NORTH COAST RESOURCE PARTNERSHIP

North Coast Regional
CLIMATE ADAPTATION REPORT

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MAPS

1. CLIMATE CHANGE VULNERABILITY & UNCERTAINTY IN THE NORTH COAST REGION

INTRODUCTION

In order to ensure healthy communities, functional watersheds, and viable economies in the North Coast, it is essential that planning efforts remain responsive to changing environmental conditions. This is because with its temperate climate and wide array of habitats, the North Coast supports not only a diverse assemblage of species, including some of the last viable salmon runs in the state, but also communities, people, and an economy that are deeply connected to and largely dependent upon the region's natural resources. As such, this report is an effort to provide insight into the projected effects of climate change on the region so that North Coast communities can better prepare for and respond to life in a changing world.

The report begins with a look at temperature trends and projections; is followed by a discussion of expected climate change impacts on the region; and concludes with an examination of adaptation strategies and resources available to North Coast communities in preparation for and in response to climate change.

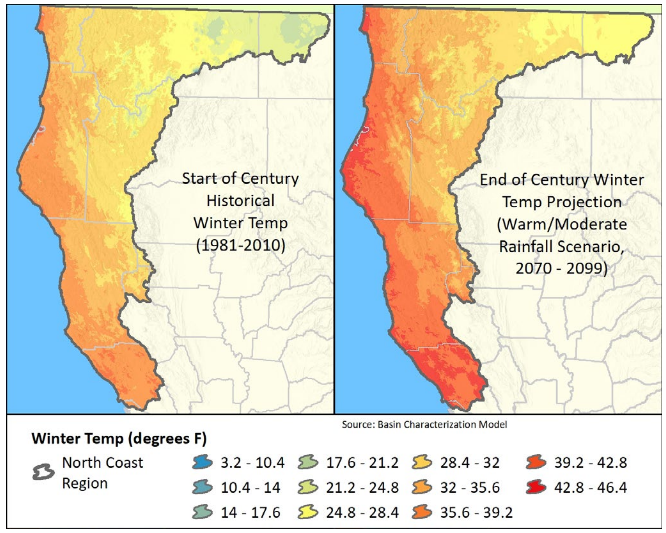
MAP 1. THE NORTH COAST REGION

TEMPERATURE TRENDS AND PROJECTIONS

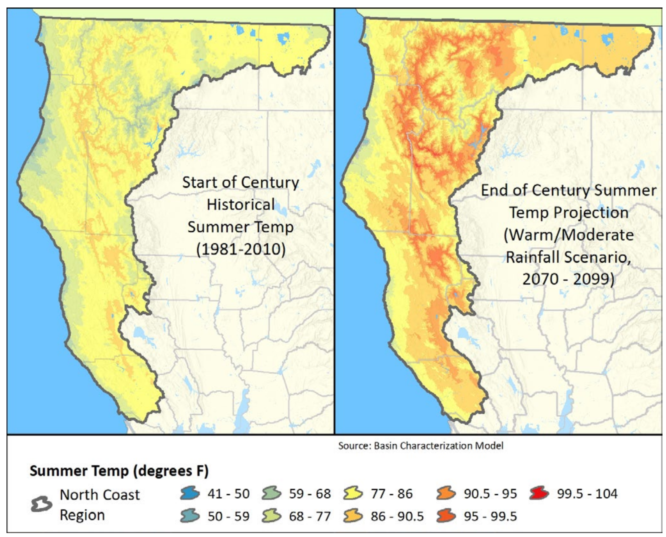
The rate at which the global mean temperature has been increasing over the past century, and during the last 50 years in particular, is well documented, leading the Intergovernmental Panel on Climate Change (IPCC) to conclude in its Fourth Assessment Report that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC, 2007). Indeed, since 1970 the global mean temperature has been rising at roughly 0.3°F (0.17°C) per decade, more than twice as fast as the 0.13°F (0.07°C) per decade increase observed since 1880 (NOAA, 2017a). This rise in temperatures has been particularly evident of late, with 11 of the 12 hottest years on record occurring in the last 14 years (NOAA, 2017b).

Unfortunately, predicting future temperatures is not as simple as projecting historic trends forward. There are innumerable variables at play, which inevitably leads to a fair amount of uncertainty about future conditions. Some of this uncertainty results from shortcomings in the climate models; some is due to the inherent variability of the Earth's climate and our need for greater understanding of the processes involved. However, complicating climate projections more than any other variable is the unpredictable response of humanity to this global challenge (NRC, 2010). Every nation (except the United States) has pledged to reduce its greenhouse gas (GHG) emissions as part of an international agreement on climate change, but global development pressure, political change, and demand for low-cost energy can make predicting future GHG concentrations difficult. Adding to this uncertainty, projections grow less precise as predictions reach further into the future. For these reasons, scientists rely upon numerous climate models and possible future scenarios to help them better understand possible climate change impacts around the globe.

MAP 2. PROJECTED AVERAGE CHANGE IN MIN. JANUARY TEMPERATURE (2000-2099)



MAP 3. PROJECTED AVERAGE CHANGE IN MAX. JULY TEMPERATURE (2000-2099)



One of these models, the USGS California Basin Characterization Model, has been used by Pepperwood Preserve and the United States Geological Society (USGS) to better understand possible climate change impacts on the North Coast region. As part of their review, the group ran model simulations for projected temperature increases under a high-emissions RCP8.5 scenario. RCP8.5 is often referred to as the "business as usual" scenario because it assumes, among other things, that the world will continue to rely heavily on fossil fuels for power generation rather than transitioning to alternative energy sources to reduce GHG emissions. Under such an RCP8.5 scenario, the region's average summer temperature is projected to increase 5-7°F by the middle of the century and 8-11°F by century's end, while the average winter temperature is projected to increase 3-5°F by mid-century and 6-9°F by century's end (Micheli et al., 2016). With these projected temperature increases, several climate-related impacts on the region are expected, including:

- Higher sea levels and coastal flooding
- Increasingly volatile weather
- More frequent drought and wildfires
- Changes in species distribution and loss of biodiversity
- Human health impacts

Each of these impacts and what is known about them relative to the North Coast is discussed in greater detail below.

HIGHER SEA LEVELS AND COASTAL FLOODING

In the coming years, the slow, persistent rise of the world's oceans is expected to significantly impact a large number of people and major population centers around the globe. In the United States alone, for instance, between 489 and 668 coastal communities, more than 50 of which currently have populations greater than 100,000, are expected to experience chronic coastal flooding due to sea level rise by the end of the century (Spanger-Siegfried et al., 2017). Because of gently sloping shorelines and high population densities along the southern and eastern U.S. coasts, many of the at-risk coastal communities are located in these regions. Nevertheless, despite substantial buffering from Northern California's dunes and tall coastal bluffs, the region is hardly immune. In fact, a recent report by the Ocean Protection Council indicates that as climate change accelerates over the course of the century and the rate of freshwater input from the major ice sheets increases, sea levels are expected to rise faster along the California coast than elsewhere in the United States (Griggs et al., 2017). Further, as sea levels rise, the rate at which the region's dunes and coastal bluffs are eroded is expected to accelerate (NRC, 2010; RCPA, 2016; Russell and Griggs, 2012).

Along with sea level rise comes projected flooding of low lying coastal areas. This has the potential to redefine the coastline and impact the lives of many of those who live by it. Without proactive adaptive planning, low lying homes, businesses, and infrastructure can become badly damaged or destroyed, resulting in severe structural and economic losses, displacement of individuals, and the potential release of contaminants into the environment. Low-lying roads that are not decommissioned and rerouted in anticipation of sea level rise may become impassable, impacting the flow of goods and people and delaying emergency response times. As the ocean's reach extends further inland along floodplains, freshwater aquifers can become impacted by the intrusion of salt water, impairing water supplies and damaging pasture and crops. The ocean's slow advance inland can also cause streams to "back up" resulting in worse flooding upriver from the coast. Moreover, when coastal flooding is combined with extreme high tides and/or storm surge (i.e., an increase in sea level during large storm events), the extent of flood impacts can be made substantially worse.

Potential damage due to sea level rise, however, is not limited to structures, spirits of those affected, environmental quality, or the economy. Also at risk is the region's iconic seashore and the flora and fauna that depend upon it for survival. The rise in sea levels, particularly when coupled with high tides and storm surge, threatens to erode coastal habitats, such as beaches, mudflats, dunes, and bluffs, and badly damage or destroy wetlands and marshes (NRC, 2012; CNRA, 2009; IPCC, 2007; RCPA, 2016).

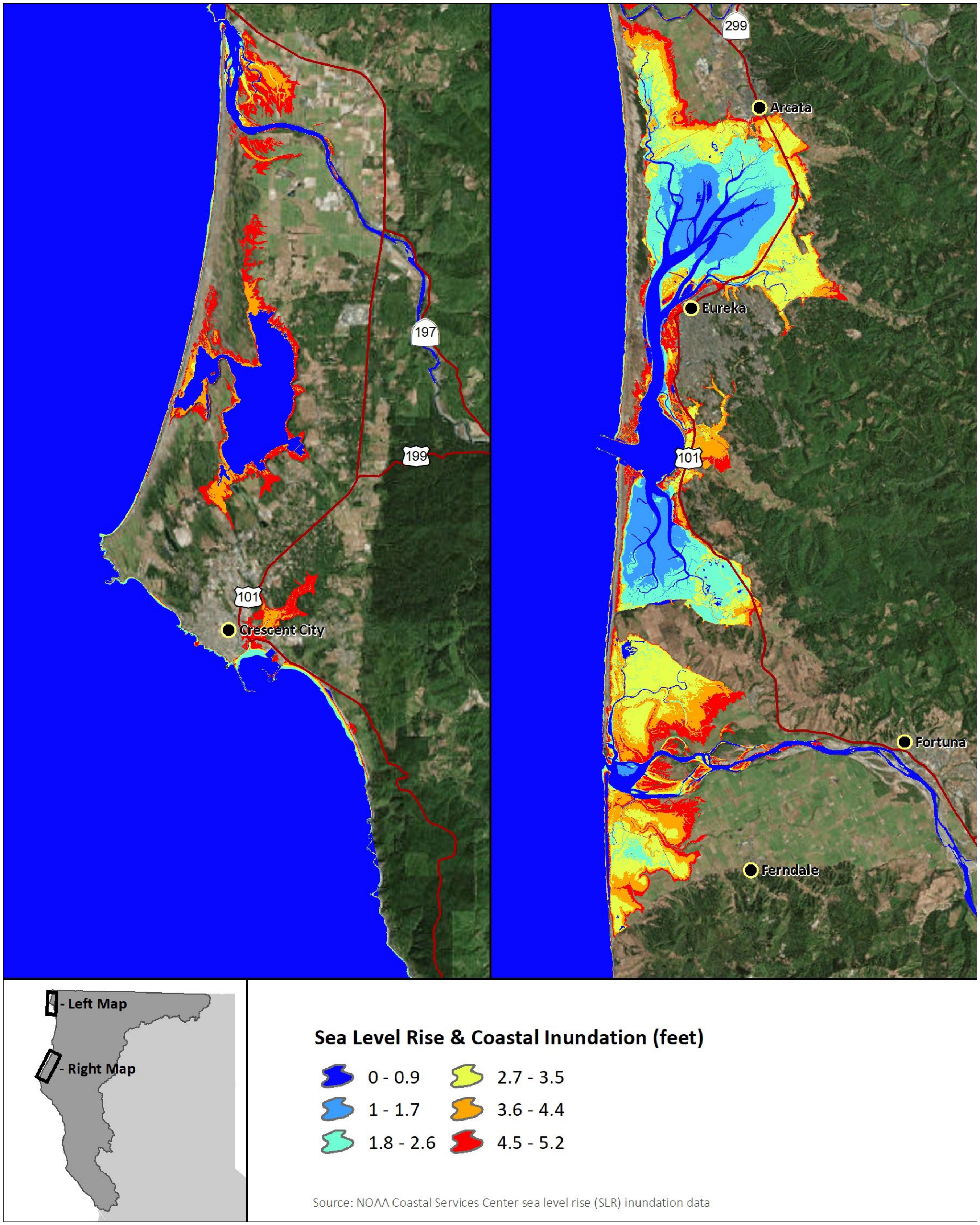
So why exactly are sea levels rising? Paleoclimatologists have long been aware that sea levels have risen and fallen throughout Earth's history in response to global temperature change. During periods of global warming, ocean volume swells in response to heat uptake (i.e., thermal expansion), as well as from the addition of freshwater from melting ice. The opposite is true during periods of global cooling when a majority of Earth's freshwater returns to a frozen state and the ocean's volume contracts. These changes typically occur over very long periods of time, with the current period of ocean expansion dating back to the end of the last ice age (Clark et al., 2016). During the latter part of the 20th century and into the 21st century, global mean sea level has been observed rising at an accelerated pace.

Recent estimates indicate that throughout most of the 20th century, global mean sea level rose at an average rate of 0.6 to 0.7 inch (1.5 to 1.8 mm) per year (Thompson, 2016), but since 1993 when scientists began using satellite altimetry to measure sea levels, global mean sea level has been rising roughly twice as fast, at an average rate of 0.13 inch (3.4 mm) per year (NASA, 2017). Although it's difficult to accurately forecast the rate sea levels will continue to rise, in part due to the ocean's delayed response to heat inputs (i.e., thermal inertia), scientists believe that "it is very likely that the rate of global mean sea level rise during the 21st century will exceed the rate observed during 1971–2010" (IPCC, 2013). What this means is that by the end of the 21st century, global mean sea level is likely to be anywhere from 10 to 55 inches (26 to 140 cm) higher than it is today (NRC, 2012; IPCC, 2013).

