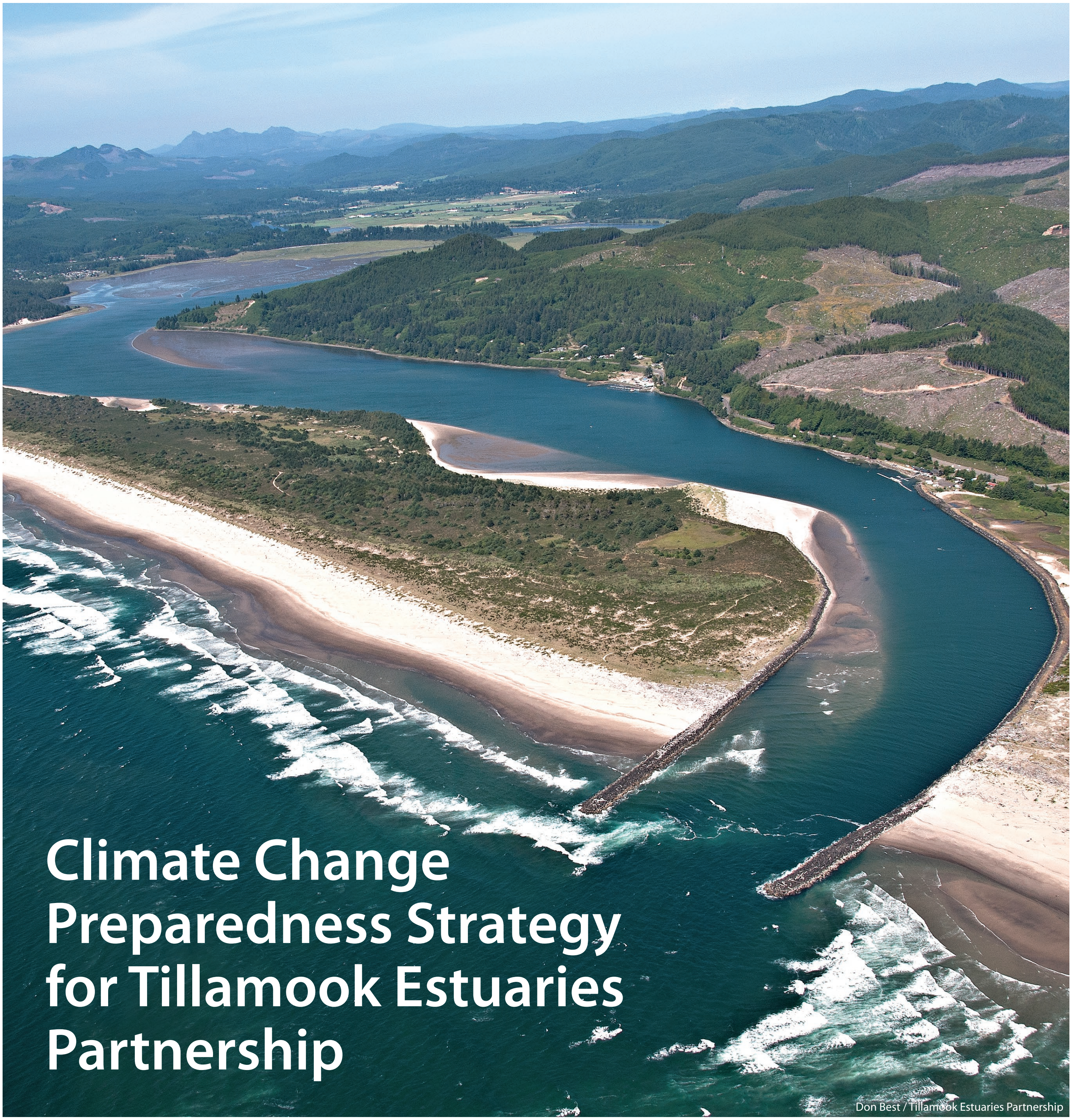

Climate Change Preparedness Strategy for Tillamook Estuaries Partnership

Nehalem Bay

August 2018

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Prepared for the
Tillamook Estuaries Partnership

GEOS INSTITUTE

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Tillamook Estuaries Partnership
A National Estuary Project

Netarts Bay

Don Best/Tillamook Estuaries Partnership

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Students sample invertebrates at Twin Rocks Friends Camp — Tillamook Estuaries Partnership

Executive Summary

The five estuaries of Tillamook County and their watersheds are home to biologically important species and resources that also support the local economy, provide recreational opportunities, and bring natural beauty and overall well-being for people throughout the region. Tillamook Estuaries Partnership (TEP) plays an important role in the restoration and management of natural resources throughout the county, especially by working with partners, landowners, and other stakeholders throughout the region.

The diversity and abundance of natural resources in the region are vulnerable to impacts from numerous stressors, including climate change. Climate change is already affecting the species and resources of the region and is expected to accelerate and worsen over time. Ocean acidification, from an increase in carbon dioxide in the ocean, is causing a decline in larval survival among shellfish. Other climate change stressors include warmer rivers and streams with more algal blooms and lower oxygen levels, larger and more destructive storm and flood events, greater storm surge impacts, more frequent heat waves and drought conditions, loss of important conifers in the area, more frequent forest fires, and numerous other impacts.

TEP has spent decades successfully working with numerous partners to improve natural resource conditions and socio-ecological resilience throughout Tilla-

Primary Climate Stressors for Tillamook Estuaries and Watersheds

- Summers 5-8° F and winters 4-7° F hotter by 2085, on average
- Severe heat increasing 3-10 days per year, on average, by 2085; hottest days becoming 2-9° F hotter
- More variable precipitation by 2085, with wetter winters, drier summers, and much drier conditions overall
- Earlier peak in stream flow with larger winter pulses and lower low flows
- Continued increases in water temperture due to higher air temperature and lower flows
- Increased likelihood of extreme precipitation and flooding
- Increasing coastal storm surge, wind, and wave heights
- 2-5 feet of sea level rise by late century
- Ocean acidity disrupting bivalves by 2030 and doubling by late century
- Wildfire frequency expected to double; area burned to increase by about 140% by late century
- Species of aquatic and terrestrial wildlife expected to experience declines in some areas and increases in others
- Increases in pests, disease, and invasive species
- Loss of important wetlands and their associated ecosystem services

Note: Projected changes are associated with varying levels of uncertainty. Some variation comes from modeling processes. Most uncertainty, however, is associated with unknown human behavior and whether or not people reduce greenhouse gas emissions.

mook County. However, these positive results are at risk of being undone as climate change progresses in the region. In addition, current efforts may become less effective and/or could fail due to climate change. TEP is reassessing its goals and management actions in light of climate impacts, to identify a positive path forward for the natural ecosystems and socioeconomic well-being of all residents.

Climate change model projections specific to this region were reviewed. Based on these projections, primary climate stressors were identified (left) and local stakeholders and experts assessed specific risks to TEP's ability to meet its goals. Climate risks to the region and its resources are available in more detail in the climate change vulnerability assessment.[1]

TEP and its partners can take action to reduce the risks associated with climate change and protect people and the region's righ biological diversity from climate impacts. Strategies and actions to reduce climate risks were developed and prioritized specific to meeting TEP's conservation goals.

Twenty-three strategies were developed, with 72 medium and high priority actions. These priority strategies and actions were categorized into seven groups:

- Existing Management Practices
- Expand Restoration and Conservation
- Infrastructure Improvement
- Education and Outreach
- Research and Monitoring
- Capacity Development
- Planning and Policy

TEP is already implementing many of the adaptation strategies that were identified in this report. Thus, the importance and relevance of TEP's ongoing work was validated and magnified by the climate change vulnerability assessment and development of adaptation strategies. New strategies were identified, and shifts in the focus of TEP's work were suggested based on the projected advance of climate change throughout the region and the globe. TEP's role in climate change adaptation in the Tillamook region will become even more important as different sectors respond to climate change in a variety of ways that could potentially create new resource conflicts and degradation. TEP's continued role as a partnership organization that works across sectors and interests is increasingly vital to providing a trusted voice on climate science, to facilitate communication, and to address new and exacerbated stressors to the local communities and natural resources within the Tillamook estuaries and watersheds.

