling season (April to August, though future timing of upwelling is uncertain - see below) waters over the shelf are expected to cool. This cooling may extend into late summer/fall with the expected delayed end to the upwelling season as climate changes.	Medium
Upwelling Winds	Enhanced alongshore winds have been documented, and a cooling trend in surface water temperatures has been observed during the upwelling season.	Projections suggest that global warming will lead to **stronger alongshore winds** and **enhanced coastal upwelling**. As the earth warms, the land is expected to heat up faster, resulting in an increase of the land-sea temperature difference that drives upwelling winds.	The seasonal timing of upwelling is expected to vary, with models indicating an enhancement of upwelling in the late summer and fall and a delayed end to the season.	Medium

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pH	Average global pH of surface waters has dropped from 8.2 to 8.1 since the start of the Industrial Revolution; a 26% increase in aciditiy, and decrease of 0.02 units per decade. pH is very low in upwelling regions including the study region. In spring 2007, strong upwelling resulted in understaturation of aragonite up to 50m.	**pH is expected to continue to decrease,** resulting in greater acidification of coastal waters. This decrease will be more pronounced in upwelling centers, including the coast of western US.	Acidification is intensified during the upwelling season (April to August, though future timing of upwelling is uncertain - see above). Acidification may also be driven by increases in freshwater input which are expected to increase in winter months.	High
Extreme Weather Events	Studies have observed an increase in the occurrence of extreme conditions, though not necessarily in the frequency of events. Extreme wind speeds have increased in both Atlantic (since 1981) and Pacific (since 1948) cyclones.	Models suggest that the tracks of storms in the northeast Pacific Ocean will migrate, on average, further north and experience an **increase in occurrence of extreme conditions**, though the number of extreme events may not change. For example, the number of El Nino events likely will not change, though the likelihood of super El Ninos doubles from one every 20 years in the previous century to one every 10 years in the 21st century[3]. The high waves during El Niño events will be more extreme when combined with the climate-change trend of increased wave height.	There are many natural climate fluctuations that will increase the variability of extreme events. During the positive phase of the Pacific Decadal Oscillation (PDO), climate-change warming may be accelerated along with enhanced rainfall and wave activity, but during the negative phase, climate-change warming effects will be slowed. High waves that occur during El Niño events are likely to be more extreme when combined with higher sea level and increased wave heights due to climate change.	Medium

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Species Range Shifts	In response to warming temperatures, the paleontological record indicates that species have shifted their ranges pole-ward. In Monterey, this was demonstrated over a 60-year period, with an increase in 10-11 southern species and a decrease in 5-7 northern species. Kellet's whelk, Humboldt squid and volcano barnacles have documented range shifts.	**Species are expected to continue shifting their ranges pole-ward**, though predictions based solely on climate projections may lead to erroneous projections due to complicated nature of species interactions and abiotic and biotic factors. Caution should be used in projecting these impacts.		Low
Phytoplankton Shift	Though there is little direct evidence for long-term change of zooplankton communities in the study region, the shift towards a more "southerly" planktonic fauna has been observed both north and south of the region. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) dataset in southern CA demonstrated a decline in zooplankton biomass (by 80% since 1950) associated with warming waters.	**Pole-ward shifts in distribution and earlier timing** of life cycle events are expected, and a possible phytoplankton shift from diatoms to dinoflagellates.	Earlier timing of life cycle events is expected. For example, the annual timing of peak biomass of a sub-arctic copepod has narrowed and shifted earlier (6 weeks over 30 years) as a result of warming ocean temperatures.	Low

[1] Largier, J.L., B.S. Cheng, and K.D. Higgason, editors. 2010. Climate Change Impacts: Gulf of the Farallones and Cordell Bank NMS.

[2] National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future.

[3] Cai et al. 2013. Increasing Frequency of Extreme El Nino Events Due to Greenhouse Warming. Nature Climate Change.