It is important to note that changes in sea level are not consistent around the globe, or even along the California coast for that matter. This is due to several factors, including changes in land elevation, atmospheric pressure, and ocean circulation (IPCC, 2013). As a result, sea level might be observed rising in one location while falling in another. For this reason, scientists track both changes in sea level and land elevation to determine relative sea level change, or the change in sea level relative to the land around it (NRC, 2012). It is the rate of relative sea level change that is of most importance to communities potentially affected by coastal flooding, including those in the North Coast.

In Crescent City, for instance, the land is being uplifted via plate tectonics faster than sea level is currently rising, such that relative sea level has been falling by about 0.4 inch (0.97 mm) per year (Northern Hydrology & Engineering, 2015). At the same time, just 80 miles south of Crescent City, in and around Humboldt Bay, the land is subsiding due to plate tectonics, so relative sea level is rising faster there than anywhere else in California, at an average rate of 0.1 to 0.23 inch (2.5 to 5.8 mm) per year (Patton et. al., 2014; Northern Hydrology & Engineering, 2015; Russell and Griggs, 2012). As a result, by the end of the century, sea levels in Humboldt Bay are expected to be 19 to 68 inches (49 to 174 cm) higher than they are today (Northern Hydrology & Engineering, 2015). This is clearly an issue for the communities in and around Humboldt Bay, and the cities of Eureka and Arcata, at 39 feet (12 m) and 23 feet (7 m) above sea level respectively, and the County of Humboldt have already begun planning for the effects of sea level rise on the region (Laird, 2015, Laird, 2016, Humboldt County, 2014a).

MAP 4. SEA LEVEL RISE & COASTAL INUNDATION



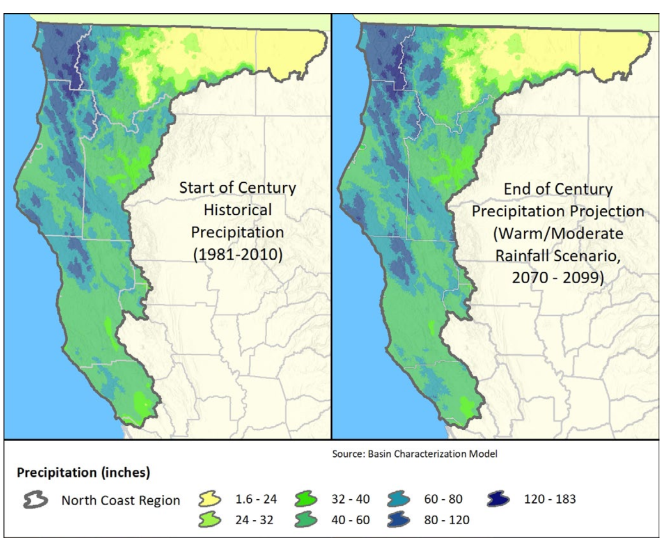
Source: NOAA Coastal Services Center sea level rise (SLR) inundation data

While not quite as extreme as the sea level rise forecast for Humboldt Bay, sea level rise projections for the rest of the California coast are barely better. Scientists believe that relative sea levels south of Cape Mendocino will rise 5 to 24 inches (13 to 61 cm) above 2000 levels by 2050 and 17 to 66 inches (43 to 168 cm) by 2100 (NRC, 2012). As a result, the coastal areas of Mendocino, Del Norte, and Humboldt counties are expected to experience about an 18% increase in land vulnerable to a 100-year flood, while a 14% increase in land at risk of a 100-year flood is predicted around Bodega Bay on the southern Sonoma coast (NCRP, 2014a; Reza Environmental, 2016).

INCREASINGLY VOLATILE WEATHER

Extreme weather events are often cited as a likely outcome of climate change. This is because for each 1°C of warming, the atmosphere can hold approximately seven percent more water vapor, and with increased warming there is more water evaporating from the Earth's surface for the atmosphere to hold (IPCC, 2013). Further, because this water vapor contains energy in the form of latent heat, more water in the atmosphere means that there is more energy to feed the atmospheric instability that drives large storms (NASA, 2017b). Indeed, scientists note that in addition to a four percent rise in atmospheric water vapor over the past 25 years (NASA, 2017b), there is strong evidence of an upward trend in more extreme weather throughout the United States (Kunkel et al., 2013). For instance, since 1960 there have been more than twice as many severe snow and ice storms in the U.S. than occurred in the 60 years prior, and over the past century "the amount of rain falling in the heaviest downpours has increased approximately 20% on average" (Thomas and Peterson, 2009).

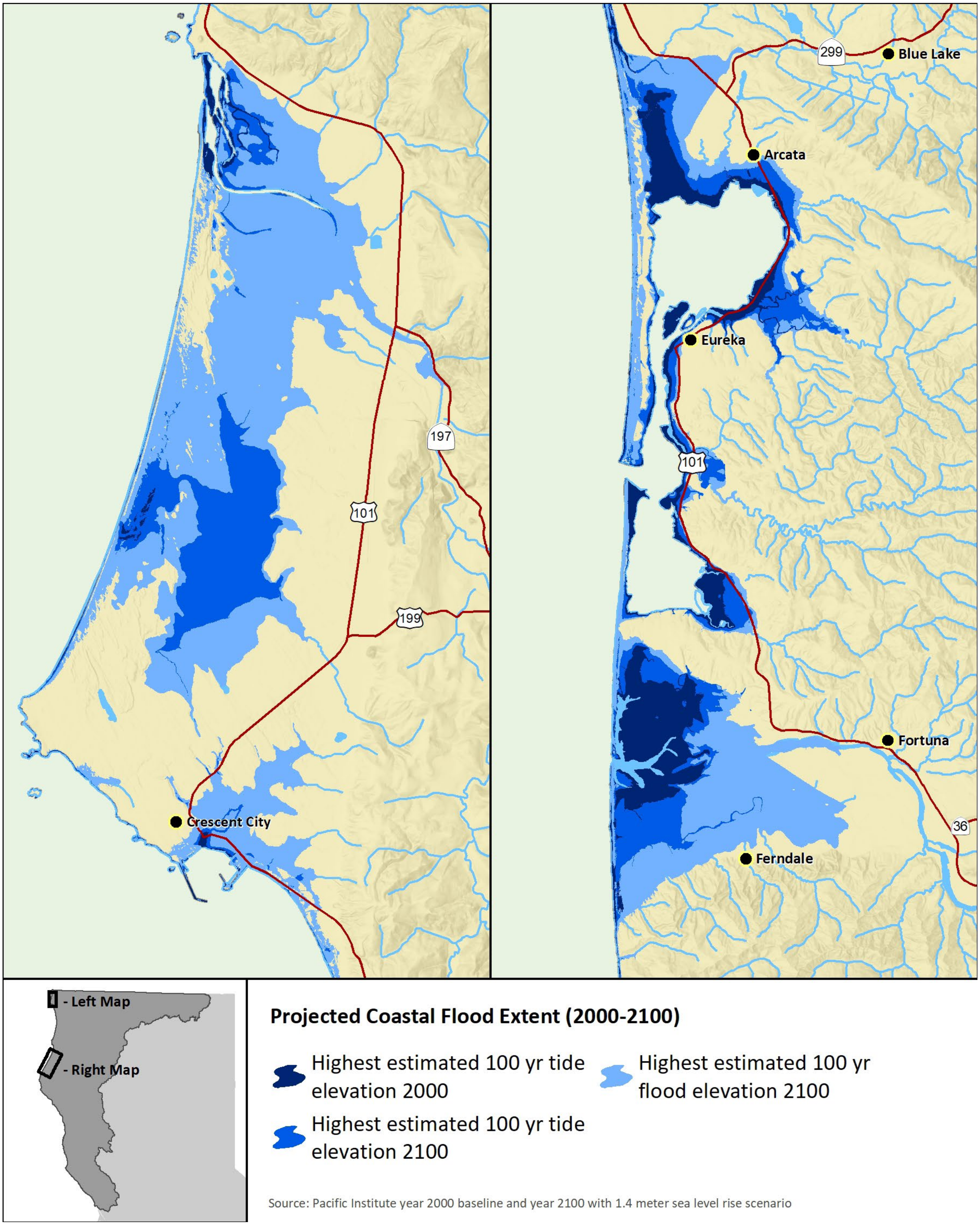
MAP 5. PROJECTED AVERAGE CHANGE IN PRECIPITATION (2000-2099)



Nevertheless, much like sea level rise, the effect of a warming climate on extreme weather events is not consistent around the globe. This is because wetter areas of the planet have more water available to feed storms than drier areas. Hence, the greatest observed increases in precipitation in the U.S. have been in the wetter areas of the country, such as the Northeast, Midwest, and Southeast (NOAA, 2017a). In fact, according to the climate change vulnerability assessment prepared for the region, there is little agreement among climate models about whether the North Coast is likely to experience wetter or dryer winters as a result of climate change (2NDNATURE, 2013). While some climate models predict decreased precipitation, others are calling for above average rainfall, and yet others still predict fewer, but more intense storms each year (Cayan et al., 2009; Flint and Flint, 2012). This inconsistency in the climate models is due to several factors, including the relatively large internal variability of California's climate, as well as California's location at a transition zone between those areas expected to become wetter as a result of climate change and those areas expected to become dryer (Allen and Luptowitz, 2017; Putnam and Broecker, 2017).

With both water shortages and catastrophic flooding possible as a result of inadequate planning, this lack of consistency in the climate models is potentially problematic for water managers. Further, because runoff projections are largely tied to conflicting precipitation models, the predictions for runoff in the region are equally divergent, with some models predicting decreased runoff and others a large increase in flows (Thorne et al., 2012). Interestingly, however, flooding is not tied to precipitation alone. In fact, as the region becomes increasingly warmer, more of the precipitation that does fall is expected to fall as rain, and both earlier snowmelt and rain-on-snow events will become increasingly likely (Knowles et. al, 2006). In addition, climate models align in projecting less precipitation during the spring and fall, essentially condensing the period of time that the North Coast receives its annual precipitation (Cayan et al., 2009; Thorne et al., 2012). When these predicted shifts in the timing of runoff are combined with atmospheric rivers that already deliver most of the state's annual precipitation during relatively few days each year (Dettinger et al., 2011), increased flooding in the region due to climate change becomes more likely (Condon et al., 2015).

MAP 6. PROJECTED COASTAL FLOOD EXTENT (2000-2100)



Source: Pacific Institute year 2000 baseline and year 2100 with 1.4 meter sea level rise scenario

To better understand the potential for future flooding in the North Coast, Lisa Micheli, Celeste Dodge, and Lorraine Flint modelled changes in flood frequency for three North Coast drainages under different rainfall and temperature scenarios using annual flows that exceed the 90th percentile per decade as an indicator of flood (see **Table 1.4.1**). According to their findings, the frequency of flooding is expected to increase in all three drainages under moderate and high rainfall scenarios and decrease under a low rainfall scenario. While it is not surprising that increased precipitation under a "warm, high rainfall" scenario is likely to generate more frequent flooding, the degree to which flood frequency could increase is significant. Further, because the "warm, moderate rainfall" scenario used in the model is based on 30-year precipitation averages comparable to baseline and recent conditions, the data suggest flood frequency in the North Coast is likely to increase based on warming alone.

Table 1.4.1. Projected Annual Discharge Extremes for Eel River, Redwood Creek, and Russian River: High Runoff Frequency

Basin	Historical Record (Time Period Varies)	Hot, Low Rainfall (2010-2099)	Warm, Moderate Rainfall (2010-2099)	Warm, High Rainfall (2010-2099)
	Annual Cumulative Discharge Exceedances of the 90th Percentile per Decade			
Eel River	5	1	12	28
Redwood Creek	10	5	19	29
Russian River	8	2	9	29

(Micheli et al., 2016)

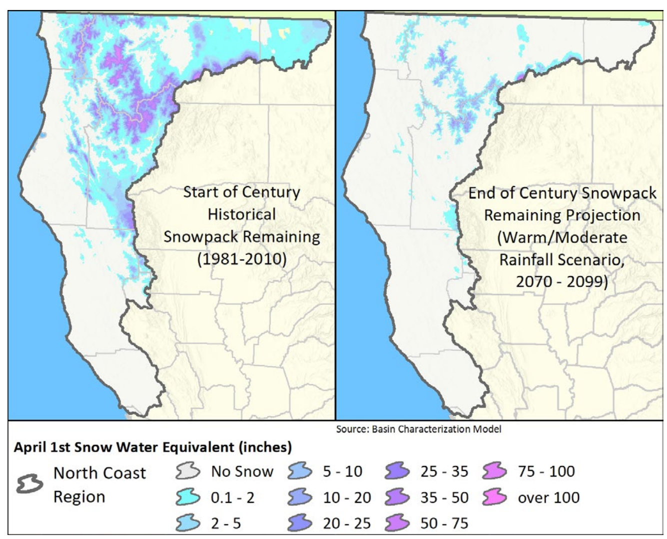
MORE FREQUENT DROUGHT AND WILDFIRES

Drought

It is the forecast of drought that generates more concern in this country and around the globe than any other climate change impact (Pew Research Center, 2017). That may be because unlike rising seas or volatile weather, the impacts of drought on the landscape are so apparent and can be incredibly far reaching. Not only do droughts make water levels in lakes, reservoirs, streams, and groundwater basins drop, sometimes significantly, they can create food shortages, spur wildfires, throttle economies, and drastically alter the living environment and people's lives (NOAA, 2017c). On the other hand, it could also be because despite relatively little variability in the frequency of droughts around the world over the past 60 years (Sheffield et al., 2012), this century has already seen record droughts in southern Europe, the eastern Mediterranean, India, Australia, North America, China, Africa, the South Pacific, Brazil, and the Caribbean (World Resources Institute, 2015; NASA, 2016).