Children help trailblaze at Kilchis Point Reserve

Tillamook Estuaries Partnership

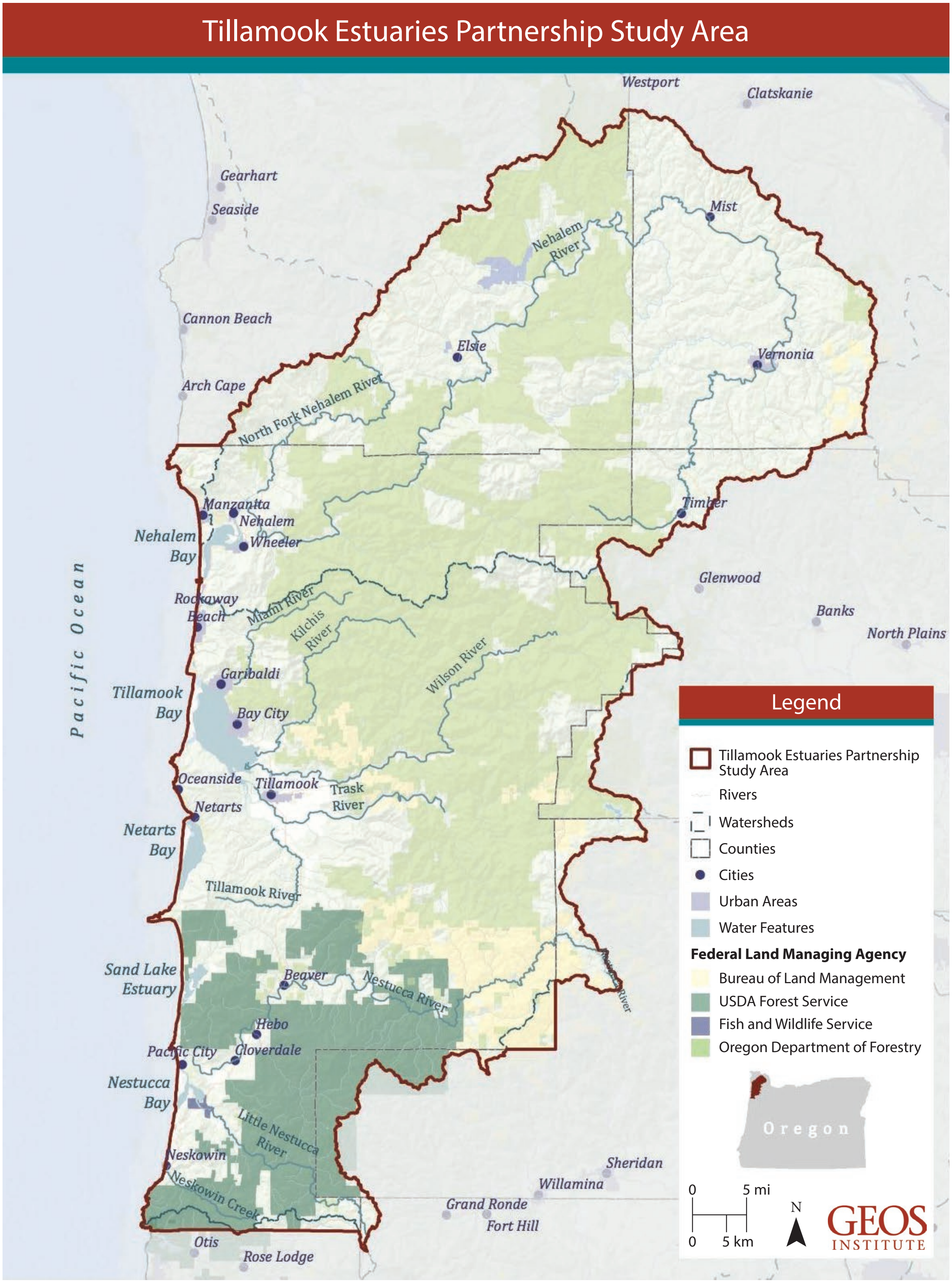


Figure 1 Map of land ownership and major features in the TEP study area.

View from Oregon Coast Trail

Introduction

The five estuaries and their watersheds that make up Tillamook County are vitally important for biological diversity, industry, local communities, and quality of life along this northern portion of the Oregon coast. The dynamic waterways, coastlines, and beaches draw tourists and locals for outdoor recreation. Tillamook County's uplands and forests are important for wildlife habitat, farming, forestry, and outdoor activities such as hunting, hiking, and mountain biking. The estuaries and rivers provide important habitat for fish, shellfish, and other aquatic organisms.

The five estuaries of Tillamook County include Tillamook, Netarts, Nestucca, Nehalem, and Sand Lake (Figure 1). The watersheds include seven major rivers and countless tributary streams, extensive coastlines and beaches, forested peaks, diverse communities, and agricultural lands.

Diverse partnerships are critical to balancing the needs and resources that sustain both people and nature in the region.

Tillamook Estuaries Partnership (TEP) is a non-profit organization that works with partners and stakeholders throughout Tillamook County to address issues such as flooding, habitat enhancement and restoration, salmon recovery, water quality, and environmental education. The National Estuary Program first designated Tillamook Bay as a "Bay of National Significance" in 1994. In 1999, the Comprehensive Conservation Management Plan (CCMP) was developed,[2] and in 2002, TEP's geographic scope was expanded to include all five Tillamook County estuaries and their watersheds, from the highest upland peaks to the estuarine and near shore habitats.

These lands, natural resources, and people are vulnerable to the impacts of climate change, which are already being reported.[3] TEP's overarching goals are to improve watershed and habitat function, foster biodiversity, and reduce the expected negative impacts of climate change on people as well as nature, thereby leading climate change preparedness and furthering societal adaptation.

In response to the increasing threat of climate change to coastal resources, the Environmental Protection Agency (EPA) developed the Climate Ready Estuaries Program (CREP) to assist National Estuary Programs in integrating climate change adaptation strategies into their Comprehensive Conservation and Management Plans. Following the EPA's workbook, *Being Prepared for Climate Change: A Workbook for Developing Adaptation Plans*,[4] the report herein provides a summary of the results of the Vulnerability Assessment and adaptation strategy development for Tillamook County's estuaries and watersheds, which make up TEP's study area.

This climate change adaptation strategy was developed by TEP, local stakeholders, and the Geos Institute, in order to identify achievable strategies to address climate change risks to TEP's ability to meet its goals. The risks that were identified for the region, its resources, and TEP's goals, are provided in detail in the Vulnerability Assessment. This climate adaptation and preparedness strategy provides an overview of those risks, as well as the strategies and actions developed to increase climate change preparedness and resilience of the region's natural resources. In turn, the priority strategies and actions presented in this report informed the update of TEP's guiding document, the 2018 Comprehensive Conservation and Management Plan (CCMP).

Wilson River

Past and Future Climate Trends

The earth's climate has been changing over millennia, but human activities, especially since the industrial revolution, have resulted in change that is expected to accelerate over time. Environmental data and direct observations allow us to measure rates and trajectories of change in the past, while models of the earth's climate system allow us to assess potential future change. The current and projected rates of warming and change are unprecedented during human habitation of the earth, leading to a prospect of novel and poorly understood conditions that people and natural systems will need to navigate in the future, if warming goes unabated.[5]

Climate change data and models

The earth's climate is regulated by a layer of gases commonly referred to as greenhouse gases for their role in trapping heat and keeping the earth at a livable temperature. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O). CO_2 plays an especially prominent role due

Table 1 Overview of climate change trends for the Tillamook region, from the Climate Trends Primer (Appendix A).

Historical Trends

- Temp. ↑ 1° F from 1901–2009
- Precip. ↓ 1.8 in. since 1901
- Large storms ↑ more frequent
- Sea level ↓ 1 inch since 1925
  (note – sea level rise has been balanced out by local upward land movement)
- Ocean acidification ↑ since pre-industrial levels

Likely Future Trends

- Temp. ↑ 4–7° F by 2080s
- Summer temp. ↑ 5–8° F by 2080s
- Number of days above 90° F ↑
- Precipitation ↑ 5% by 2080s
- Winter precipitation ↑, summer ↓
- ↑ flooding and ↑ drought
- Sea level rise ↑ 2–5 ft. by 2100
- Ocean acidification ↑ doubled
- Winter stream flow ↑ and summer ↓

to its long residence time and relative abundance. The atmospheric concentration of CO_2 has risen from 280 to over 400 parts per million (ppm) in the past century, driven largely by fossil fuel combustion, deforestation, and other human activity.[6]

Information from ice cores provides us with a glimpse into CO_2 levels over hundreds of thousands of years. These data show us that CO_2 has fluctuated between about 175 and 300 ppm over the last 800,000 years. The current level above 400 ppm is far above anything detected in the ice core analyses. As CO_2 has fluctuated in the past, it has tracked closely with changes in temperature, and we can expect this relationship to hold in the future as CO_2 and other greenhouse gases continue to increase.

The Intergovernmental Panel on Climate Change (IPCC), which is made up of thousands of leading scientists from around the world, has created a suite of 22+ global climate models (GCMs) from different institutions with which to assess future trends. These models were created independently, and vary substantially in their output. In addition, there are different potential "pathways" for future greenhouse gas concentrations (called Regional Concentration Pathways, or RCPs), which depend on whether or not the international community cooperates on reducing greenhouse gas emissions.

Climate change data and models can help us understand historic and future trends, including the trajectories, timeframes, and magnitudes of changes that can be expected. All models have uncertainty, because complex processes are simplified and assumptions are made about how the earth's processes work. Thus, different models show different trends in future climate. How much they vary gives us information about uncertainty. The uncertainty is similar to that associated with other types of models that we use every day to make decisions about the future, including economic models, population growth models, and environmental models.

Much of the data on future trends in this report are compiled from an "ensemble" or average across 13 GCMs, which have been adjusted from the global scale (course scale) to local scales (fine scale) using fine scale climatological data that reflects variation across the local landscape. When ensembles are used, it is important to understand the range of variation among the different models in the ensemble, as it can be quite great. In general, precipitation projections are associated with higher uncertainty (i.e. more variation among models) while temperature projections are associated with lower uncertainty. Also, short- to medium-term projections have lower uncertainty than long-term projections.

Historical trends

Temperature – A report by the Oregon Climate Change Research Institute (OCCRI)[7] assessed historical changes in climate for the Tillamook Bay Watershed. They found that warming has already occurred in the region, by 1° F from 1901-2009. This amount is lower than the average warming of 2.6° F for the state of Oregon,[8] likely because of the moderating coastal influence.