This is not to say that these recent droughts were the result of climate change. Indeed, in many areas of the world, such as California, droughts are a natural part of the climate's inherent variability. In fact, scientists believe that the most recent drought to grip California was not part of a long-term change in precipitation due to climate change, but a recurring natural phenomenon that entailed a high-pressure ridge parking over the Pacific similar to historic droughts, albeit for an extended period of time (Seager et al., 2014). Still, for those in the North Coast that recently witnessed severely depleted snow pack, drained reservoirs, increased tree mortality, impaired fisheries, dry wells, and the scars of large wildfires, the cause of the most recent drought matters little, particularly in light of projected climate change impacts on the region. This is because as temperatures in the North Coast continue to rise throughout the 21st century (Micheli et al., 2016; NOAA, 2016; Cayan et al., 2009), they are expected to influence the frequency and severity of droughts in several ways, such as extended dry seasons, decreased snowpack, earlier snowmelt, increased evapotranspiration, greater variability in runoff and recharge, and increased water demand (Micheli et. al, 2016; Cayan et al., 2009).

MAP 7. PROJECTED ANNUAL AVERAGE SNOWPACK REMAINING (2000-2099)



Although nobody knows for certain how much more often droughts will occur, the climate change vulnerability assessment prepared for the region indicates that drought frequency in the North Coast could increase approximately 50% by the end of the century (2NDNATURE, 2013). While this is hardly encouraging, other forecasts are even less optimistic. For example, Micheli, Dodge, and Flint evaluated the same North Coast drainages for drought frequency that they assessed for changes in flood frequency, this time modelling annual flows that fall below the 10th percentile per decade, and found that the frequency of very low annual flows (i.e., drought) could potentially double in two of the three drainages by the end of the century with no change in precipitation (see **Table 1.5.1**).

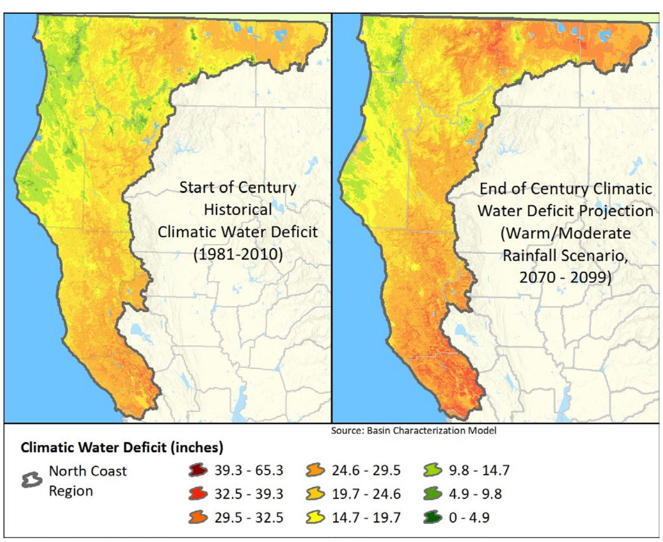
Table 1.5.1. Projected Annual Discharge Extremes for Eel River, Redwood Creek, and Russian River: Low Runoff Frequency

Basin	Historical Record (Time Period Varies)	Hot, Low Rainfall (2010-2099)	Warm, Moderate Rainfall (2010-2099)	Warm, High Rainfall (2010-2099)
	Annual Cumulative Discharge Exceedances of the 10th Percentile per Decade			
Eel River	5	12	9	3
Redwood Creek	9	7	10	0
Russian River	7	19	14	2

(Micheli et al., 2016)

But it is not simply the incidence of drought-like conditions that matters when it comes to understanding how this could affect the region. This is because some droughts are not as severe or long lasting as others, and it is the strain on the environment and agriculture created by drought that is so potentially detrimental. For this reason, Micheli, Dodge, and Flint also modelled climatic water deficit (CWD), or the amount potential evapotranspiration exceeds available spoil moisture, for several watersheds in the region (see **Table 1.5.2**). Because CWD integrates the combined effects of rainfall, air temperature, topography, and soil structure to estimate where and by how much water demand will exceed availability, it serves as an excellent measure of drought stress.

MAP 8. PROJECTED AVERAGE CHANGE IN CLIMATIC WATER DEFICIT (2000-2099)



As shown in the table below, there was little change in the average CWD across region between 1951 and 2010; however, according to the climate model, CWD in the North Coast could potentially increase 10-19% by mid-century and 16-32% by the end of the century. If this occurs, it will represent an effective loss of three to six inches of rainfall equivalent from soils relative to current conditions (Micheli et al., 2016). This suggests that, even if the North Coast receives more annual precipitation as a result of climate change, the elevated temperatures are expected to intensify drought stress in the region.

Table 1.5.2. Watershed Average Climatic Water Deficit (inches/year)

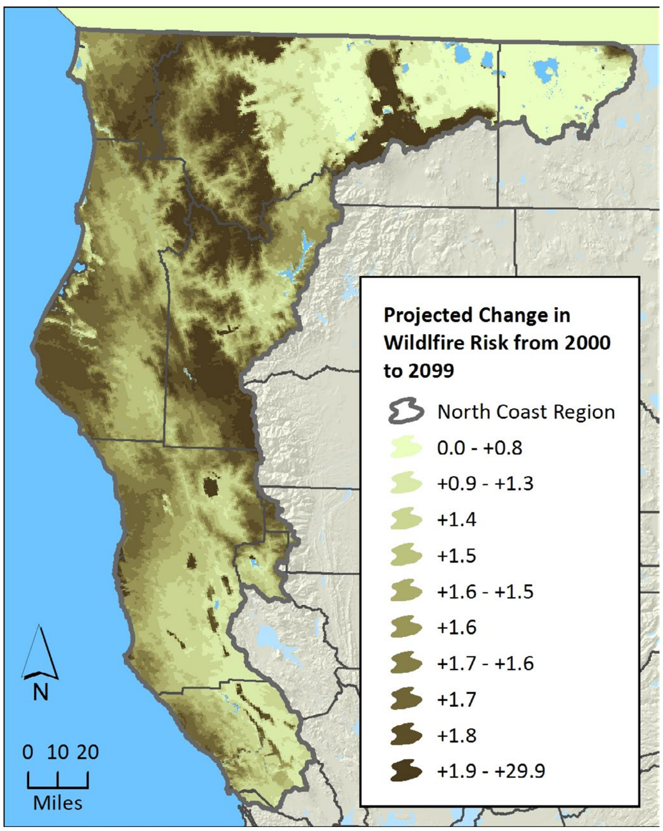
Watershed	Historical 1951-1980	Recent 1981-2010	End of Century (2070-2099) Warm, Moderate Rainfall	Warm, High Rainfall	Hot, Low Rainfall	Change w/ Low Rainfall
Lost	23.1	24.1	28.8	29.4	32.5	41%
Mattole	14.3	14.2	16.2	17.5	19.9	39%
Mad-Redwood	14.9	14.8	17.0	18.6	20.7	39%
Smith	13.9	13.9	15.2	17.8	19.2	38%
Shasta	22.2	22.7	26.3	27.2	29.3	32%
Scott	20.8	21.3	25.1	26.0	27.6	33%
Salmon	17.9	18.3	21.7	22.9	24.5	37%
Upper Klamath	22.4	23.1	26.8	27.6	29.4	31%
Lower Klamath	16.4	16.5	18.5	20.5	22.0	35%
Trinity	18.9	19.1	22.2	23.3	25.1	33%
South Fork Trinity	21.6	21.5	25.0	25.8	28.0	30%
Upper Eel	25.0	24.8	28.0	28.2	30.9	23%
Lower Eel	19.6	19.3	22.1	23.0	25.4	29%
Middle Fork Eel	23.4	23.2	26.9	27.3	29.8	28%
South Fork Eel	19.9	19.5	22.3	22.9	25.5	28%
Gualala-Salmon	26.4	26.7	29.7	29.8	33.1	26%
Russian	27.5	27.9	30.8	30.7	33.8	23%
Tomales & Drake's Bay	28.0	28.5	31.6	31.6	35.0	25%
Regional Average	**20.9**	**21.1**	**24.1**	**25.0**	**27.3**	**32%**

(Micheli et al., 2016)

Wildfires

Although there are several factors that affect the size and frequency of wildfires, the progressively warmer temperatures and associated drought stress projected for the region are expected to contribute to an increase in wildfire size and frequency that climate models predict will worsen over time (Krawchuck and Moritz, 2012; Yoon et al., 2015). Micheli, Dodge, and Flint note that the probability of fire over a 30-year period is expected to increase across the region on average by 40% by the end of the century (Micheli et al., 2016). Given that 13 of California's 20 largest wildfires over an 85-year period have occurred since 2000 (CAL FIRE, 2017), it's not surprising that some scientists believe that the combined effects of increased heat and drought are already contributing to larger and more frequent wildfires in California (Krawchuck and Moritz, 2012; Yoon et al., 2015). Interestingly, however, a 2012 study of the Klamath, Mendocino, Shasta-Trinity, and Six Rivers National Forests found that, although wildfire size and frequency have been trending upward, the severity of wildfires has not been (Miller et al., 2012). This lead the study's authors to conclude that, under appropriate conditions, fire could be more extensively used in the region to achieve management objectives. (Adaptation strategies, including forest fuels management, are discussed in **Section 2.6** below.)

MAP 9 PROJECTED CHANGE IN WILDFIRE RISK (2000-2099)



CHANGES IN SPECIES DISTRIBUTION AND BIODIVERSITY LOSS

Along with those physical impacts on the environment discussed above, climate change is expected to affect the region's living environment as well. Whether as a result of thermal stress; increased drought and fire activity; the spread of pathogens and invasive species; greater variability in stream flows; habitat loss; changes in phenology; or ocean acidification, climate change is expected to influence the distribution and abundance of North Coast species in several ways (2NDNATURE, 2013; Barr et al., 2010). In general, however, as existing habitats shift in response to changing environmental conditions and become less suitable for the species they currently support, species are expected to either migrate toward more favorable conditions, adapt to the new conditions, or die (CNRA, 2009).

For example, as the chronic stress of decreased soil moisture and more frequent droughts continues to build, trees that are currently under duress will be more likely to perish and others may become increasingly strained and vulnerable to attack from damaging insects and pathogens (Das et al., 2013). Even long-lived species that have adapted to life an increasingly drier climate like the coast redwood (*Sequoia semperivens*) could be impacted. In fact, because climate change could potentially result in decreased frequency of California's coastal fog, redwood habitats may be at risk of further contraction (Johnstone and Dawson, 2010). Moreover, when tree loss is combined with an increase in wildfires capable of opening large areas of habitat for colonization, as well as the migration of other species toward more favorable conditions, the range and composition of North Coast forests is likely to shift (CNRA, 2009). In addition, because invasive species are generally able to thrive under a wider range of conditions than native species, their competitive advantage, and therefore presence in North Coast habitats, could become even greater in the coming years (CNRA, 2009).

With these changes in natural community composition, relationships between species will also be affected. Moreover, as the timing of natural events (e.g. flowering, insect emergence, and bird migration) shift in response to increasingly warmer temperatures, interactions among co-evolved species could become disrupted, placing species at risk (CNRA, 2009).

For those species that are specialists, are currently vulnerable to environmental stressors, and/or that have limited populations (e.g., the region's 86 special-status plant and animal species), climate change is likely to create an even greater risk of regional extirpation, or in the case of species endemic to the North Coast, potential extinction (CNRA, 2009; Burge et al., 2016). This includes denizens of the region's aquatic habitats, like salmon and steelhead, that require cold, clean, oxygenated water to survive and reproduce. Already facing multiple challenges to their survival, these anadromous species could face further reductions in range and abundance due to the warmer water temperatures and more variable stream flows that are predicted (Moyle et al., 2012; CNRA, 2009). In addition, for those alpine species that live near the upper limits of available habitat, such as whitebark pine (*Pinus albicaulis*) and American pika (*Ochotona princeps*), there is already little habitat left for them to migrate toward (Barr et al., 2010). Indeed, studies suggest that both of these species are already disappearing from the western United States as a result of climate change (Beever et al. 2016; Aitken et al., 2008).

Marine species are also at risk. In addition to the effects of elevated ocean temperatures, which could allow some marine diseases to spread, such as the one that causes withering syndrome in abalone (Rogers-Bennett et al., 2011), researchers have found that the higher concentrations of CO_2 in the atmosphere are making marine waters more acidic. This ocean acidification, which is projected to worsen over time as CO_2 levels continue to increase (NOAA, 2017d), can adversely impact the ability of marine species to develop shells and exoskeletons. For instance, research conducted by Jason Miller of the Northwest Fisheries Science Center has found that small changes in pH, consistent with projected CO_2 induced ocean acidification, results in higher mortality and delayed larval development in Dungeness crabs (*Metacarcinus magister*), a commercially important species in the North Coast (Miller et al., 2016). Other marine species that play a role in the region's economy, such as Kumamoto and Pacific oysters, are also already experiencing declines along the Pacific coast due to ocean acidification (Chan et al., 2016).

HUMAN HEALTH IMPACTS

With predictions for more frequent wildfires and extreme heat events, degraded air and water quality, and increased abundance of pests and pathogens in the coming years, climate change has the potential to impact the health of North Coast residents as well as the environment (CNRA, 2009). Further, because climate change is expected to result in contaminated water supplies and higher food costs, it also has the potential to impair access to the most basic of necessities for the most vulnerable members of society.

Wildfires and Extreme Heat Events

Wildfires not only impair air quality over large geographic areas with toxic particulate matter found in smoke, but they can obviously also result in life-threatening burns and the loss of life for those directly affected by it. Moreover, when residential, commercial, and industrial properties are impacted, wildfires can leave behind a mess of dangerous debris in their wake. Just this year, when some of the most destructive wildfires in the state's history ravaged Sonoma, Napa, Mendocino, and Yuba counties, over 180 persons were injured, 44 lives were lost, the Bay Area population of roughly 7 million people were blanketed in smoke, and EPA cleanup crews were tasked with removing hazardous waste from nearly 7,000 fire-damaged properties in Sonoma and Napa counties alone (US News& World Report, 2017; The Press Democrat, 2017; USEPA, 2017a).

When it comes to forecasts for extreme heat, heat-related illnesses are always a concern. That's because without the ability to stay cool and adequately hydrated during periods of prolonged heat exposure, health impacts that begin with fatigue and cramping can quickly escalate to heat stroke and death (HAW CAT, 2013). Although exposure to extreme heat can affect everyone, health risks are greater for vulnerable members of society, including pregnant women, persons with a pre-existing chronic disease (cardiovascular and respiratory illnesses in particular), the elderly and very young, and persons who are economically disadvantaged. Further, because of increased exposure to the environment, persons who work outdoors are also at elevated risk (CDC, undated).

Geographic location also plays a critical role in one's exposure to, tolerance of, and general preparedness for extreme heat. For example, a hot day inland away from the moderating influence of the ocean can be significantly warmer than a "hot" day on the coast. Therefore, it makes sense that inland residents are much more likely to be exposed to temperatures that can cause thermal stress in the body. However, at the same time, coastal residents are generally less acclimatized to higher temperatures, less likely to recognize the signs of heat-related illness, and are less likely to be living in homes equipped with air conditioning because it is so rarely needed. In fact, during the 2006 California heat wave, there was a greater increase in trips to the hospital for heat-related illnesses within coastal counties versus inland counties (Gershunuv et al., 2011).

North Coast communities with highly-modified urban landscapes may also be disproportionately affected during periods of extreme heat. That's because in addition to typically having fewer shade trees and less evapotranspiration than surrounding less-developed areas, urban landscapes also tend to have higher concentrations of dark, thermally absorptive surfaces, such as roads, rooftops, parking lots, and buildings. Furthermore, after absorbing the sun's heat throughout the day, the asphalt and concrete that are so frequently used in urban development continue to radiate heat long after sundown, such that nighttime temperatures are generally warmer in cities. In fact, this phenomenon, known as urban heat island effect, can result in temperatures in cities that are as much as 10 °F warmer than in surrounding areas (CDC, undated).

Air and Water Quality

The impact of climate change on air quality is not limited to irritants and potentially carcinogenic contaminants contained in smoke from wildfires. That's because with projections for warmer temperatures and higher concentrations of CO_2, plants are expected to grow more vigorously and produce more pollen, or in the case of fungus, it may result in the release of more spores (Wayne et al., 2002; CNRA, 2009). This increase in allergens is expected to induce and/or worsen allergies, asthma, and other chronic pulmonary conditions. Moreover, because some plants also release volatile organic compounds that are harmful to human health, the predicted increase in plant growth could result in additional health concerns (CNRA, 2009).

Heat also facilitates the formation of ground-level ozone and other air contaminants that cause inflammation of the airways, diminished lung function, and other human health impacts. Because these pollutants are byproducts of power generation, industrial emissions, and motor vehicle exhaust, however, concentrations are expected to be higher in the region's urban centers and along major transportation corridors than in the North Coast's many rural communities (CNRA, 2009; HAW CAT, 2013).

During late summer, when flows on North Coast streams are low and temperatures are high, toxic algal blooms can develop that can sicken and/or kill humans and other animals exposed to the toxins. These blooms, which have been observed on the Mattole, South Fork Eel, Trinity, Van Duzen, Klamath, and other North Coast streams, are expected to occur more frequently due to the higher temperatures and more frequent drought-like conditions that are forecast for the region (The Times-Standard, 2013; The Times-Standard, 2017; CNRA, 2009).

Pests and Pathogens

There is also a connection between climate change and infectious disease (IPCC, 2013). In some instances, it is the transmissibility of pathogens that can increase with warmer temperatures. In other cases, it is the abundance and range of vectors that carry disease that can shift in response to temperature. For example, with warmer winter temperatures, there will be fewer freezing nights in the North Coast, allowing certain pests, like ticks, fleas, rodents, and mosquitoes, to survive through the winter and grow more abundant. Moreover, with the changing environmental conditions that are forecast, pathogens that are currently absent from the North Coast could become increasingly common. This could mean that in addition to increased exposure to existing vector-borne diseases, like Lyme disease, plague, hantavirus, and West Nile virus, pathogens that have yet to be seen in the North Coast could appear (CNRA, 2009).

Contaminated Water Supplies and Higher Food Costs

Climate change also threatens access to safe drinking water. For example, because of the warming climate, coastal aquifers are expected to face an elevated risk of contamination from saltwater intrusion due to increased pumping of groundwater (USGS, 2017) and in response to sea level rise (Werner and Simmons, 2009). In addition, with the forecast for more frequent heavy storms, nutrients, pesticides, and other contaminants are much more likely to be flushed from the land into nearby streams, lakes, and reservoirs, with potentially catastrophic impacts on the region's water quality. For example, during heavy storms and peak runoff events, stormwater collection systems and wastewater treatment plants can become overwhelmed, resulting in combined sewer overflows and the release of unprocessed wastewater into adjacent water bodies (USEPA, 2017b). When these inputs of excessive nutrients, bacteria, and other contaminants occur, water quality is significantly impaired and blooms of toxic algae, like the ones briefly discussed above, are more likely develop. Moreover, after the blooms of algae die, dissolved oxygen in the impaired waterbody can become depleted by the decomposition process, resulting in potentially large fish kills, the loss of other aquatic life, and further impacts to water quality.

Along with potential impacts to water quality, climate change also threatens food security through diminished crop yields, impacted fisheries, decreased livestock productivity, and the higher resultant food costs (CNRA, 2009; Chavez, et al., 2017). For example, at the same time more frequent extreme heat events and diminished water supplies are expected to decrease agricultural productivity, fewer freezing nights could result in more abundant pests and higher use of pesticides (CNRA, 2009). This decrease in agricultural output and increase in operating costs, which is estimated to include as much as $950 billion more per year for water delivery in the United States by the end of the century (NRDC, 2008), is expected to result in escalating food prices that will affect everybody in the region. However, the increased food costs will be particularly difficult for the most vulnerable members of society who already struggle to afford healthy food choices for themselves and their families (Morello-Frosch et al., 2009; CNRA, 2009).

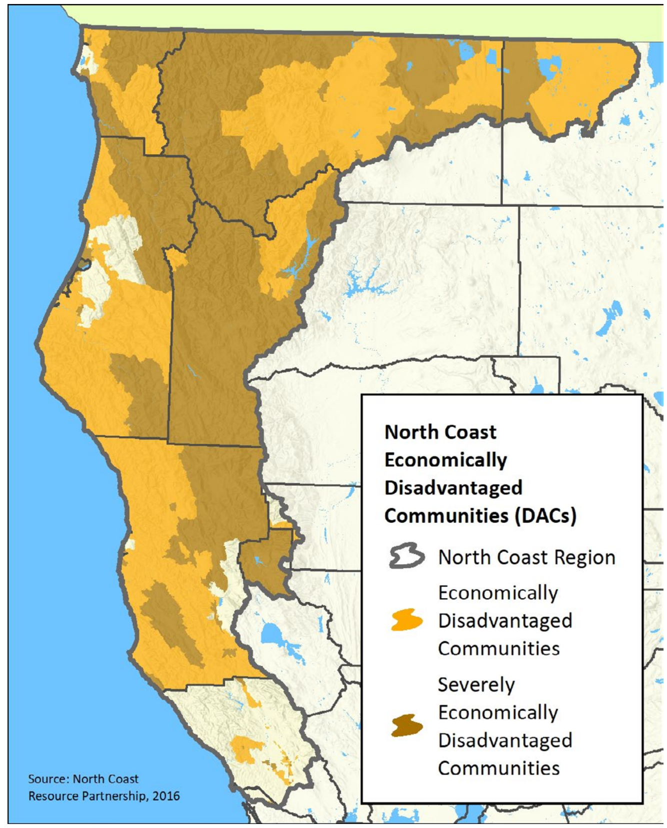
DISPROPORTIONATE IMPACTS ON ECONOMICALLY DISADVANTAGED COMMUNITIES

In addition to the greater challenges that economically disadvantaged communities (DACs) in the North Coast already face due to their rural location and more limited financial resources, DACs are also likely to experience disproportionate impacts because of climate change. That's because in addition to having less of the human and economic capital needed to move toward climate resilience, DACs also have a higher proportion of low-income residents that, for a variety of reasons, will be disproportionately impacted by the effects of climate change.

For example, low-income individuals and families will not only struggle to afford the higher food prices discussed above, but they will also be more likely to be harmed by the increasingly frequent extreme heat events forecast for the region. This is due in part to the many fixed-income elderly in the North Coast that, because of their age, are less able to thermoregulate to avoid overheating. Moreover, these economically disadvantaged seniors are also more likely to have pre-existing health conditions that are exacerbated by the heat, such as pulmonary and cardiac disease. However, it's not just the low-income elderly that will face elevated risks. Because the poor are more likely to be employed in occupations that require physical exertion and/or exposure to the environment, such as agriculture, forestry, and construction, even healthy working-age individuals will face disproportionate heat-related health impacts. In addition, for those with very limited financial resources, the cost of air conditioning and its operation can be prohibitive. The same is true for automobiles, with low-income individuals being less likely, on average, to have reliable transportation for accessing cooling centers and/or escaping to locations where temperatures are less oppressive. Finally, low-income individuals are less likely to have access to health care should they become sickened by the heat, and they are also more likely to have asthma and other chronic conditions made worse by the heat (Morello-Frosch et al., 2009; CNRA, 2009).

With all seven counties represented in the NCRP defined, at least in part, as DAC per the State of California definition (NCRP, 2014), impacts on the region and its resilience to the effects of climate change may prove all the more challenging.

MAP 10. ECONOMICALLY DISADVANTAGED COMMUNITIES



2. CLIMATE ADAPTATION & DISASTER RESILIENCY STRATEGIES

Although projected climate change impacts are likely to occasionally test the mettle of the region's residents, North Coast communities that work together to diligently prepare for life in a changing world will not only endure, they will turn the present challenge on its head – using it as an opportunity to build greater capacity and ensuring that the region moves into the future stronger, healthier, and more resilient than ever before. For this reason, it is so important that local governments, industries, and individuals in the North Coast educate themselves about the potential impacts of climate change on their community and region and work together to prepare for what lies ahead. Hence, the following sections provide a discussion of adaptation strategies and resources that North Coast communities will likely want to consider when preparing for and responding to the effects of climate change.

COPING WITH EXTREME HEAT

Resiliency to increased heat events and other impacts of climate change requires proper planning. Where appropriate, existing and future community plans should be updated or developed with consideration of heat event projections (CEMA and CNRA, 2012). In addition, local agencies will want to consider adopting new strategies and standards that lessen the impact of heat events on their communities. This could include provisions for green or reflective roofs, increased building energy efficiency standards, best practices for thermal comfort and healthy indoor air quality, expansion of urban forest programs, use of cool pavement, and other approaches that are specific to the needs of the community (HAW CAT, 2013). Whenever possible, public outreach and education should be integral to the process.

Urban Heat Island Reduction

In more densely populated areas, resiliency to heat events is enhanced through development and implementation of an urban heat island reduction program (CEMA and CNRA, 2012). These programs can assist communities in coordinating a variety of actions to reduce elevated temperatures associated with highly modified human landscapes.

Because urban heat islands are largely the result of increased absorption and retention of solar radiation by the built development, one of the more effective cooling strategies entails increasing solar reflectivity. This can be accomplished through use of lighter colored surfaces (e.g., more reflective rooftops and paving materials), as well as through a process known as urban greening. Urban greening includes several strategies to increase vegetative cover in cities, including expansion of urban forest programs (i.e., tree planting), creation and maintenance of parks and greenways, use of green roofs, encouraging urban agriculture, restoration of open space, use of green infrastructure, and other similar methods. Increasing vegetative cover not only increases solar reflectivity, but additional shade trees reduce the amount of surface warming and heat retention that can occur. Research also suggests that the resultant increase in evapotranspiration may provide greater indirect cooling than the direct cooling effect of shading (McPherson et al., 1994). Further, besides mitigating increased temperatures associated with urban heat island effect, urban forest programs have been shown to provide several other benefits to society (Westphal, 2003).