Precipitation – Precipitation in the Tillamook region has declined about 0.18 inches per decade, or 2 inches overall, from 1901-2011.[7]

Extreme events – The number of storms producing more than 2.10 and 2.99 inches in a 24-hour period have increased in frequency by about 0.5 and 1 additional day per century, respectively.[7]

Sea Level – Global mean sea level is rising due to higher temperatures that cause ocean water to expand, as well as melting ice sheets. Since 1993, global sea level has risen about 3 mm per year.[9] Along the coast of Oregon, sea level consists of two often opposing trends – the global sea level and the elevation of the coastline (Figure 2). Because Oregon's coastline is rising in many locations due to plate tectonics, net sea level is declining in some areas. However, as sea level rise accelerates, it is expected to outpace changes in the land surface. In Astoria, which has better data, sea level declined by about an inch from 1925-2006. Overall, global mean sea level rose about 7.5 inches from 1901-2010.[8]

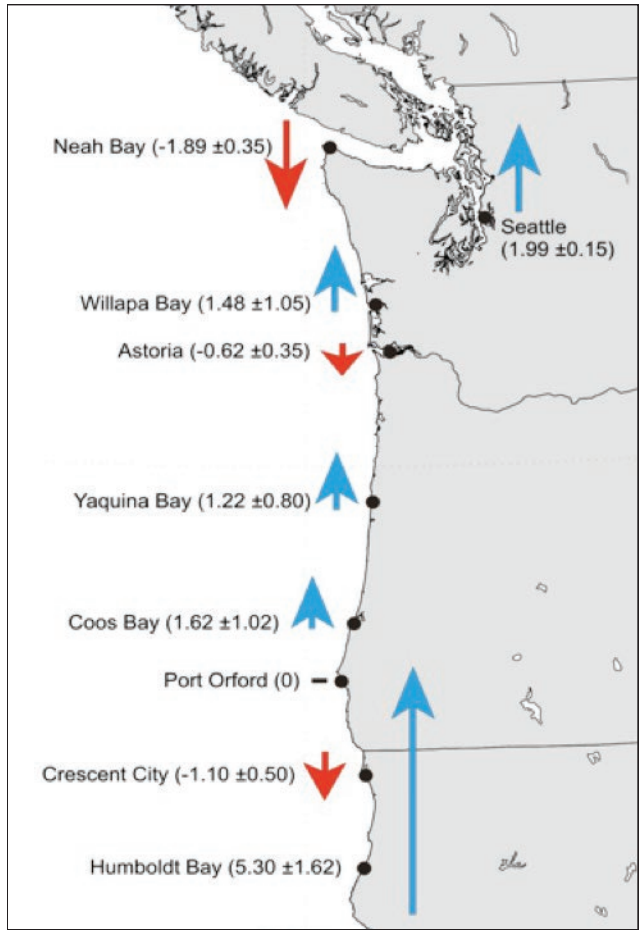


Figure 2 The net effect of sea level rise and land upheaval, over the last several decades, along the coast of CA, OR, and WA. Figure from OCCRI 2013.[7]

Wave Height and Storm Surge – Wave heights have increased in the northeast Pacific over the past several decades, as have extreme wave events and recent increases in coastal flooding and erosion.[10] Major El Niño years, such as 1982-83 and 1997-98 can result in "hot-spots" of erosion from high water levels and waves, leading to significant impacts to coastal resources and infrastructure.[11] Wave heights are increasing about 3 inches/yr. throughout the region.[12]

Ocean Acidification – The ocean absorbs a large proportion of our CO_2 emissions, causing it to become more acidic. Ocean acidity has increased by more than 30% worldwide. Increased acidity reduces carbonate, which is needed by many marine organisms to form shells. In Oregon, naturally occurring upwelling brings acidic waters from deeper areas, compounding the problem. Netarts Bay has been recognized for the impacts that acidification has had on the Whiskey Creek Shellfish Hatchery's ability to produce oyster larvae for commercial shellfish growers.[13]

Stream flow – Mean annual stream flow across Oregon has decreased since the middle of the century, with the greatest decreases in the summer.[8]

Wildfire – Over the last several decades, warmer and drier conditions during the summer months have enabled more frequent large fires, an increase in the total area burned, and a longer fire season across the western United States. Across the Pacific Northwest, fire season length has increased over the last 40 years, from 23 days in the 1970s to 116 days in the 2000s.[8]

Projected Future Trends

Most projections provided herein are based on ensembles averaged across 13 GCMs and two different emissions pathways - continued higher emissions (RCP 8.5) and lower emissions (RCP 4.5). Figure 3 shows the variation among emissions pathways for the state of Oregon.[8]

In general, all of the models predict warming, but some predict faster warming than others. Similarly, all models predict sea level rise, but some are showing much faster sea level rise than others, especially the more recent models. Most models agree on more intense storms, wetter winters, drier summers, and more frequent extreme heat and wildfire.

Temperature – Average air temperature across the Tillamook Bay Watershed is expected to warm by 3-4° F by mid-century and 4-7° F by late century, depending on emissions trajectories.[7] Air temperature increase of 5.5° F is likely to result in estuarine water temperature increase of up to 3° F.[14]

Precipitation – Annual mean precipitation is expected to increase throughout the century, by 3-5% by the 2080s. Summers, however, are expected to be drier and winters wetter.[7] Summer precipitation is expected to decline by 14-19%. Winter precipitation is expected to increase by 7-13%.[7]

Extreme events – The number of days above 90° F is expected to increase throughout the

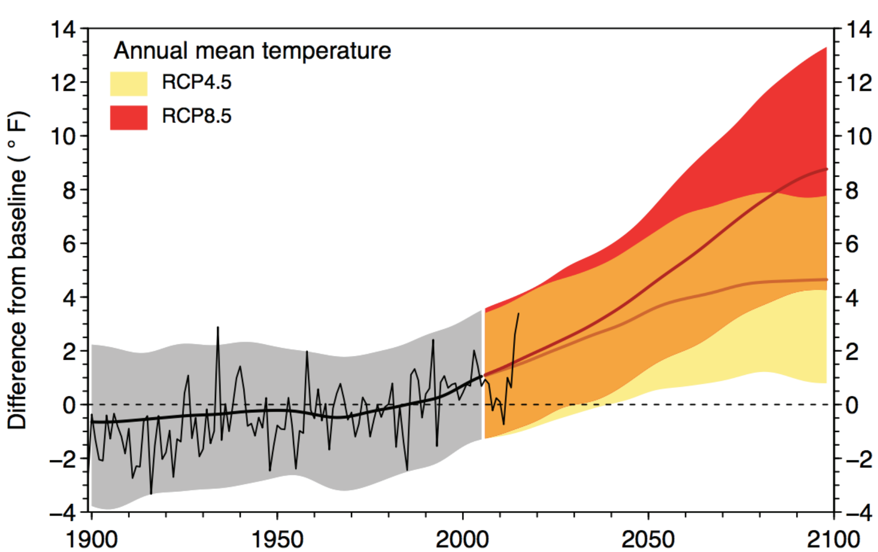


Figure 3 Historical and future warming across the state of Oregon, based on observational data (black lines) and ensemble model projections. RCP4.5 (yellow and orange) assume lower emissions and RCP8.5 assumes continued higher emissions of greenhouse gases. Figure from OCCRI (2017).

Table 2 Projected changes in extreme events for Tillamook Bay Watershed, based on estimates from graphs in OCCRI (2013).[7]

Variable	Low Emissions	High Emissions
# days above 90°F	+2.5 days	+10 days
Hottest day – coast	+2° F	+8° F
Hottest day – inland	+5° F	+9° F
# nights below freezing – coast	-15 days	-17 days
# nights below freezing – inland	-33 days	-40 days
# days >2 inches precip. – coast	+1 day	+2 days
# days >2 inches precip. – inland	+1 day	+2 days

century (Table 2). The hottest day of the year is expected to become 2-9° F hotter, and nights below freezing will become far less frequent, especially inland. The frequency of storms with more than 2 inches of rainfall is also expected to increase.[7] Landslides, already a significant hazard in the region, could become more common with increasing large storms.

Sea Level – Numerous studies on sea level rise are available, with slightly different projections. Table 3 shows the National Research Council's projections from their 2012 report[9] for the Oregon Coast, which have an overall wider range than some other projections.

Wave Height and Storm Surge – Future projections of wave height are difficult to make due to the complexity of projecting changes in extra-tropical storms and extreme winds.[9]

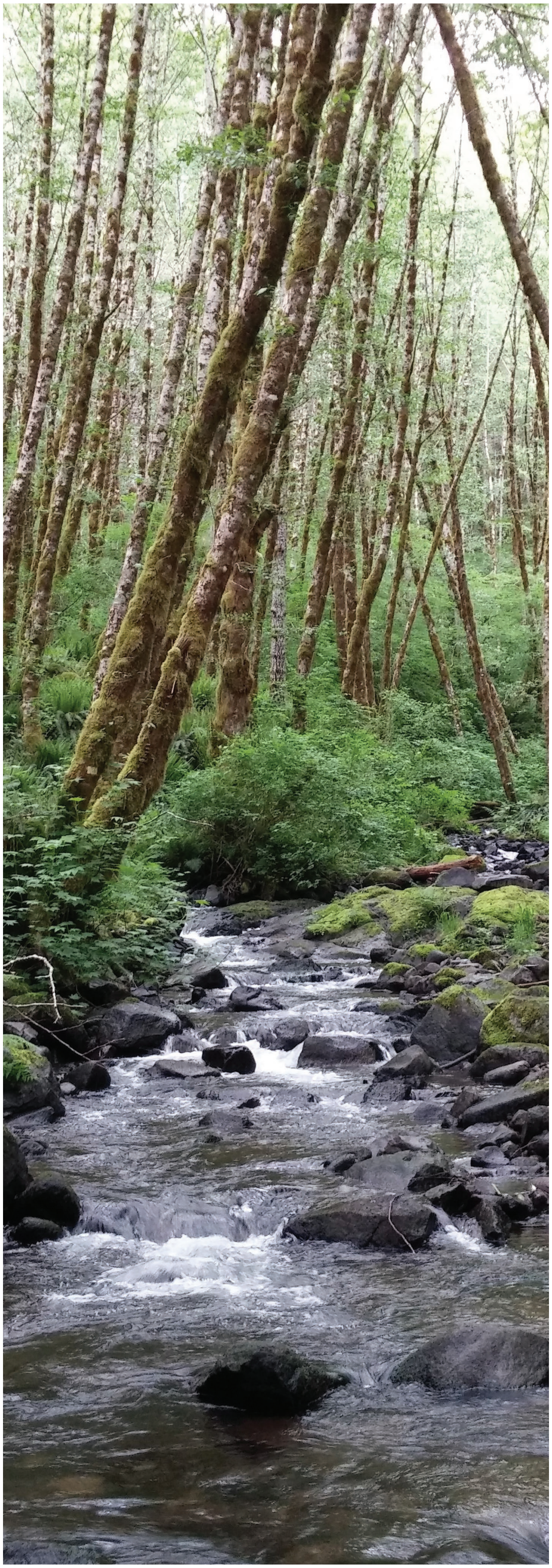
Table 3 Projected sea level rise in Oregon.[15] These projections are based on the A1B (lower) and A1F1 (higher) emissions scenarios.