When selecting tree species for urban forest programs, it's important that planners and landscape architects consider potential allergen side effects and be aware that some vegetation emits isoprene and monoterpenes, which play a role in the formation of photochemical smog (Sailor, 2006). By carefully choosing correct species, unintended consequences can be avoided while benefits are maximized. To this end, the Urban Forest Ecosystems Institute has developed SelecTree, an interactive program designed to identify tree species based on desired characteristics, such as maximum height; shape, leaf, flower, and fruit characteristics; site conditions; resistance to pests and disease; and health, safety, and environmental concerns.

Another effective cooling strategy for communities impacted by urban heat island effect is the use of cool roof and pavement materials (USEPA, 2017c). The term "cool" with respect to roofing refers to materials that increase solar reflectivity so that the structure absorbs less heat. As an added benefit, cool roof materials, which cost about the same as traditional roofing materials, are expected to last longer because they endure less thermal cycling (Sailor, 2006). "Cool" pavement on the other hand refers not only to materials that increase solar reflectivity, but also materials that remain cooler than traditional materials and/or are permeable. By increasing groundwater infiltration, use of permeable pavement reduces the amount of heat transferred to the surrounding environment and near-surface air temperatures are reduced through evaporative cooling (USEPA, 2008).

Shading existing pavements is another cooling strategy that can be employed, with some communities installing shade canopies that incorporate solar panels in parking lots, such as at the Luther Burbank Center in Sonoma County.

Cooling Centers

Many communities set up cooling centers during heat events. These are typically established in community centers and other public places so that affected residents have access to air-conditioned shelter during periods of extreme heat. When setting up a cooling center, it is important that communities have resources in place to identify and assist vulnerable members of the community who require help getting to the center. Further, operators of cooling centers should be prepared to accommodate companion animals, as many residents will arrive at the shelters with them (CEMA and CNRA, 2012).

Outdoor Workers

Strategies to safeguard outdoor workers during extreme heat events include:

- **Local governments** can offer incentives for local businesses, enforce labor laws protecting outdoor workers, implement cooling strategies for their own employees, issue heat warnings, and establish call centers that provide heat stress prevention tips and guidance, and that serve as reporting centers for labor law violations.
- **Employers** can implement business practices that minimize outdoor employees' exposure to heat stress. This can include scheduling more intensive activities earliest in the day when temperatures are coolest and relying upon mechanical equipment whenever possible. In addition, employers can implement buddy systems where all workers are aware of the signs of heat-related illness and are capable of intervening should a co-worker become affected. Employers can also ensure outdoor workers have access to adequate shade, are wearing appropriate clothing for the conditions, take regular breaks during periods of intense heat, and have access to hydrating and replenishing fluids (NRDC, 2013).

Extreme Heat Programs

An effective extreme heat program contains a publicly approved plan that includes clear criteria for extreme heat events, coordinated public outreach with consistent messaging, strategic action plans that include formal check-ins and buddy systems, strategies and recommendations for staying cool, cancellation policies for outdoor activities and events, and opportunities for post-season performance reviews and continuous public input. In addition, the plan should identify designated public cooling shelters, partner agencies, and vulnerable populations. (This type of program should be part of the broader process for climate change and disaster response preparedness, since many of the same partners, stakeholders, and vulnerable populations are involved and similar types of public outreach and education will be necessary.)

Table 2.1-1, Select North Coast Community Strategies; Increased Heat Events

Hoopa Tribe	The Hoopa Office of Emergency Services operates cooling centers during periods of extreme heat. The threshold for opening cooling centers is three consecutive days of a heat index of 105 °F for at least three hours per day and when the heat index is 80 °F or more at night and forecasts predict a fourth consecutive day of similar heat indices. The Tribe also assists with communication and welfare checks for previously identified vulnerable populations and clients (Hoopa Office of Emergency Services, 2007).
Karuk Tribe	The Karuk Tribe provides air-conditioned facilities for use by the public during periods of extreme heat (Karuk Tribe, 2015).
Sonoma County	The North Bay Climate Adaptation Initiative recently released A Roadmap for Climate Resilience in Sonoma County that recommends several responses to extreme heat events, including: bolstering vulnerable communities' resilience through reduction of non-climate economic and health stressors; addressing substandard housing; providing neighborhoods with ample shade and green spaces; providing education and resources to vulnerable populations to improve access to services; and safeguarding outdoor workers during extreme heat by working within existing worker safety programs to reach workers and supervisors that are mobile, working in remote locations, and/or undocumented (Cornwall et al., 2016).
Yurok Tribe	As described in the Yurok Tribe Hazard Mitigation Plan, the Tribe participates in opening local cooling centers when extreme heat continues for extended periods. The Tribe also proposes to establish shelters that include generators due to lack of electrical infrastructure on much of the reservation. The plan specifies that shelters should, at minimum, include kitchens, shower facilities, and air conditioning and be able to meet access needs (Tetra Tech, 2013).

RESILIENCY TO CLIMATE VOLATILITY AND NATURAL DISASTERS

Planning

Resiliency to climate volatility and natural disasters starts with planning, and local planning departments, health departments, and emergency managers should work to incorporate risks associated with projected climate change impacts into existing emergency preparedness plans and/or develop new plans as needed. While some impacts, such as wildfires and floods, have likely already been addressed in existing local hazard mitigation plans, risks should be re-evaluated and plans periodically updated in light of evolving climate models and trends (CEMA and CNRA, 2012).

Capacity Building

Communities can increase resiliency for climate volatility and natural disasters through the development of social and community support networks. Each community should consider building collaborative relationships with neighboring communities and forming regional partnerships to promote development of complementary adaptation strategies and cohesive regional approaches. Many climate change impacts and disasters extend beyond jurisdictional boundaries, and these issues are best addressed in collaboration with neighboring jurisdictions to ensure complementary actions and conservation of limited resources (CEMA and CNRA, 2012). Especially with respect to disaster resiliency, neighboring communities should develop coordinated first response actions that kick in during emergency situations to best allocate limited resources and avoid redundant actions (CEMA and CNRA, 2012). Together, communities can refine existing emergency preparedness and response plans, and conduct both individual and tandem exercises to augment preparedness. Preparation should also ensure completeness and availability of identified emergency supplies and resources, including but not limited to items such as water main repair parts, generators, pumps, sandbags, road clearing equipment, medical supplies, and communication equipment.

Communities with limited resources for building capacity for climate volatility and natural disasters can turn to the Institute for Local Governments (ILG), an organization that, among other things, assists California communities in establishing collaborative relationships with other communities and regional entities.

In addition to expanding capacity through collaborative relationships, and because of potential threats to infrastructure as result of climate change, resiliency should also be developed whenever possible and appropriate through redundancy in critical infrastructure. Should one system fail due its vulnerability to exposure, limited service could at least be provided by the other system on a temporary basis. For instance, if one community's water main were to be disabled in a landslide resulting from heavy rains on a fire denuded hillside, an intertie with a nearby community's water delivery system would at least allow for fire protection services to continue.

Community Outreach

To ensure public buy-in to climate adaptation measures, a robust public outreach program is necessary. As with most aspects of climate adaptation and disaster resiliency strategies, the most effective strategies are tailored to fit local conditions, constraints, and opportunities. Local government outreach for climate change resiliency and disaster preparedness should begin with identification of the most vulnerable populations. This can be accomplished by incorporating social and community engagement into local health departments and prioritizing adaptation efforts where vulnerabilities are highest and the need for safety and resilience is greatest (CEMA and CNRA, 2012).

Communities unfamiliar with outreach can utilize online resources to assist them, such as the Community Resilience Toolkit (Bay Localize, 2009). This guide for community groups and planning agencies in leading workshops to plan for resilience offers Bay Area-specific resources and action ideas in six key sectors: food, water, energy, transportation and housing, jobs and economy, and civic services.

For communities wanting a more formal commitment to the outreach process, organizations exist to help them through the process, such as Transition US. The Transition movement consists of communities within the U.S. that have committed to transitioning off fossil fuels, living in balance with resource limits, and building equity for all. The mission of the organization is "to catalyze and strengthen a national network of citizen-powered groups who are building local resilience through community action." The organization supports, networks, and trains individuals and their communities as they consider, adapt, adopt, and implement the Transition approach to climate resilience. In the North Coast, the cities of Sebastopol, Santa Rosa, and Healdsburg, and the county of Humboldt are "official" Transition communities. Of these, Transition Humboldt, the 148th officially recognized Transition Initiative in the US, appears to be the most active. Transition Humboldt promotes community resilience through programs and workshops meant to empower community members to develop skills for building resilient communities. They regularly hold potlucks with presentations and salons with topical conversations, and host a sustainable living skills fair.

Additionally, Transition Humboldt has begun to implement the Transition Streets program in several Humboldt Bay neighborhoods. The Transition Streets program engages the community on a street-by-street basis, with neighbors working collectively to save money and resources and build community resilience. The Transition US organization provides a curated guidebook to change, empowering neighbors with proven actions to conserve energy and water, reduce waste, and save money. The local effort brings neighbors together to implement simple household changes that are expected to cumulatively save significant resources and reduce the neighborhood carbon footprint.

Monitoring for Adaptive Management

Finally, as with all planning and implementation efforts, monitoring results is crucial to determining success and adjusting management for optimal efficacy. Whenever possible, communities should establish an ongoing monitoring program to track local and regional climate change impacts and adaptation strategy effectiveness. Climate change impacts vary spatially and uncertainties and contextual considerations make accurate prediction of impacts difficult. Adaptation strategies should be adjusted based on effectiveness of a strategy and adequacy of the strategy to address projected changes. Monitoring will provide the data necessary to adjust course as necessary.

Monitoring can be labor and cost intensive, so indicators should be chosen carefully. The most severe impacts should be identified by each community along with indicators that will measure effectiveness of adaptation actions as well as continued assessment of the expected impact. Potential indicators for community resiliency and climate change are provided on several websites, as follows:

- The Governor's Office of Planning & Research has developed California @ 50 Million. By 2050, California's population will have reached 50 million. Accommodating this growth while achieving environmental and economic goals will shape the direction of the state's growth. This website provides links to the state's goals and key indicators for tracking progress toward meeting them.
- The Sustainable Community Indicator Catalog prepared by the Partnership for Sustainable Communities helps communities identify indicators that can measure progress toward their sustainability objectives. The indicators in the catalog focus on relationships among land use, housing, transportation, human health, and the environment. The database is searchable by indicator topic, geographic scale, level of urbanization, and issue of concern.
- NOAA's Coastal Zone Management Act Performance Measurement System Contextual Indicators includes a suite of "contextual" indicators on the status of coastal societies, economies, environments, and natural hazards. Contextual indicator data supplement performance measurement data collected by state coastal zone management programs and give context to state activities by illustrating the many pressures on coastal areas.
- In addition, NOAA's Performance Measures provides national performance measures to evaluate the National Coastal Zone Management Program. Performance measures, a framework to identify performance indicators, and other relevant documents are available.
- US EPA partnered with government agencies, academic institutions, and other organizations to compile a key set of indicators of climate change, Climate Change Indicators in the United States.

Table 2.2-1, Select North Coast Community Strategies Resiliency to Climate Volatility and Natural Disasters

Sonoma County	In 2009, Sonoma County established the Regional Climate Protection Authority (RCPA) with the purpose of improving cross-agency coordination and collaboration on climate change issues between Sonoma County's nine cities and multiple agencies. The RCPA fosters collaboration, helps to set goals, pools resources, forms partnerships, and aims to create local solutions to complement state, federal, and private sector actions (BACERP, 2014). There is enormous potential for similar groups throughout the North Coast to establish a similar organization to link jurisdictions subject to the same climate events so they can coordinate responses and potentially pool resources.
	The Sonoma County Climate Resilience Team is a public-private coalition of stakeholders in the county participating in the Partnership for Resilience and Preparedness (PREP), which seeks to empower a data-driven approach to building climate resilience. The PREP aims to help planners, investors, and resource managers more easily incorporate climate risks into the decision-making process by enhancing access to relevant data and facilitating collective learning. Sonoma County is one of a few initial participants in the beta version. During the next phase of the PREP, any user will be able to create and share their own climate resilience "dashboards." Sonoma County's Climate Resilience Dashboard provides access to climate impact maps and tools including the Climate Smart Restoration Toolkit, the Sonoma County Water System Interactive Map, and many other climate-related resources specific to the county.

PLANNED/STRATEGIC RETREAT FROM SEA LEVEL RISE

Rising sea levels threaten thousands of California coastal residents and billions of dollars' worth of coastal property with increased risk of flooding, storm damage, shoreline erosion, saltwater intrusion, and wetland loss (NRC, 2012; CNRA, 2009; IPCC, 2007). Consequently, California's coastal communities will need to build greater resilience to sea level rise by minimizing potential vulnerabilities and adapting to new sea level conditions. When considering different adaptation strategies to implement, there will likely be tradeoffs between preservation of coastal ecosystems that need to migrate landward to survive inundation and the protection of existing development and property rights.