Timeframe	Lower Emissions	Higher Emissions
2050	+7 inches (0.6 feet)	+19 inches (1.6 feet)
2100	+25 inches (2.1 feet)	+56 inches (4.7 feet)

Ocean Acidification – The ocean's acidity is expected to double by the end of the century, if emissions are not reduced.[15] Along the Oregon coast, the nearshore domain may see an annual mean pH as low as 7.82±0.04 by 2050 (compared to a pre-industrial value of 8.03±0.03).[16] By 2030, mean annual aragonite saturation state of the surface seawater off the Oregon coast is projected to reach a threshold known to disrupt calcification and development in larval bivalves.[17] Reductions in calcifying organisms at the base of the marine food web could have cascading effects on higher trophic marine fish, birds, mammals, and the people who rely on these resources.

Stream Flow – Both winter and summer flows are expected to change substantially, although these changes balance out when looking at mean annual change. Higher winter precipitation could cause higher flows in winter. Conversely, increased summer evaporation and evapotranspiration (water use by plants) are expected to lead to lower summer flows.[18] Higher winter and lower summer stream flows can have significant impacts. Lower summer flows are expected to be accompanied by warmer water temperatures, which can affect fish and other organisms, while high winter flows could increase sedimentation and erosion.

Wildfire – Wildfire frequency and area burned are expected to increase in the Pacific Northwest. Model simulations for areas west of the Cascade Range project that the fire return interval (average number of years between fires) may decrease by about half, from about 80 years in the 20th century to 47 years in the 21st century.[19] The same model projects an increase of almost 140% in the annual area burned in the 21st century compared to the 20th century, assuming effective fire suppression management and continued high emissions.[18] Modeling of wildfire across the Western


Trask River flickr OSU CC BY-SA 2.0

U.S., however, is complex and still in its infancy as far our understanding of the relationship among wildfire, drought, fuels, and vegetation change related to climate change.[20] Thus, while there is wide agreement that wildfires are expected to increase with climate change, timeframes and locally specific trends are poorly understood.

Based on this summary, and informed by the climate change stressors evaluated in the *Regional Framework for Climate Adaptation for Clatsop and Tillamook Counties*, the following list of climate stressors was used to guide the identification of risks to TEP's goals and objectives.

- Warmer summers
- Warmer winters
- Increased likelihood of extreme heat
- Increased likelihood of drought
- Changes in hydrology related to timing
- Changes in hydrology related to water temperature
- Increased likelihood of extreme precipitation and floods
- Increased coastal storm surge, wind, and wave height
- Coastal erosion, landslides, and inundation from sea level rise
- Increasing ocean acidification and change in ocean chemistry
- Increase in wildfire frequency and intensity
- Change in abundance and distribution of habitat for aquatic and terrestrial wildlife
- Increases in pests, diseases, and invasive species
- Loss of wetlands and ecosystem services

Nestucca Bay — Don Best/Tillamook Estuaries Partnership

Impacts and Vulnerabilities

Climate Impacts to Water, Forests, Fish, and Wildlife

The impacts of climate change on the Tillamook estuaries and watersheds were explored based on four main sectors. These included water resources, forests, wildlife, and fisheries. While climate impacts to all of these sectors are listed below, only a subset of those impacts are relevant to TEP's goals as outlined in the CCMP. However, with the update to the CCMP, additional vulnerabilities may be identified based on the impacts identified in this process. Below is an overview of climate impacts and risks to the four natural resource sectors. In the following section, the specific vulnerabilities that are relevant to TEP and its primary goals are addressed more thoroughly.

Water Resources

Water resources are the central focus of TEP and its partners, especially considering the designation of the five estuaries as part of the National Estuaries Program, the importance of water for both people and wildlife, and the close link that local communities have to both freshwater and brackish waters for their

Climate change threatens to exacerbate existing stressors and result in new ones. Existing stressors to water resources in the Tillamook estuaries and their watersheds include:

- algal blooms
- contamination from pollutants, waste, nutrients, or toxins during large storms
- excess sediment deposition from storms and land use
- low river flows due to competing demands
- warmer water temperatures lethal to fish
- bacteria concentrations that affect health and shellfish safety
- dissolved oxygen levels that are often too low to support aquatic life

livelihoods (including for transportation, irrigation, commercial and recreational aquatic species, and tourism, among others). Managing water resources for long-term sustainability is vital to the future of the region.

Climate change poses serious risks to water resources in the region including projected changes in timing of flows, variability of flows, water temperature, water chemistry, and extreme events that increase erosion and sedimentation. In addition to those direct impacts, climate change threatens to exacerbate existing stressors to water resources (see box).

Increasing air temperature can have substantial effects on stream temperature.[23] As temperatures increase and low river and stream flows further exacerbate warming, the protection and enhancement of cooler waters will be vital. Forest cover and riparian vegetation provide shading that maintains lower temperatures. Retaining forest canopies near waterways, identifying areas with deep pools and maintaining flows from higher elevations as long as possible into summer months will all be needed.

Trask River

Freshwater – Tillamook County communities rely heavily on surface water for municipal and agricultural use. Hotter air temperatures are expected to substantially increase the demand for water in both sectors. Crops and yards alike will need more water for irrigation as evapotranspiration increases. Hotter inland temperatures could also bring more tourism to the coast, at times when stream flow is low, waters are warm, and excess water is not available. Because of the limited storage opportunities in the region, sustainable off-channel storage may need to be considered.

Many streams are currently not meeting the temperature standards for a portion of the summertime periods. The number of days above temperature targets has been increasing in some reaches of Tillamook, Nehalem, and Nestucca watersheds.[24] This trend is expected to continue unless there are significant efforts to reduce water temperature as the climate warms. Because water temperature may be affected more by air temperature than streamflow[23], efforts to reduce greenhouse gas emissions and the overall magnitude of climate change could be most effective.

All of Oregon's salmonids are affected by warming, but the southern range of chum salmon (*Oncorhynchus keta*) distribution could be most vulnerable, as more variable flows are already starting to affect chum habitat and weaker populations could disappear. Spring Chinook (*O. tshawytscha*) are most affected by warmer summer water temperatures.

Estuaries – The estuaries of Tillamook County are prized resources in the region. The five estuaries encompass extensive tidal wetlands, open water, mudflats, and other important habitats. The diverse aquatic resources supported by these estuaries are vital for the local and regional economies, as well as overall culture and quality of life for residents.

Climate change impacts to Tillamook County's estuaries include warmer waters, which can lead to increases in disease, parasites, bacteria, and invasive species. Warmer waters act to exacerbate existing stressors to water quality in estuaries, by allowing bacteria, algae, and invasive species to flourish and by stressing native species that rely on cold and oxygen-rich waters. In addition, warm waters favor the occurrence and spread of wasting disease, which leads to the widespread loss of eelgrass.[25] Eelgrass provides important estuarine habitat for fish, crabs, mollusks, and other wildlife species. A study of the Yaquina Estuary, to the south of Tillamook, found that air temperature warming of 7° F would lead to an additional 40 days where water temperatures are too warm to meet the criteria for salmonids and trout.[13] The lower estuaries may experience less warming (due to rising sea levels and increased ocean influences) than upriver portions, especially during summer months.

The Warm Blob

Since 2013, extraordinarily high temperatures in the North Pacific ocean have developed, due to lower than normal heat loss from the ocean to the atmosphere, as well as weak mixing of the upper ocean. The waters affected have been termed "the warm blob." The blob has had a strong influence on both terrestrial and marine habitats, and is thought to have contributed to severe negative consequences for numerous salmonids along the Pacific coast, including Oregon coho populations. These observations provide evidence that climate change will present enormous challenges for salmon.[34]

Sea level rise impacts include changes in both vertical and horizontal distribution of salt water in estuaries, with deeper tidal channels and inundation of important marsh habitats (vertical), as well as salt water intrusion further into freshwater systems (horizontal), thereby changing the types of plants that are able to grow therein. More brackish conditions are expected to develop, while freshwater wetlands become rarer. This affects the types of fish and wildlife that are found in the area. Each estuary is expected to respond differently to sea level rise due to geological and topographical complexity.[26]

Increased precipitation intensity and frequency often cause more erosion, sediment transport, and deposition (sedimentation). Measures to reduce severity of impacts due to higher storm intensity could also help maintain functional estuaries and their transition to new conditions.