Planned retreat, also called strategic retreat, managed realignment, managed retreat, set back, or de-embankment, entails establishing thresholds to trigger removal and relocation of development threatened by rising sea levels. As part of this process, actively maintained defenses against storm surge and sea level rise will most likely need to be adjusted over time, typically further inland and to higher ground, in response to encroaching waters.

Planning for strategic retreat entails first identifying vulnerable properties and structures and then developing incentives, such as regulatory, tax, and market-based tools, to encourage and achieve realignment. These options, as identified by NOAA (Eastern Research Group, 2013), are described as follows:

- **Transfer of Development Rights** are provided for in ordinances that allow property owners to transfer development rights from one location to another, and can be used as an incentive to redirect development away from vulnerable areas. The most controversial aspect of this type of program is the selection of receiving areas that will be subject to increased development densities. Community acceptance of this strategy will require public outreach and education. Local land trusts will likely be valuable collaborators in developing such programs (CEMA and CNRA, 2012).
- **Zoning and Development Standards** can be used in areas vulnerable to sea level rise and storm surge as a means of reducing impacts on future development. This is accomplished through enforcement of zoning ordinances that limit permitted densities and intensities of development, restrict allowable uses, establish setbacks and height limits, and implement various other land use controls. Development standards should ensure that new development does not increase the severity of flooding elsewhere and that structures constructed in areas subject to flooding are designed to accommodate floodwaters without damage. Local ordinances must, at a minimum, comply with federal requirements for developing within floodplains.
- **Purchase of Development Rights** is commonly used to preserve open space and farmland and entails local governments and nonprofits purchasing development rights so that the land remains under private ownership. By purchasing the development rights for vulnerable properties rather than the land itself, future development is restricted while allowing the property to be used for less intensive uses, such as grazing. In the context of coastal flooding, this can be used to prevent development in areas needed for habitat migration and to encourage development elsewhere.
- **Rolling Easements** are enforceable legal agreements entered into with property owners to allow wetlands, beaches, and other shoreline to migrate naturally without interference from engineered barriers or other types of coastal armoring. As these natural areas erode or are inundated by sea level rise, development that ends up seaward of a defined point inland must be removed from harm's way. As the shoreline continues to recede, the easement "rolls" farther inland. The intent of a rolling easement is to allow natural erosion or accretion to occur so as to preserve natural sediment transport systems, wetlands, and other tidal habitats. Easements can be purchased by a local government or donated by a landowner.
- **Fee-Simple Acquisitions** prevent new development from being placed in harm's way and can be used to remove development that is already in harm's way. Fee-simple acquisition can be used by local governments to purchase waterfront properties that are vulnerable to erosion and flooding. In the context of coastal flooding, the purpose of fee-simple acquisition is to remove and prevent development in vulnerable areas and to reduce future damage associated with coastal flooding. Fee-simple acquisitions can be used in conjunction with other managed retreat policies to preserve open space, wetlands, and other green infrastructure, and to further increase community resilience to coastal flooding.
- **Preservation of Open Space** can be used in coastal areas to not only prevent development from occurring in vulnerable areas, but also to secure undeveloped lands for the purpose of accommodating and retaining floodwaters. As discussed above, open space preservation is typically accomplished through land acquisition and conservation easements. A conservation easement is a voluntary agreement that limits development on a property while maintaining private ownership of the land. In the context of coastal flood mitigation, open space preservation is used to prevent development in vulnerable areas and mitigate the severity of flooding. This strategy often is employed in conjunction with other green-infrastructure-based flood mitigation measures.
- **Infrastructure Relocation** involves physically relocating existing infrastructure, constructing replacement infrastructure, or otherwise shifting the function of the infrastructure to a different location. One way to shift function to a less vulnerable area is through regionalization of facilities. For example, capacity could be expanded at an existing wastewater treatment plant in a community that is safe from sea level rise with the intention of eventually decommissioning a wastewater treatment plant in a nearby community that is vulnerable to sea level rise.

Because local governments largely determine the future of coastal development through implementation of local land use plans and regulations, city and county general plans and ordinances can play a significant role in sea level rise adaptation. However, despite information on adaptation planning being available, many local governments lack the resources and guidance to assist them in integrating adaptation strategies into existing plans and regulations. Furthermore, in developing new regulations, the new and amended land use plans and ordinances must be able to integrate with existing local regulations as well as comply with existing state and federal laws. To this end, the State of California's recently updated its General Plan Guidelines to include guidance on incorporating climate change adaptation into local general plans. However, there are currently still no state-specific "best practices" examples for local governments to model sea level rise ordinances on. Nevertheless, the legal framework for doing so is explained in Megan Herzog and Sean Hecht's Combatting Sea Level Rise in Southern California: How Local Governments can Seize Adaption Opportunities While Minimizing Legal Risk (Herzog and Hecht, 2013).

PUBLIC HEALTH STRATEGIES

Planning

A preliminary step in establishing public health resiliency is completion of a community-wide vulnerabilities assessment (or reassessment). Specific populations and locations with increased vulnerabilities to climate-related health problems should be identified to support development of a multi-faceted program to address needs. Some of the data needed for these assessments may already exist, as many public health departments have developed plans for vulnerable segments of the community. In coordination with public health departments, data and plans should be incorporated into other planning efforts. Additionally, many local governments are now using mapping technologies that can be used to geographically identify vulnerable segments of the community. Differential exposures to impacts of climate change, such as excessive heat and extreme weather events, can be examined from a geographic and social equity perspective by using GIS maps overlaid with vulnerability models and current socioeconomic, racial/ethnicity, and cultural group distributions (Morello-Frosch et al., 2009).

Existing community-wide assessments should be reevaluated for new, additional, or different risks associated with climate change. Housing assessments should be conducted or updated to determine whether structural modifications are required to address unmet needs. For example, such assessments could identify homes occupied by seniors and disabled persons; assess a residence's safety, energy, and water use efficiency; and develop a framework for modifying or retrofitting homes. Retrofits could include weatherproofing, efficient appliance and fixture upgrades, and installation of reflective roofing and shade coverings.

Many climate change adaptation strategies can focus on or be paired with strategies to address social equity and public health issues (CEMA and CNRA, 2012). For example, efforts to link land use with transportation can be combined with affordable housing plans. Likewise, efforts to ameliorate heat events and urban heat islands can be combined with plans to increase recreation opportunities. Finally, strategies to increase reliance on local goods and reduce transportation needs (e.g. farmers' markets and community gardens) can be used to address community development, food security, and access issues. Not only does this type of crossover make sense from an efficiency standpoint, it also increases social capital and strengthens local government. When government staff from different departments, such as planners and health care workers, work together, each department gains a more holistic understanding of community needs that they can bring to subsequent projects and planning efforts.

Planners and decision-makers should incorporate health, socioeconomic, and equity concerns into public education efforts, assessments, and recommendations for both large-scale land use decisions and individual projects. Further, general plan policies and zoning regulations can provide leverage for addressing health issues. To further strengthen social equity and justice within a community, local governments can institutionalize considerations of health in local and regional planning documents.

Outreach to Vulnerable Populations

Overall, local and regional planning efforts in the North Coast do not receive a great deal participation from vulnerable populations due to issues such as language barriers, lack of resources to participate, and feelings of disenfranchisement. In some cases, disadvantaged groups are too busy meeting basic needs to participate in community planning events. Thus, it is vital that communities endeavor to increase participation among low-income, racially and ethnically diverse, and special needs segments of the community (CEMA and CNRA, 2012).

One outreach method is to employ bilingual community health outreach workers with existing relationships, access to, and knowledge of low-income and underrepresented segments of the community to connect with vulnerable community members. Where job duties permit, these health workers can also disseminate climate and emergency response information and gather input to feed back into the climate adaptation planning process. Environmental and social justice organizations working with vulnerable segments of the community should also be included in climate adaptation planning to increase breadth of outreach and build social capital. Since these organizations already possess a trust relationship with the community, they are more likely to garner support and participation in the planning process and proposed solutions. Additionally, bringing in non-traditional partners broadens the coalition working towards climate resiliency, strengthening the process, and increasing public knowledge.

Another way to obtain input from vulnerable members of the community is to focus planning and intervention programs on neighborhoods currently experiencing social or environmental injustice or that bear a disproportionate burden of potential public health impacts. Proactive strategies that address current inequities can build adaptive capacity. For example, strategies that address today's risks of extreme heat events and lack of access to cooling shelters can also contribute to community resiliency and reduce the potential for climate change to worsen inequities and public health impacts. It is vital that vulnerable members of the community are involved in determining implementation strategies to ensure environmental justice goals are met and because community buy-in is essential for effective government.

Monitoring Outcomes

Communities should use performance metrics to evaluate and monitor the impacts of climate change adaptation strategies relative to public health and social equity. By monitoring outcomes, planners can gain insight into whether implementation measures are benefiting vulnerable segments of the community and whether modifications to the strategies are needed. Further, these monitoring efforts should be coordinated with county health departments to ensure that climate change resiliency, as it relates to public health, is being achieved. Finally, performance metrics should be developed concurrently with adaptation strategies to ensure that appropriate data will be available to evaluate success. Performance metrics can include cost-benefit analysis with distributive weights, where benefits related to social justice receive greater consideration (CEMA and CNRA, 2012). Fortunately, social and public health indicators are available on a county level and are shared openly (e.g., County Health Status Profiles 2017, US Census Data Viewer, US Census American FactFinder Community Facts).

Table 2.4-1, Select North Coast Community Strategies Public Health

Del Norte County	In an effort to promote readiness for climate change impacts, the California Department of Public Health synthesized health information for California counties based on recently published reports by state agencies, as well as other data. The report highlights the public health dimensions of climate change along with its environmental impacts. The report for Del Norte County is summarized below to illustrate the type of local information available. In Del Norte, climate vulnerable groups include approximately 1,700 children under the age of 5 and nearly 4,000 adults over the age of 65. About 2% of households do not have someone over the age of 14 who speaks English proficiently, and nearly 20% of adults over the age of 25 have less than a high school education. About 22% of the population lives below the federal poverty level, with 20% of households paying at least half of their yearly income on housing. Approximately 20,000 outdoor workers will be at risk due to increased heat events. Nearly 40% of the county lives in Moderate or Very High Fire Hazard Severity Zones, while 6% lives within a 100-year flood zone (Maizlish et al., 2017). This type of information, when provided spatially, will enable Del Norte County planners to best plan for and protect the county's most vulnerable citizens.
Sonoma County	The Sonoma County Planning and Community Development Department, Department of Health Services, Agricultural Preservation and Open Space District, Transportation Authority, and the Leadership Institute for Ecology and Economy collaborated to develop the Healthy by Design Workbook, which provides guidance and strategies for addressing public health and equity threats (Jacobson et al., 2010). The workbook focuses on general plan policies and regulations, programs, projects, and other steps needed to implement those policies related to eight main topics that span both climate and health-related issues. The topics are: access to open space and outdoor recreation, access to healthy food, walkable communities, opportunities to bicycle, senior health, youth health, air quality, and access to quality health care.
	Sonoma County has also created Health Action, a framework for community engagement to get people involved in creating a healthier county. Its mission is to "mobilize community partnerships and resources to achieve equity and improve health for all in Sonoma County" and it proposes to accomplish this through community and individual pursuit of Health Action goals across educational attainment, primary care, and economic security. This strategy is expected to increase adaptation capacity, particularly amongst segments of the community most vulnerable to effects of climate change.
	The Sonoma County Healthy and Sustainable Food Action Plan was developed by the Sonoma County Department of Health Services in partnership with the Food System Alliance. The guide describes local action for food production, land and natural resource stewardship, job development, public health, and equity in the food system. It encourages practices to support the agricultural sector's ability to adapt to climate change, and emphasizes the health, sustainability, and equity of the food system to enhance community resilience to climate change. The website for the Food Action Plan also provides a database of projects that is searchable by Action Area or Goal to facilitate community involvement.

ECONOMIC ADAPTATION MEASURES

Impacts of climate change have already contributed to economic losses worldwide. Heat waves and drought in the 21st century have led to projected losses of 1 to 12% of GDP per country per year; this is based on current climate patterns, but this figure rises to as high as 19% under projected conditions (Changa, 2014). An economic approach to climate adaptation policy must compare the cost of inaction with the costs of adaptation measures to identify a portfolio of cost-effective measures. Because of the uncertainty inherent in climate model projections, however, there are significant challenges to estimating adaptation costs and benefits.

Uncertainty about future conditions impacts the cost of inaction, as well as the value of benefits provided by different actions. Additionally, the nebulous nature of many adaptation actions makes it difficult to tease out actions that directly reduce climate change impacts from those that improve baseline "adaptive capacity" and address associated issues. For example, the development of emergency networks and protocols contributes towards climate resiliency, but general emergency preparedness for events that are not climate related, such as earthquakes, is also enhanced. Actions taken to reduce the impact of extreme heat events, like increasing urban green spaces and tree cover, also contribute toward ameliorating environmental and social injustices often found in areas that lack these amenities. Therefore, even though there is a strong foundation for understanding risk and the consequences of different alternatives under current climatic conditions, economists have not yet developed a standardized approach to assessing risk associated with climate change or the inherent uncertainty in climate change projections. It is crucial that analysts be aware of these uncertainties and make sure that all alternatives in a given climate adaptation scenario receive the same considerations and use the same projected conditions to ensure that alternatives are comparable.

Finally, it is vital that planners and decision makers be conscious of the difference between adaptation measures, such as air conditioning, which directly respond to climate (e.g., extreme heat) and "adaptive capacity," which refers to increasing a community's resilience to the effects of climate change. For example, measures that improve the general health of a vulnerable population, although they do not directly address extreme heat, increase the adaptive capacity of the community to be resilient to extreme heat events. While adaptation measures provide focused, short-term relief, increasing adaptive capacity strengthens community resilience across a suite of conditions.

Private Sector Involvement

Currently, most adaptation efforts are funded from public sources and private foundations, which do not seek significant monetary returns on investment. However, these funding sources are limited and typically insufficient for preparing for the projected impacts of climate change. Increased private investment is necessary, and to obtain private sector participation there needs to be a return on investment. The World Economic Forum (2014) suggests that the solution is for private and public sectors to work synergistically to create projects that generate a return on investment. The public-sector role is to frame the rules of investment and, when feasible, to allocate public funds to minimize financial risks and leverage private capital. For example, this could include providing matching funds to property owners who implement fire-reduction projects in wildfire-prone areas.

Some industries, such as real estate and insurance, are already contending with the financial challenges of climate change. Built real estate, which has an expected design life of 20 to 100 or more years, will likely experience the full extent of projected climate change in this century. Unless builders are currently considering climate-related impacts at each stage of the real estate life cycle, the long-term sustainability of developments could be compromised by a range of outcomes including premature deterioration and reduced service life; increased service disruptions and emergencies; increased repairs and maintenance; and increased health and safety risks. These factors could lead to a development being too uncomfortable or risky to live in; too expensive to operate and manage; too costly to insure; and finally, and most importantly from an investor's standpoint, not sufficiently profitable. The governmental role here typically includes direct regulation, such as zoning, building codes, setbacks, and buffers and economic incentivization, including new markets for tradable credits, economic tax and subsidies, and incentives using existing markets.

Insurance can play a dual role in climate adaptation. Access to insurance payouts can lessen the net adverse impact of climatic events on policy holders while at the same time incentivizing adaptations to reduce climate risks. If premiums are properly set, they can send appropriate signals regarding risks and encourage policy holders to undertake adaptation measures to reduce risks. Poorly designed premiums that do not adequately reflect risk can impede adaptation or even promote maladaptation (Agrawala and Fankhauser, 2008). The private insurance market can diversify the risk of large losses from extreme weather events and transform the small risk of a large loss by a single, private decision maker into the payment of a riskless insurance premium (Konrad and Thum, 2014). The insurance and re-insurance sector can spread these risks across many companies, creating resilience to large-scale natural disasters. Private insurance can incentivize individuals to implement preventive adaptation measures: if premiums are reduced according to the risk-reduction measures enacted, then individuals are expected to implement some preventive measures in pursuit of reduced insurance premiums.

Financing Adaptation Measures

Climate change adaptation and mitigation pose enormous financial challenges. In the North Coast, which contains many disadvantaged and severely disadvantaged communities, financing adaptation measures will take creativity, perseverance, and the development of a suite of options that include both private-sector and government sources. As previously discussed, local governments can either institute policies and codes to incentivize private participation in climate change preparedness or implement public projects with funds obtained through fees, taxes, grants, and other sources. For example, the Humboldt Operational Area Hazard Mitigation Plan describes charging a hazard mitigation fee to offset the cost of damages from flood events.

Fortunately, grants and low-interest loans are available to local governments and communities for projects that address projected climate change impacts. For instance, grant-funded fuels reduction opportunities to decrease wildfire risk are available through public and private sources such as the USFWS, CAL FIRE, USFS, BLM Rocky Mountain Elk Foundation, Humboldt County, Fire Safe Council, and The Nature Conservancy. Grant funding is not guaranteed, as many government and nonprofit agencies' staff are continually writing grant proposals to secure funding for adaptation actions. For some funding sources, preparatory work is vital. The FEMA hazard mitigation grant programs, for instance, require that an entity has a Local Hazard Plan in place prior to funding.

RESOURCE MANAGEMENT ADAPTATION MEASURES

Conservation lands are lands that have been set aside publicly or privately for their habitat value, ecosystem services, and in some cases, the recreation opportunities they provide. These lands will be impacted as plant and animal communities shift in response to the changing climate. Conservation lands managers are looking to expand protected areas networks so that sufficient habitat is available to accommodate projected changes. The first step, however, is an evaluation of the entire area under consideration to identify locations where the native species most vulnerable to climate change may shift or lose habitat due to projected climate change impacts (CEMA and CNRA, 2012).

When planning for conservation lands management, several sources for climate and hydrology projections are available (see **Table 2.6-1** below). The Terrestrial Biodiversity Climate Change Collaborative (TBC3) at Pepperwood Preserve in Sonoma County provides access to statewide climate and hydrology projections, potential native vegetation and habitat patterns at the landscape scale, a fire modeling algorithm that incorporates soil moisture and plant productivity indicators, and interactive mapping for the Bay Area. Land managers are encouraged to use data and tools such as these to determine optimal lands for protection.

As a community acquires and/or protects additional conservation lands, those parcels that adjoin existing public land should be given priority consideration. Additional considerations for expansion of protected areas include buffer zones, and identification and maintenance of corridors and linkages between undeveloped areas (CEMA and CNRA, 2012). Identification of potential acquisitions should also include habitat corridors with changes in elevation, so that mobile species have somewhere to migrate as temperatures increase.

Table 2.6-1 Resource Management Online Resources by Organization and Type

2014 California Basin Characterization Model Downscaled Climate and Hydrology	California Landscape Conservation Cooperative	website
Conservation Planning Atlas	North Pacific Landscape Conservation Cooperative	website
Modeling Bird Distribution Responses to Climate Change	Point Blue Conservation Science	mapping tool
Climate-Smart Restoration Toolkit	(PBCS)	website
Scenario planning for climate change adaptation: A guidance for resource managers	PBCS and California Coastal Conservancy	PDF
Bay Area Explorer Tool	Terrestrial Biodiversity Climate Change Collaborative	mapping tool
Climate Action Through Conservation Project	Sonoma County Agricultural Preservation and Open Space District	PDF
Phenology Visualization Tool	National Phenology Network	mapping tool
Forest Vegetation Simulator	Rocky Mountain Research Station, USFS	PDF
Responding to Climate Change in National Forests: A Guidebook for Developing Adaptation Options	Pacific Northwest Research Station, USFS	PDF
Habitat Conservation for Climate Adaptation: Initial Lessons from the Field	NOAA Coastal Services Center	PDF

Most communities already have policies and plans that govern the acquisition, establishment, and management of parks, open space, and conservation lands. These should be updated to assure that climate adaptation needs are included in the criteria used for determining actions (CEMA and CNRA, 2012). Conservation and open space management priorities should be modified to buffer species from the effects of climate change.

Another way for resource managers to manage lands for climate change is to reduce non-climate stressors, such as habitat loss, invasive species, and pollution by continuing current management practices, such as habitat restoration and invasive species removal. Less-stressed systems will be better able to adapt to the effects of climate change. Climate change impacts should be considered in the restoration and/or management of these properties. Goals should focus on plausible future conditions and management should strengthen existing ecological function and biodiversity protection (Cohen, 2017).

For land conservation to be successful as our climate changes, it is more important than ever to expand monitoring programs to better understand ecosystem dynamics. A monitoring and management program should be tailored to the specific local or regional setting with potential threats defined as specifically as possible to ensure that the data obtained and the management plans developed are useful (CEMA and CNRA, 2012). The National Phenology Network collects phenology data, which is the timing of natural events (e.g., tree bloom, wildlife reproduction, and leaf fall) throughout the United States with the help of citizen scientists. These data are available in an online mapping tool, and the network provides training materials, communications templates, and other support for those interested in beginning a local phenology research effort.

Table 2.6-2, Select North Coast Community Strategies Resource Management

Sonoma County	The Sonoma County Agricultural Preservation and Open Space District and local, state, and federal partners in 2010 began Sonoma Veg Map, a five-year program to map Sonoma County's topography, physical and biotic features, and diverse plant communities and habitats. The publicly available datasets produced by this program, including countywide LiDAR data and a fine scale vegetation and habitat mapping, provide an accurate, up-to-date inventory of the county's landscape features, ecological communities, and habitats. These foundational data sets are vital to facilitating good planning and management for watershed protection, flood control, fire and fuels management, and wildlife habitat conservation. These data are also critical to assessing climate mitigation and adaptation strategies and benefits provided by the landscape, such as the amount of carbon sequestration in forests or the degree to which riparian areas, floodplains, and coastal habitats may buffer extreme weather events. The 45-class vegetation map features greater specification of vegetation types, including those of most interest for conservation: old forest, riparian zones, wetlands, and rare habitats.

Forestland

Some of the most difficult climate change impacts to address are those that progress slowly and are therefore more difficult to recognize. Due to the long cycles involved in forestry harvests, this phenomenon is particularly relevant. Shifts in forest health and invasive species spread can have detrimental impacts on biodiversity, wildfire frequency, and ultimately, timber harvest. Without careful monitoring, changes in forest composition and/or structure may be missed during the early stages of forest succession. A monitoring program that is tailored to regional needs allows for responsive management of these systems and enables identification of areas where insects and disease, invasive species, and/or tree mortality levels are high or increasing. Careful management can maintain economic value, watershed function, and biodiversity. These factors not only relate to forest and rangeland health, but also wildfire risk (CEMA and CNRA, 2012).

According to researchers at the USFS Pacific Northwest Research Station, "planning needs to embrace managing forests for adaptation to new conditions by promoting the resistance of a forest to change, resilience of a forest in the face of change, and response options that facilitate the transition of forests to new conditions" (Anderson and Palik, 2011). In other words, forest managers need to consider potential climate effects, spatial scale of response, timing, and prioritization of adaptation efforts. As with conservation lands management, prioritization and planning are key to identifying vulnerabilities and developing a suite of potential actions to address those vulnerabilities.

Silvicultural planning differs from conservation planning in that the forest is managed for production of goods (timber) in addition to the ecosystem services that are also expected by society, such as filtration, pollination, wildlife habitat, and carbon sequestration. Threats to forests from climate change include warmer, drier growing seasons that increase risk of catastrophic wildfire, and milder winter temperatures that increase risk of damage from insects and disease. For foresters, an awareness of how these environmental stresses will impact individual tree vigor and stand dynamics is critical.

Management options for foresters include density management, composition management, and threat reduction. Density management has traditionally been used to favor the growth of a smaller number of larger, desirable trees; however, thinning can also make a stand more resistant to insects and pathogens. Lower tree density can increase wind speeds within a canopy, which makes controlled flight difficult for some bark beetles and it may also decrease relative humidity which could create conditions less favorable to some pathogenic fungi, but may promote infection by others (Anderson and Palik, 2011). Removing understory trees and shrubs also frees soil and water resources for commercially valuable trees and limits fire severity by removing a portion of the fuel load.

Composition management of forest stands should favor species that have characteristics suited to projected environmental changes. Such traits may include drought and fire resistance; however, it is important to understand that such traits have been developed in response to historical pressures and may not be suitable for projected conditions. Additionally, changes in phenology, such as asynchrony between flowering and pollinator development, may limit natural regeneration of otherwise suitable tree species. Development of mixed-species or multi-provenance forests decreases risks associated with pest outbreaks and promotes greater genetic diversity, and therefore resilience (Sinclair et al., 2015).

Threat reduction includes "sanitation" harvests to remove biotic threats such as insects and disease and integrated pest management to minimize risks associated with invasive plants and animals. At the landscape level, fuels management is integral to restoring fire resilience. For fuel reduction to be effective, at least 20 to 30% of the landscape should be treated by thinning in designed spatial patterns (Anderson and Palik, 2011). Considering forests at the landscape scale is also useful in prioritizing site and stand level actions to reduce overall threats to forest health and profitability.

LOCAL SUPPORT STRATEGIES

There are multiple ways a community can achieve and maintain a strong focus on climate adaptation. Regulatory tools such as codes and ordinances can require use of climate friendly practices, and incentives like "cash for grass" programs can encourage private participation. Additionally, increasing public understanding of projected climate change impacts and the actions that are available to mitigate and adapt to those conditions will improve community buy-in and capacity for good decision-making and increased collaboration. Likewise, increasing local government capacity to understand and plan for climate change impacts will be an ongoing process for many communities. Each community should collaboratively choose approaches that address community-specific characteristics, impacts, and needs.

Zoning and Regulation

Prevention is a powerful way to avert disasters. Appropriate use of zoning and development codes can prevent or minimize flooding events, as well as losses from wildfires, drought, and other climate change impacts. The US EPA recommends that communities use "Smart Growth Principles" when developing zoning and building codes (see **Table 2.7-1** below). These principles, developed in the mid-1990s, do not specifically consider a changing climate; however, many of the principles in fact either mitigate or adapt to climate change impacts. For example, protection of critical environmental areas, such as floodplains, can reduce flooding and increase groundwater recharge, boosting community resiliency to storms and drought. Likewise, mixed land use, walkable communities, compact development, and a variety of transportation options lower GHG emissions, and result in lower water and energy use, which enhance mitigation and resilience (California Strategic Growth Council, 2016).