Forests

Tillamook watersheds are dominated by mixed-age forests in the western hemlock zone. Douglas-fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*) are the main species in this type of forest. Other species include big leaf maple (*Acer macrophyllum*), cascara buckthorn (*Rhamnus purshiana*), and red alder (*Alnus rubra*). Wildfire is rare in Oregon's coastal forests (300+ year return intervals), but is characterized by large, stand replacing fires when they do occur. Root diseases like *Phellinus*, laminated root rot and black stain are the most common causes of tree mortality in the coast range. Swiss needle cast (*Phaeocryptopus gaeumannii*), a prevalent pathogen, and bark beetles can cause smaller scale die-off events.[27]

Expected impacts of climate change to these forests include increased probability of summer drought,

Oregon Army National Guard fights wildfires throughout the state

Oswald West State Park View

causing reduced tree growth and productivity; more frequent wildfire; and increased disturbance from pathogens, insects, and disease. All of these impacts are exacerbated by human activities that also reduce forest resilience and spread invasive species and pathogens. Invasive species could outcompete native species as warmer temperatures and changes in precipitation patterns cause native species to become stressed. Overall, the region is expected to lose some common species of conifers[28] while deciduous species are expected to expand.

Mature forests are more resistant to climate change as they have an insulating effect.[29] Many older forests, and especially coastal older forests, are likely to experience fewer impacts and a lower rate of change than other forests. These areas could be especially important for providing intact climate refuges, which act to maintain biodiversity as other areas experience accelerated die-off or change. In fact, maximum temperatures in old-growth forests were found to be, on average, 4.5° F cooler than simplified stands.[29]

Many impacts of climate change to the region are poorly understood. For example, the fog belt along northern California's coast has declined by about 30% in recent decades.[30] Similar changes in the fog belt along Oregon's coast could reduce the suitability of the coastline for Sitka spruce and hemlock. Douglas fir could expand throughout the coastal zone, but Douglas fir is often limited in the area by pathogens such as Swiss Needle Cast. In response to shifts in forest zones, foresters may need to plant different species and varieties of trees. Coast Redwood (*Sequoia sempervirens*), for example, is expected to experience range contractions in California, but could be planted in Oregon to ensure persistence.[28]

Fisheries

The Tillamook estuaries and rivers that feed them provide vital habitat for numerous species of fish, mollusks, and crustaceans, in many different life stages. Some of the species that are found in the five estuaries of Tillamook County include Dungeness crab (*Cancer magister*), bay clams (numerous species), razor clams (*Silqua patula*), Pacific oysters (*Crassostrea gigas*), steelhead trout (*Oncorhynchus mykiss*), coho salmon (*O. kisutch*), Chinook salmon, chum salmon, and coastal cutthroat trout (*O. clarki clarki*). Chinook salmon are especially sensitive to estuarine impacts,[31] but all species rely heavily on a healthy estuary for sustaining populations. Impacts to estuaries, in addition to climate change, include habitat loss, species invasions, hypoxia from eutrophication, and decreased water quality (from pesticides sedimentaiton, stormwater, and nutrient inputs). Compared to the rest of the nation, estuaries in northern Oregon have relatively low levels of stressors.[32]

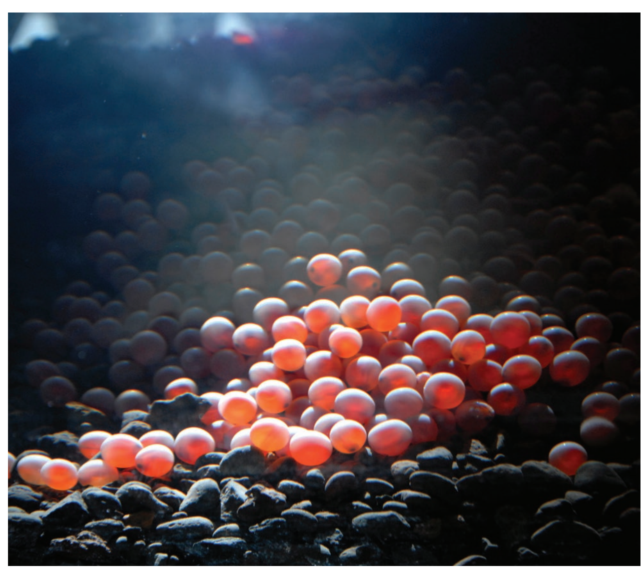
Salmon are an iconic species of the region, and have been returning to Tillamook streams and estuaries for millennia. Once thought inexhaustible due to the sheer number of fish, stocks of salmonids began to decline in the early 20th century due to over-harvest and a loss of stream, estuary, and ocean habitat. Oregon coast coho salmon, an evolutionarily significant unit, are federally listed as a threatened population. Salmon are a main focus of restoration activities in the Tillamook estuaries and watersheds due to their sensitivity to warming water and habitat impacts. Current management focuses on restoring key variables of salmonid life history in order to restore and stabilize populations. TEP plays a key role in salmonid assessments, habitat restoration, and fish passage restoration.

Numerous species of salmonids are found in the study area, including Oregon Coast coho, Chinook, steelhead, chum salmon, and coastal cutthroat trout. In the Tillamook, Nestucca, and Nehalem watersheds, coho and Chinook salmon show significant year-to-year variation in spawning individuals, but their overall trend appears to be stable.[24]

Salmon are affected by conditions and resources in the open ocean, rivers, and estuaries, giving them high potential exposure to serious climate impacts on numerous fronts.[33] In many cases, it is difficult to distinguish between climate-related impacts and other drivers such as habitat loss, water diversions, pollutants, or dams. Changes in ocean temperature and acidity are thought to be responsible for declines in ocean survival in some years.[34] Salmon could also be affected by declines in preferred marine foods (juvenile sand lance and smelts, for example) due to warmer waters, harmful algal blooms, or expansion of the dead zone (hypoxia areas). Changes in phenology, or the timing of migration and spawning, have been observed but the specific influence of climate change on phenology is difficult to determine.[34]

In rivers and streams, salmon are highly sensitive to water temperature, with many native species rarely found in waters warmer than 63° F.[35] The State of Oregon has reviewed temperature tolerances and set temperature standards under the Clean Water Act. When temperatures exceed the standards, salmon experience an increased susceptibility to disease, inability to spawn, reduced egg survival, reduced juvenile growth and survival, increased competition for habitat and food, and inability to compete with species that are better adapted to higher temperatures (often introduced species). Higher temperatures also mean higher metabolic rates in fish (more food needed), and the potential for earlier emergence of juveniles from gravel, with the risk of being flushed down to the bay. Many streams in TEP's study area are not meeting temperature standards set by the state, and trends show continued warming.[34,35]

Salmon in the stream reaches of Tillamook County are likely to be impacted by larger storms that cause more flooding and scouring of spawning habitat. Predicted changes in precipitation and flooding would be expected to more adversely affect those species that spawn in the steeper confined stream reaches that are especially susceptible to streambed scouring, such as coho, steelhead, and coastal cutthroat trout.[36]



Salmon eggs Oregon Dept of Forestry CC BY 2.0

Oyster at Whiskey Creek Shellfish Hatchery OSU CC BY-SA2.0

In estuarine habitats, climate impacts to salmonids include warmer waters, increases in disease and parasites, changing salinity, and loss of wetlands to sea level rise. In addition, warmer waters may lead to greater occurrence and spread of wasting disease, impacting eelgrass beds, which provide critical nursery habitat for juvenile fish and crustaceans.[25]

Shellfish are also increasingly vulnerable to climate impacts. They are affected by warmer water temperatures, tideflat temperatures, changes in water depth (area of intertidal zone), changes in salinity, sedimentation, hypoxia, and possibly changes in seagrass distribution. Ocean acidification is also expected to have serious impacts to shellfish. The ocean has absorbed about 25% of anthropogenic CO_2 emissions, which steadily increases the acidity of the water column. Eutrophication, upwelling, and river discharge act to further exacerbate localized acidity levels, which, off the Oregon and Washington coasts, are among some of the highest worldwide.[37]

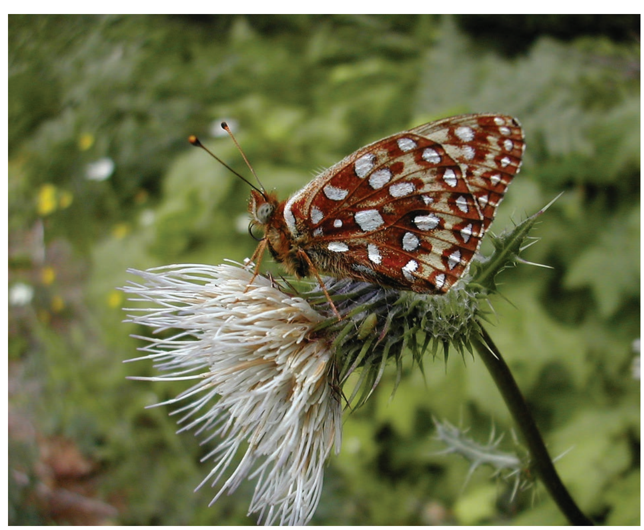
Impacts of ocean acidification to Pacific oyster fisheries have already cost the shellfisheries of the Pacific Northwest nearly $110 million.[37] The Oregon and Washington coasts are more vulnerable than other coastlines due to upwelling of acidic waters that exacerbate acidification caused by climate change.[37]

Impacts of acidification to native shellfisheries (bay clams, Dungeness crabs) are poorly understood, and it is possible that estuarine populations are relatively resilient to acidification. The larval stage could be most vulnerable, but effects of acidification to adult shellfish are understudied. Human consumption of native shellfish could also become riskier as the virulence and abundance of marine pathogens, such as *Vibrio parahaemolyticus*, increase with warmer temperatures.[13]

Wildlife

Wildlife throughout the globe, and specifically in Oregon, is already responding to climate change and associated impacts. Frogs, for example, are reproducing earlier in the year and many are becoming infected with emergent diseases. Insect development is occurring earlier in the year as well. Land birds are shifting their ranges northwards and migrating earlier. Small mammals have contracted their ranges in some areas, in response to warming temperatures.[35]

The Tillamook estuaries and their watersheds are home to a diversity of fish and wildlife. Natural ecosystems in the study area include coastal rainforests, wetlands (tidal, brackish, freshwater, etc.), estuaries, rivers, grasslands, meadows, and other



Oregon Silverspot butterfly USFWS PublicDomain types. The predicted declines in wetlands and ecosystem services could be devastating to local biodiversity, due to the disproportionate importance of such systems for a wide diversity of species.