The North Coast has many rural communities that face unique challenges associated with declining resource-based industries. Communities desperately want to maintain their historic rural character, but increasing regulations, the economic downturn, and other socioeconomic and environmental factors have caused many to be classified as Disadvantaged Communities by state standards. According to the US EPA, rural communities that want to maintain their historic character should "pursue three goals using smart growth approaches:

1. Support the rural landscape by creating an economic climate that enhances viability of working lands and conserves natural lands;
2. Help existing places thrive by taking care of assets and investments such as downtowns, main streets, existing infrastructure, and places with meaning to the community;
3. Create great new places by building vibrant, enduring neighborhoods and communities that people, especially the young, do not want to leave" (USEPA, 2012).

Acknowledging the importance of natural systems and working lands, California's Strategic Growth Council 2050 Vision Plan (2016) promotes urban-rural connectivity in all regions of California. The Plan states that recognition of the benefits of functional ecosystems and sustainable working lands relative to projected climate change impacts is vital to making "fully informed land use and resource management decisions and can serve to drive investment and jobs to rural communities, support urban-rural cohesion, and bolster the economic value of rural lands."

Zoning codes and building regulation templates are available from a variety of sources (see **Table 2.7-1** below), including NGOs, federal, state, and local sources. For example, Sonoma County is collaborating with the Emmett Institute at the UCLA School of Law to develop a model sea level rise ordinance that complies with federal and state requirements while harmonizing with other local plans and laws (Herzog and Hecht, 2015). When this model is complete, it will be available for other communities in the North Coast and throughout California that face issues associated with sea level rise.

Table 2.7-1. Code Policy, and Regulations Guidance and Templates

Agency	Title	Subject
California Attorney General's Office	Sustainability and General Plans	Examples of policies to address climate change
California Governor's Office of Planning and Research	2017 General Plan Guidelines	State requirements for implementing climate change considerations into local general plans
Center for Law, Energy & Environment, UC Berkeley School of Law	Integrating Infill Planning in California's General Plans: A Policy Roadmap Based on Best-Practice Communities	Examples of infill-supportive goals, policies, and implementation measures
City of Palo Alto	Green Building Code	Green Building
City of San Francisco	City Government Climate Action	GHG Reduction
US EPA	Codes that Support Smart Growth Development	Examples of adopted codes and Guidelines from around the US
Institute for Local Government	Sustainability Best Practices Framework	Best Practices
US EPA	Essential Smart Growth Fixes for Rural Planning, Zoning, and Development Codes	Examples of Rural Preservation Codes
US EPA	Essential Smart Growth Fixes for Urban and Suburban Zoning Codes	Examples of Sustainable Urban and Suburban Codes
San Francisco Green Building Task Force	2008 Building Code	Green Building
Smart Growth America	Smart Growth Implementation Toolkit	Policy Implementation
UC Berkeley	Integrating Infill Planning in California's General Plans	Infill Planning

Infrastructure Planning

In addition to considering climate change adaptation when developing policies and regulations, local governments and agencies should incorporate climate change trends in present day risk and vulnerability assessments for community infrastructure and update their plans accordingly. Addressing climate change in plans and ongoing operations procedures (e.g., maintenance) assures improved preparation and greater resilience to climate change impacts (CEMA and CNRA, 2012). Furthermore, particular attention should be paid to economic risks during these assessments. While retrofitting or relocating infrastructure can be costly, the costs associated with projected disruption to these systems can be even greater. Finally, it is vital that community plans and programs, such as local hazard mitigation plans, urban water management plans, stormwater management plans, regional transportation plans, and capital improvement plans, be coordinated and consistent.

Table 2.7-2, Select North Coast Community Strategies Infrastructure Planning

Del Norte County	The Del Norte Local Transportation Commission prepared a Climate Change Adaptation Study to identify infrastructure predicted to be affected by climate change by the year 2100. The study assesses approximately 680 miles of roadway in the county along with other vital infrastructure, and the results informed both the County's Regional Transportation Plan (2016) and Stormwater Management Plan (2015). The County has also recently updated its General Plan Housing Element to consider greenhouse gas emissions in compliance with a 2010 statutory change to CEQA guidelines.
Del Norte, Humboldt, and Mendocino counties	Caltrans received a Federal Highway Administration grant to study potential vulnerabilities of transportation assets to climate change throughout District 1 and to identify and evaluate a range of adaptation options to address identified vulnerabilities at four demonstration sites.

Increase Capacity

Increasing community capacity requires improving understanding of climate-related risks, effectively obtaining and using available information, and developing necessary institutions and networks. With increased capacity, local communities will be empowered to plan and build appropriate adaptation projects and monitor and evaluate outcomes to inform future management actions. Increasing capacity occurs at two levels: institutional and individual. Institutional actions to increase capacity include information sharing, fund raising, and planning and outreach to reach and empower individuals in the community. However, increasing capacity can also be achieved through community-based efforts. One such community-based movement is the Transition Streets movement, which empowers neighbors to work collectively to save resources and build community resilience at the neighborhood scale.

To increase local adaptation capacity, communities need to incorporate climate change adaptation into all relevant local and regional plans and projects in all sectors of community and government (CEMA and CNRA, 2012). This will promote consideration of projected climate change impacts and potential consequences in all relevant local policy. Because community and staff understanding of and support for climate adaptation strategies are critical for comprehensive integration and long-term implementation, integration of climate adaptation into community plans should be pursued in parallel with outreach and education.

Together with ongoing planning integration efforts, communities need to establish a climate change adaptation public outreach and education program. Long-term implementation of climate change adaptation will require ongoing community support, which is only possible if probable consequences of climate change are understood. Education programs should raise public awareness of threats associated with climate change and the community benefits of taking action.

Communities should emphasize tangible threats, such as lack of water, property damage associated with sea level rise, and public safety risks, such as flooding and wildfire. Co-benefits of implementing climate adaptation projects should be clearly explained, such as water supply reliability, food security, social justice, and improved quality of life. It is vital to the engagement process to also provide opportunities for community input, which will both empower the community and result in greater community buy-in.

There are many sources for accurate climate-related tools and trainings for both government staff and the public. For instance, NOAA's Office for Coastal Management Digital Coast Academy offers over 100 coastal-based training resources including: *Climate Adaptation for Coastal Communities*, *Coastal Inundation Mapping*, *Introducing Green Infrastructure for Coastal Resilience*, *Planning Effective Projects for Resilient Coasts*, *Seven Best Practices for Risk Communication*, and other instructor-led classes that empower participants. In addition, NOAA's Office for Coastal Management makes available a sea level rise viewer and Coastal County Snapshots, which provide easy-to-understand charts and graphs that describe complex coastal data.

On the state level, the Climate Change Portal provides resources for local governments related to climate change adaptation and mitigation, while the California Strategic Growth Council provides assistance with sustainability planning. Further, the California Energy Commission has developed the Cal-Adapt website, which is dedicated to "exploring California's climate change research" and provides access to interactive maps and charts, raw data, research and publications, and social media.

Additional resources are available from nonprofits, universities, and other organizations. These include Climate Solutions University (CSU), which is a project of the Model Forest Policy Program that provides assistance to communities in developing climate adaptation plans. To date, two North Coast communities have developed plans through the CSU: The Watershed Research and Training Center (2011) and the Mattole Restoration Council (2012). In addition, the Nature Conservancy has developed Climate Wizard, a web-based interactive mapping platform that provides access to accurate, up-to-date climate change information and the ability to visualize impacts. Cornell University hosts Cornell Climate Change, a website that provides current research, education, and public engagement resources. Climate Access, developed by Stonehouse Standing Circle and Rutgers Initiative on Climate and Society, provides a network for those engaging the public in the transformation to low-carbon, resilient communities.

In addition to the resources described above, there are many other useful resources developed by the federal government, other states, universities, and NGOs. Each community should find and use the mix of accurate, vetted resources that work best for its current and projected situation.

AGRICULTURE

"Best practices" is a term used in land management for practices that alleviate land use impacts, improve land productivity, and/or reduce operational costs. The term evolved around changing management practices to minimize non-point source water pollution, but has grown to encompass practices that address water supply reliability, climate change adaptation and mitigation, and ecosystem services, such as pollination, air quality improvement, and habitat for listed plant and animal species. Resource Conservation Districts (RCDs) are strong leaders in disseminating information about best practices and obtaining funding for landowners to implement them. They also provide technical assistance for planning, implementation, and monitoring. Nonprofits such as the Salmonid Restoration Federation, local watershed groups, and agricultural support organizations are also important participants in the establishment of best practices. Funders for implementation of best practices include land trusts and agricultural and open space districts, USFS, USDA Natural Resource Conservation Service (NRCS), and NOAA.

Agricultural associations, cooperative extensions, RCDs, and other entities are uniquely positioned to understand the needs and concerns of farmers. Working with these entities allows jurisdictions to identify and disseminate locally relevant agricultural information and techniques. Outreach and education methods may include distribution of educational materials, workshops, or demonstration/training sessions on adaptive techniques (CEMA and CNRA, 2012). These organizations can introduce adaptation techniques and shorten the time it takes for new scientific findings and adaptive approaches to reach farmers. For example, a consortium of RCDs in the Bay Area (including Gold Ridge and Sonoma RCDs) is working with the Marin Carbon Project to enhance rangelands through compost application, a practice that also stores atmospheric carbon. As these RCDs work with farmers to implement carbon farming, on-the-ground results are informing the development of carbon markets and NRCS best practices, which will be disseminated throughout the country.

Local governments can bolster agricultural sustainability by adjusting land use regulations to encourage the diversification of potential sources of farm income, including value-added products, agricultural tourism, roadside stands, organic farming, and farmers markets (CEMA and CNRA, 2012). Diverse income sources can help reduce the financial consequences of climate change impacts on agricultural landowners. Adjustment of land use regulations will allow and encourage practices such as agricultural tourism or other commercial operations; however, adjustments to allow such activities should carefully consider adjacent land uses and potential consequences of new commercial operations, such as increased traffic.

Farmers and ranchers have a leadership role to play in local adaptation to and mitigation of climate change impacts. Described below are just some of the many ways that agricultural producers can adjust their management practices to help conserve water, sequester carbon, improve soil and water quality, and protect wildlife habitat.

Water Supply

Water supply reliability is an ongoing issue for agriculture throughout much of the region, with agricultural withdrawals from streams and groundwater basins occurring during the summer when instream flow is limited. Summer withdrawals can lead to insufficient flows for native wildlife, including threatened and endangered salmonid species. A recent development in agricultural irrigation is the use of small-scale storage tanks to store winter rains for use during the summer dry season. The Center for Ecosystem Management and Restoration (CEMAR) has conducted extensive streamflow data analyses on the watershed scale in coastal California. These analyses compare measured streamflow to the amount needed for human activities and show that there is more than enough water to meet human needs; however, it is falling during winter, when agricultural (and urban) demand is low. CEMAR's conservation hydrology program focuses on increasing summer instream flow by reducing human diversions during the summer months through use of small-scale ponds and tanks (CEMAR, undated). These techniques have been applied extensively in several watersheds in the North Coast, including the Mattole River and the Estero Americano.

Farmers and ranchers can switch to alternative irrigation techniques to use both less water and less energy. When less water is pumped from groundwater or other storage basins, energy is saved, thereby reducing greenhouse gas emissions (CEMA and CNRA, 2012). Local jurisdictions can promote alternative irrigation techniques through partial or full coverage of cost and technical support. In some cases, the conversion to alternative irrigation techniques can be funded as offsite mitigation of greenhouse emissions as part of a project's CEQA review. An incentive program should be accompanied by an outreach program to raise awareness of the program and irrigation alternatives. Existing irrigation techniques and the growing requirements for crops in an area must be evaluated in developing a program and/or fund to support irrigation upgrades. Changed irrigation practices often entail substantial investment, labor, and energy and may not be useful for all crops. A water demand reduction farm plan should include consideration of optimal irrigation techniques and identify crops suitable for projected conditions.

Soil Conservation

Soil moisture conservation practices, such as conservation tillage, are potential adaptation measures to reduced rainfall. In conservation tillage, some or all the previous season's crop residue is left on the soil surface. This can protect the soil from wind and water erosion and retain moisture by reducing evaporation and increasing infiltration. Compost application has been proven beneficial to rangelands for both increased productivity and increased soil moisture (Ryals and Silver, 2013). Increased soil organic matter will not only improve the water holding capacity but also improves soil structure (Laaser et al., 2009), leading to more sustainable agricultural lands.

Another soil conservation measure is catch crops, which are usually sown after the harvest of one crop and before the sowing of the next. They offer forage and/or green manure by providing nitrogen for the soil, thereby reducing need for nitrogen supplements for the next crop. Catch crops are quick-growing plants that will establish before winter and can also be planted amongst crops in intercropping systems. Their adaptation benefits include reducing nitrous oxide emissions or leachate (through less need for fertilizer), improving nitrogen-use efficiency, and soil carbon sequestration. During winter floods, catch crops help to stabilize soil and prevent erosion.

3. DOCUMENTS REFERENCED AND/OR INCORPORATED BY REFERENCE

The following documents and online resources were used to document climate change vulnerability and uncertainty in the North Coast region of California, as well as to identify climate adaptation and disaster resiliency strategies that can be employed by North Coast communities in response to climate change impacts.

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