Some taxa have been identified as more vulnerable to climate change than others. Salamanders, for example, have low dispersal capabilities and are heavily impacted by changes in moisture and temperature. The TEP study area is home to both Columbia and Southern torrent salamanders (*Rhyacotriton kezeri* and *R. variegatus*), among others. Torrent salamanders are found in coastal coniferous forests and rely on aquatic environments during their larval stage. They have extremely low tolerance for desiccation or warm water, and have been identified as "extremely vulnerable" to climate change in the University of Washington's Climate Change Sensitivity Database. Torrent salamanders are expected to experience severe climate impacts, including decreased fitness, reduced dispersal, increased moisture stress, disruption of their lifecycle, and increased exposure to predators.[27]

The Oregon silverspot butterfly (*Speryeria zerene ssp. zippolyta*), a state and federally listed species that is limited to only five localities, could be at risk due from climate change and its effects on changing habitats and life history timing. Increases in invasive species with climate change pose a significant risk to the silverspot due to potential displacement of its preferred host plant, the early blue violet (*Viola adunca*). Phenology, or the timing of life history stages, could become misaligned with climate change, as the developmental stages are timed to occur in synchrony with other biological events that are closely linked to climate.[27]

Additional rare and poorly understood species of the coast range are likely to be impacted by climate change, but without close monitoring many impacts could go undetected. Changes in small mammal populations could affect Northern Spotted Owls (*Strix occidentalis caurina*) in the region. Neotropical songbirds are expected to change in abundance and distribution with climate change, with some species losing important specialized habitats over time.

American Dipper

In the 2010 State of the Birds report,[38] Oregon's coastal birds were shown to be most vulnerable to climate change, including Marbled Murrelet (*Brachyramphus marmoratus*) and Black Oystercatchers (*Haematopus bachmani*). While Black Oystercatchers are threatened by sea level rise and ocean acidification, Marbled Murrelets are at risk from a loss of important mature coastal rainforest habitat. Fog-dependent spruce hemlock forests could be affected by a contraction of the fog belt, which would limit their distribution. Increasing forest pests and disease, such as Swiss needle cast, are expected to increasingly affect stressed trees throughout the region, causing a potential risk to wildlife species dependent on mature forests in the area.

Numerous species of wildlife are expected to expand or increase with climate change, especially those that prefer burned, disturbed or more open habitats, such as mule deer (*Odocoileus hemionus*) and Roosevelt elk (*Cervus canadensis roosevelti*). Increases in human-wildlife conflicts could occur if deer and elk are displaced from their natural habitats by fire or other disturbances, and become more common near agricultural areas.

Dogwood at Brown's Camp Oregon Dept of Forestry CC BY 2.0

Risks to TEP's Goals

The Tillamook Bay CCMP is TEP's guiding document for fulfilling its mission of conservation and restoration of Tillamook County's estuaries and watersheds in their entirety. The original CCMP included 18 goals and 55 action items under four main priority areas – Key Habitat, Water Quality, Erosion and Sedimentation, and Flooding. Many of the goals that TEP has focused on since 1999 are at risk from climate change. The 2018 revision has condensed the priority areas to three – Habitat, Water Quality and Community Education and Engagement. Natural hazards and climate change risks and strategies are woven throughout all three priority areas.

A broad risk-based vulnerability assessment was conducted following the steps of the EPA's *Being Prepared for Climate Change* workbook,[4] which was developed specifically for the Climate Ready Estuaries Program resource and watershed managers. For more information on the process and information that fed into the Vulnerability Assessment, see the final Vulnerability Assessment report.[1]

Goals related to the two priority topics Water Quality and Key Habitats were found to have the most specified risks (37 and 26, respectively; Table 4 and Appendix B), although many risks are closely related and may be addressed together.

In addition to developing new strategies to address the risks to TEP's existing goals, new goals may be warranted based on climate-related stressors that have recently emerged (e.g. ocean acidification).

Risks to TEP's ability to meet its goals were ranked based on the likelihood, consequence, and time frame of each risk (Figure 4). Further, one of four general management approaches were identified for each risk: Mitigate, Transfer, Accept, or Avoid. Some risks may be able to be mitigated through the types of activities and actions that TEP already does, or by developing new adaptation actions that address the risk. Others may need to be transferred to other organizations or agencies, although TEP may provide assistance. In certain instances, risks may simply be accepted and accommodated with little change to TEP's overall mission or goals. Finally, risks can be avoided by changing or abandoning specific goals that are associated with those risks, if mitigation is not feasible or practical. The Advisory Committee and TEP staff decided, for each risk, the appropriate approach. Those that were assigned to the "Mitigate" approach are the

Table 4 The number of identified risks to each of TEP's original CCMP goals, under each of the four priority areas (Key Habitats, Water Quality, Erosion and Sedimentation, and Flooding). A total of 74 risks to TEP's goals was identified and assessed. Each risk was ranked as High, Medium, or Low, based on the likelihood of the risk and the consequence to TEP's ability to meet its goals. The near-term time frame is shown because it affects the prioritization for developing adaptation actions.

	Higher Risk	Medium Risk	Lower Risk	Near Term
Key Habitats	**20**	**5**	**1**	**14**
Assess, protect, and enhance riparian habitat	3	0	1	3
Assess, protect and enhance instream habitat	6	2	0	5
Assess, protect and enhance wetland habitat	5	0	0	1
Assess, protect and enhance estuary and tidal habitats	5	1	0	4
Assess health of salmonid, shellfish, and other aquatic species stocks	1	2	0	1
Water Quality	**21**	**12**	**4**	**12**
Promote beneficial uses of the bays and rivers	10	7	3	5
Improve farm management practices	4	4	1	2
Assess and upgrade wastewater treatment infrastructure	0	0	0	0
Assess and upgrade urban non-point treatment infrastructure	0	1	0	0
Reduce instream temperatures to meet salmonid requirements	4	0	0	3
Reduce instream suspended sediments to meet salmonid requirements	3	0	0	2
Erosion and Sedimentation	**7**	**1**	**0**	**4**
Reduce sediment risks from forest management roads	3	0	0	0
Reduce the adverse impacts of rapidly moving landslides	1	1	0	1
Improve channel features to improve sediment storage and routing	1	0	0	1
Reduce the adverse impacts of erosion and sedimentation from developed and developing areas	2	0	0	2
Reduce the adverse impacts of erosion and sedimentation from agricultural areas	0	0	0	0
Flooding	**1**	**1**	**0**	**0**
Improve floodplain condition	1	1	0	0
Develop and maintain a comprehensive floodplain management plan	0	0	0	0

High Likelihood — Lower Likelihood

High Consequence — Lower Consequence

Near-term vulnerabilities that TEP is planning to mitigate

1. Scouring of redds and displacement of juveniles
2. Change in distribution and survival of native aquatic organisms
3. Fish stranded from broadening and contraction of distribution
5. Salmonid population declines from warmer water
6. Exacerbated stress to fish from higher water demand
8. More resources and funds required by TEP and partners
9. Negative impacts to shellfish, crabbing, and fishing

Mid- to late-term vulnerabilities to be mitigated

10. Lower survival of newly planted riparian vegetation
28. More runoff and sedimentation of streams, as well as landslides
29. Changes in the distribution and extent of tidal habitats, including low salt marsh, high marsh, and mudflats
30. Some species of wildlife lose habitat while others gain
31. Increased flood damage and declining water quality

Near-term vulnerabilities that TEP is planning to mitigate

11. Difficulty meeting suspended sediment targets
12. Contamination of waterways and disruption to fish passage

Mid- to late-term vulnerabilities to be mitigated

32. Reduced water and habitat quality from sedimentation
36. More road and culvert maintenance needed for legacy roads
38. Bacteria from waste affecting shellfish closures
39. Reduced effectiveness of restoration of habitat for fish and wildlife
40. Exacerbate stressors and push systems beyond ecological thresholds
42. Loss of wetland endemic species and specialists

Near-term vulnerabilities that TEP is planning to mitigate

14. Lower dissolved oxygen and decreased survival of aquatic species
17. Spring Chinook eggs disrupted by higher peak flows
19. Native fish less competitive against warm water fish
20. More gravel deposits and downed wood in streams
23. Estuary protection more difficult due to development of barriers
24. Changes in ocean-based prey, affecting many species
25. Reduced ability of TEP and other partners to restore habitats
26. Declines in aquatic organisms sensitive to higher temperatures

Mid- to late-term vulnerabilities to be mitigated

44. Infrastructure failure during king tides, affecting natural areas
46. Warmer water causing human illness due to water-borne diseases
47. Low flows causing human illness due to water-borne diseases
48. Large scale die offs of certain tree species

Near-term vulnerabilities that TEP is planning to mitigate

53. Reduced survival of riparian plantings near steep slopes

Mid- to late-term vulnerabilities to be mitigated

54. Reduced instream habitat quality from less shading and warmer water
55. Reduced water quality from sedimentation, nutrients, and bacterial contamination related to livestock
56. Impacts to native aquatic wildlife (especially fish) and vegetation
57. Water treatment facilities shut down from sedimentation
60. Simplification of riparian areas, loss of side channels for flood abatement and significant impacts to fish
69. Declines in water quality and beneficial uses of bays and rivers

Mid- to late-term vulnerabilities to be mitigated

63. Shifts in energy budgets for fish from lower oxygen
66. Greater use and damage to bays and rivers
67. Economic stress to farmers from increasing inundation of agricultural lands with sea water

Mid- to late-term vulnerabilities to be mitigated

70. Loss of important riparian habitats for species such as birds, small mammals, insects, and amphibians

Mid- to late-term vulnerabilities to be mitigated

71. Impacts to desirability of the region for tourist travel from beach closures

FIGURE 4 Vulnerabilities of TEP's goals to climate change were evaluated based on the likelihood of each risk and the severity of the consequence. Only those risks that were identified to be mitigated are shown here. More details on each risk can be found in the Vulnerability Assessment.[1]

focus of the strategies that were developed.

The most serious near term risks to TEP's ability to meet its goals are those considered to have the highest likelihood, the most severe consequences, and are already occurring or expected to occur within the next 15 years. Addressing these risks will be vital to conservation efforts throughout the region. Based on the results of the Vulnerability Assessment, the most severe near-term climate risks, ranking highest in both likelihood and consequence to the ability of TEP to meet its goals, included the following:

- Potential salmonid declines from warmer water
- Potential salmonid declines due to larger storms that scour redds and displace juveniles
- Salmonids and other native species potentially affected by increased incidence of disease
- Changes in distribution and lower survival of numerous native aquatic organisms
- Negative impacts to shellfish, crabbing, and fishing from ocean acidification
- Broadening and contraction of pools in streams, leading to stranded fish
- Lower survival of newly planted riparian vegetation and failure of restoration efforts
- TEP and partners requiring more funds to keep up with increasing stressors
- Increased water demand leading to exacerbated stress to fish populations
- Negative impacts to conservation efforts from increased installation of erosion control measures in response to larger waves and higher storm surge

Over longer time frames, additional risks are expected to further threaten TEP's ability meet its

Homestead Coho

goals. And yet, the importance of the work TEP does becomes amplified with climate impacts. Risks including overall changes in species composition and distribution, changes in the extent and distribution of tidal habitats, increasing runoff and sedimentation of streams, worsening landslides, greater flood damage, and difficulty for agricultural producers to meet water temperature requirements, will require that TEP continuously evolves and remains flexible to respond to changing conditions.

The natural resources of the Tillamook estuaries and watersheds are central to the social and economic well-being of the communities scattered throughout this region. While these resources have always been dynamic, the rate of change is expected to accelerate in coming years and much needs to be done to increase the overall resilience of the natural systems in this region. The Vulnerability Assessment provided the foundation needed to develop strategies that promote resilience and sustainability of Tillamook County's estuaries and watersheds in the face of ongoing change.


Trask River temperature monitoring

Strategies and Actions

Climate change risks can be addressed in numerous ways. Over longer time periods, the most effective approach will be to reduce greenhouse gas emissions quickly and substantially, to reduce the overall magnitude of change. This is the only way to effectively protect both people and nature from many of the most serious impacts, but it relies on communities and governments all over the world to do the same. Because many of the effects of climate change are already being seen and felt, near-term actions are also needed. Further, based on greenhouse gases emitted today, climate change will continue for many decades, making continued action vital. Thus, both adaptation (preparing for and adapting to change) and mitigation (reducing greenhouse gas emissions) are needed in order to address climate change vulnerabilities.

Because of TEP's mission and goals, the organization is most suited to implementing adaptation strategies that address the increasing vulnerability of the region's natural resources to climate change. However, TEP can take the lead on mitigation in many instances as well, such as in organizational operations and communicating with the public. Climate change "mitigation" in relation to reducing greenhouse gas emissions should not be confused with the more common use of "mitigation," which is to reduce the impacts of extreme events or other impacts (such as in emergency response). Below, in the terminology of the EPA, the word was used in the latter context.

Adaptation Strategies and Actions

Following the EPA's framework, risks to TEP's goals were addressed using one of four different approaches. These included:

1. **Mitigate** – developing adaptation strategies to reduce the risk
2. **Transfer** – identifying another group or agency responsible for adaptation
3. **Avoid** – changing the original goal to avoid the risk or failure to meet the goal
4. **Accept** – continue as usual, allowing the climate impacts to occur

Seventy-four individual risks were identified. Forty-four of these risks were assigned to the *Mitigate* approach, 27 were assigned for *Transfer*, and 3 were assigned as *Accept*. No risks were assigned to the *Avoid* approach. Strategies and actions to address risks were developed and prioritized for those vulnerabilities which may be mitigated.

Local experts and stakeholders identified 23 general strategies and 78 specific actions to address the vulnerabilities (Table 5). For each adaptation action, the following variables were addressed:

- **Co-benefits** – Any additional benefits that the action provides, beyond those directly related to the risk being addressed
- **Potential barriers or conflicts** – Major issues that would need to be resolved or that could prevent the action from being successfully implemented or supported
- **Partners** – The local, state, and federal agencies or organizations that could assist in implementing the action
- **Effectiveness** – How effective the action is expected to be in reducing the specific climate risk (ranked as Low, Medium, or High)
- **TEP influence** – The ability of TEP to implement the action and affect the target resource or population (ranked as Low, Medium, or High)
- **Relative cost** – Compared to other actions that TEP implements, the overall cost of the specific actions being considered (ranked as Low, Medium, or High)

These variables allowed potential adaptation strategies and actions to be compared and prioritized. Actions were ranked as High, Medium, or Low based on the prioritization process. High and medium priority actions were grouped into seven categories: Exisiting Management Practices, Expanded Restoration and Conservation, Infrastructure Improvement, Education and Outreach, Research and Monitoring, Capacity Development, and Planning and Policy. High (red type) and medium (turquoise type) priority actions are summarized below. Low priority actions had little support among the stakeholder and expert group, but are included in Table 5 and Appendix D.

EXISTING MANAGEMENT PRACTICES

TEP takes an active role in existing restoration and monitoring efforts. A Volunteer Water Quality Monitoring (VWQM) network of volunteers has been collecting water quality samples from Tillamook County rivers, creeks, and bays for over 20 years. These biweekly samples are analyzed for bacteria levels and the results are posted on TEP's website. Viewers can use an interactive water trail map, with a bacteria level overlay, to see which waterways are safe for recreational activities. TEP also developed a Project Effectiveness Monitoring Program, to measure environmental parameters and determine if restoration strategies result in desired changes in habitat conditions. These and other restoration and monitoring efforts are increasingly important as climate change impacts worsen over time.

Strategy: Continue water quality monitoring – **Water quality monitoring will become increasingly important** to detect and reverse declines. **Point source and bacterial DNA identification** can provide additional information on the sources of specific contaminants. Potential partners include DEQ and ODA.

▶ Addresses risks #9, #24, #47, #64

Strategy: Maintain Riparian Management Areas (RMAs) Strategies – Ongoing **management strategies for riparian areas should be continued** in order to protect vital habitat. **Monitoring for changes** will allow for timely response if vegetation composition or cover is affected by climate stressors. **Managers may need to consider alternative types of vegetation used in restoration** in response to monitoring results.

▶ Addresses risks #54, #70

EXPANDED RESTORATION AND CONSERVATION

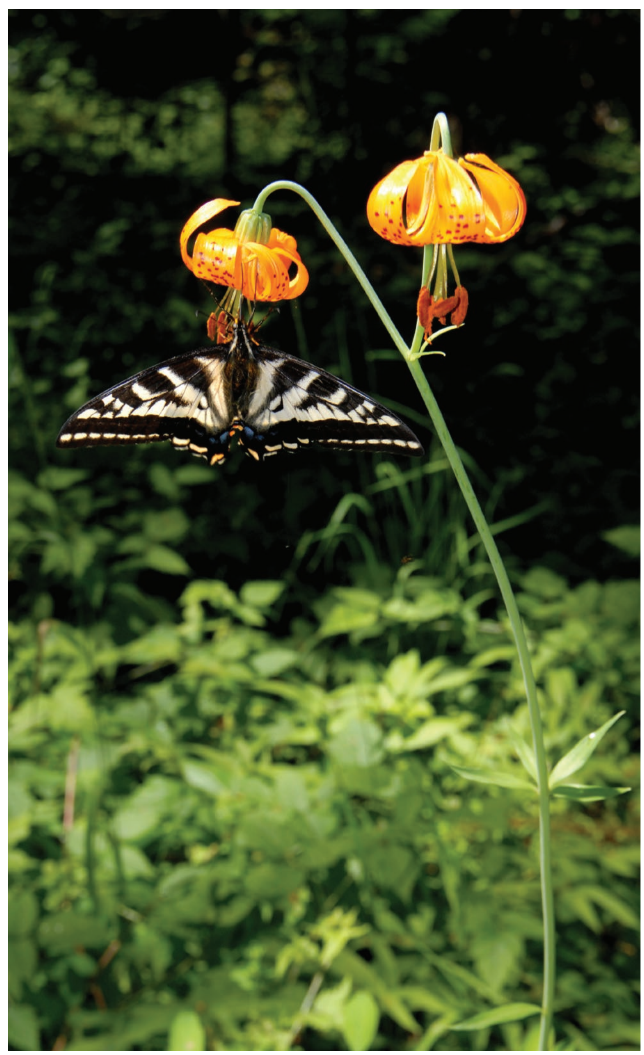
Strategy: Plan for habitats of the future – Current conservation areas may not be sufficient in protecting important habitats in the future. **Areas that will become new habitat with sea level rise will need to be conserved** so that habitat shifts are able to occur and keep pace with the needs of fish and wildlife. **Management areas may need to be expanded to continue to protect important habitats** as they shift over time. Conservation could increasingly compete with development pressures, but conservation areas can also act as buffer between infrastructure and climate impacts related to storm surge and/or flooding.

▶ Addresses risk #29

Red = high priority action
Turquoise = medium priority action

Strategy: Increase restoration efforts for vulnerable wetland habitats – **Estuarine and freshwater wetlands play a disproportionate role in supporting biodiversity, and should be identified and prioritized for restoration**. Freshwater wetlands are expected to be most vulnerable under drought scenarios and with higher evaporation rates. **Wetlands, including tidal and freshwater, should be restored with species that are resilient in response to climate impacts**, including longer drought and larger storms. **Improving the drainage function of lower tidal wetlands** can also improve upland productivity in agricultural areas. County, state, private, NGO, and federal partners will all be needed for these efforts.

▶ Addresses risks #26, #30, #31, #42, #67



Anise Swallowtail and tiger lily

Strategy: Increase floodplain connectivity and natural water storage – **Floodplain connectivity for freshwater and tidally influenced wetlands should also be restored**, with an increased understanding of the underlying influences on hydrology. **Large scale, holistic floodplain management** can maintain and enhance complexity and function. Floodplain connectivity has the potential to ameliorate the effects of future increases in discharge on streambed dynamics. Floodplain connectivity in unconfined reaches limits vulnerability of salmon spawning habitat even in large floods with return intervals of decades to centuries.[39]

Restoration of beaver habitat in the uplands should be promoted to increase natural water storage and reduce floods from extreme storms, but care would need to be taken to avoid warmer water (from ponds) and landowner misperceptions of beaver reintroduction. **Connectivity should be restored to springs, wetlands, and floodplains that can provide cold water refuges**. **Inline impoundments that exacerbate warming should be identified and removed.** Working with private landowners will be vital to implementation.

- Addresses risks #1, #2, #3, #5, #6, #9, #11, #14, #17, #19, #26, #30, #31, #38, #40, #42, #48, #56, #60, #63, #71

Red = high priority action
Turquoise = medium priority action

Strategy: Increase conservation and restoration activities in riparian habitats – **Conservation of existing riparian vegetation and restoration of stream-related wetlands** will become increasingly important for maintaining important riparian habitats, endemic species, and wetland specialists. Restoration will also lower water temperature and prevent habitat loss. **Improving restoration success, by planting diverse species, replanting**

Trask River

as needed, and monitoring survival, is an important component, as well as **aggressive control of invasive species** (Partnership for Regional Invasive Species Management (PRISM) approach as a model). **Riparian management practices in areas affected by wildfire may also need to be reviewed**. Important partners include private landowners, state and federal agencies, OSU Extension, other NGOs, and watershed councils.

▶ Addresses risks #1, #2, #3, #5, #6, #10, #11, #14, #17, #19, #25, #39, #53, #54, #56, #70

Strategy: Increase in-stream complexity of habitats and off-channel habitat – **Maintaining or restoring channel complexity and hydraulic roughness** from large wood may further mitigate the effect of higher flows on salmon spawning habitat.[36,40] TEP should continue to work to **increase diversity and complexity of in-stream habitat** to create more salmonid life-history options, including through **stream channel restoration** and **improving access to off-channel habitat**.

TEP can partners with watershed councils for in-stream management activities.

▶ Addresses risks #1, #2, #3, #5, #6, #11, #14, #17, #19, #20, #56, #63

Strategy: Protect water quality of streams and rivers – Exclusion of livestock from rivers, streams, and riparian areas will become increasingly important with warmer temperatures. This can be achieved through **off-channel watering of livestock**, **rainwater collection for animal watering**, **installation of animal exclusion fencing**, and **managing livestock crossings of waterways**. **Improvements to manure management** can reduce the influx of nutrients and bacteria. **Assisting landowners with developing farm water quality plans** that incorporate climate change trends will help to protect water quality. **Bacterial DNA identification and point source identification** can identify common sources of contamination. Potential partners include DEQ and Oregon Department of Agriculture.

▶ Addresses risks #9, #24, #38, #46, #47, #55

Red = high priority action
Turquoise = medium priority action

Holistic approach to climate change adaptation

People can reduce the impacts of climate change in two ways – (1) by increasing preparedness and overall resilience (adaptation), and (2) by reducing greenhouse gas emissions and the overall magnitude of change (mitigation). While preparedness measures increase resilience in the short-term, these measures will eventually fail without coordinated efforts to aggressively reduce greenhouse gas emissions as well.

There are many ways to coordinate across mitigation and adaptation, in a holistic approach to land and resource management. Land managers and farmers, for example, can sequester carbon in soils to reduce emissions, while also increasing productivity of the soil. A holistic approach to agricultural management might also include larger riparian buffers to provide shade and reduce sedimentation from larger storms.

All adaptation strategies should be assessed for their possible contributions to both adpatation and mitigation. Oftentimes a small tweak or a new innovation can result in reductions in greenhouse gas emissions as well as preparedness and resilience. And those emissions reductions, in the long run, will have even greater benefits to the resources and ecosystems of Tillamook County.

Strategy: Increase restoration activities in upland forest habitats – Increasing water absorption by soils in managed forest lands will help to protect in-stream habitat from damage due to extreme precipitation events. Also, **conservation and restoration activities should be expanded** to ensure maintenance of specific habitat types, including upland forest types. TEP can partner with private forestry companies, USFS, and other entities to **encourage land management that promotes absorption**. **Forest plantings will need to increase forest diversity** to increase overall resilience.

- Addresses risks #1, #2, #3, #5, #6, #11, #14, #17, #19, #48, #56, #63, #70

Forest road recontouring — Prism Oly USFS

INFRASTRUCTURE IMPROVEMENT

Strategy: Prioritize, replace, remove, remediate existing infrastructure – Based on the best available studies, projections and mapping, and considering conservation needs over long time frames, TEP should **assist in efforts to prioritize upgrades and removal of existing infrastructure most at risk** of failure or damage, especially when such failure or damage will lead to the degradation of important natural resources and habitats. **Many unmaintained forest roads can be fully decommissioned**, **culverts will need to be properly sized, other septic, wastewater, and stormwater infrastructure should be updated**, and **impervious surfaces should be targeted for removal**. Where applicable (a few in Nahalem, Bay City, and Cloverdale) **wastewater treatment lagoons should be upgraded to cisterns**.

While many infrastructure upgrades and/or removal are relatively expensive compared to other types of adaptation strategies, proactive actions are expected to avert even higher costs related to extreme events and disasters.[41] Potential partners for infrastructure updates or removal include private landowners, the Oregon Department of Transportation, Oregon Department of Forestry, U.S. Forest Service, other NGOs and other groups.

- Addresses risks #9, #12, #23, #24, #28, #32, #38, #44, #46, #47, #71

Strategy: Sustainable off-channel water storage – As streamflow continues to decline during summer months, manipulation to maintain sufficient flows may become necessary. **Development of sustainable off-channel storage** would allow water diversion during large storms and high flows, and release during times of low flows. TEP would need to partner with diverse state, federal, and local entities to develop a sustainable approach, with careful consideration of local water rights.

- Addresses risks #1, #2, #3, #5, #6, #11, #14, #17, #19, #38, #46, #47, #56, #63, #71

Red = high priority action
Turquoise = medium priority action

USFS

EDUCATION AND OUTREACH

Strategy: Education and outreach on water quality – Water quality is expected to worsen with climate change. Tourists and residents will need **information on current water quality conditions** in order to manage exposure to pollutants, bacteria, and other harmful contaminants.

▶ Addresses risks #69

Strategy: Education and outreach on habitat recovery – Wetlands and other important habitats are expected to become stressed from higher temperatures, larger storms, and loss of vegetation. **Education and outreach to keep users away from stressed areas** will be needed to allow them to recover.

▶ Addresses risks #69

Strategy: Education and outreach on manure management – With larger storms and the increasing potential for agricultural waste to contaminate streams, rivers, and estuaries, **education and outreach on manure management** could improve water quality and protect important recreational and commercial fisheries.

▶ Addresses risks #38, #46, #47

Red = high priority action
Turquoise = medium priority action

Strategy: Education and outreach on pollution and trash – Warmer temperatures and increased frequency of heat waves during summer months could lead to greater use of coastal areas by tourists escaping the heat. **Education and outreach related to reducing the impacts of tourism**, including pollution and trash, could be needed.

▶ Addresses risk #66

Strategy: Education and outreach on water conservation – Projections for streamflow indicate changes to the hydrograph, including lower low flows during summer months. These low flows coincide with periods of higher demand for agriculture, residential use, and tourism. **Education and outreach to reduce demand** will allow for more water in streams to support salmonids and other important aquatic species and habitats.

▶ Addresses risks #6, #56

Children learning about riparian areas at Kilchis Point Reserve Tillamook Estuaries Partnership

Strategy: Education and outreach on infrastructure upgrades and standards – Following research and review of streamflow projections to determine appropriate storm standards for infrastructure, **outreach and education to share new information on infrastructure standards will be needed**. TEP can work with diverse partners to share updated storm standards for culverts and other infrastructure to private landowners and industry groups.

▶ Addresses risk #36

Strategy: Education and outreach on reducing greenhouse gas emissions – Many of the most severe impacts of climate change can only be reduced and/or avoided if emissions are reduced quickly and aggressively across the nation and globe. While reducing emissions is the most effective approach to protecting the people and natural resources of Tillamook County, it requires widespread cooperation and implementation. **Education and outreach to reduce emissions at the local level** will reduce the long term magnitude of impacts. Greenhouse gas emissions in the Tillamook region stem from numerous sources, including transportation, energy production, timber harvest, and agriculture. All sources will need to be addressed to reduce emissions and increase carbon sequestration in forests and soils. An assessment completed as part of this project (Appendix C) provides guidance on framing and engagement on climate change specific to Tillamook County and TEP's stakeholders.

▶ Addresses risks #9, #24, ALL OTHERS

RESEARCH AND MONITORING

While TEP is not a research institution, the organization serves an important role in identifying research needs in order to improve management practices. TEP's primary role in the following activities is to facilitate collaboration among researchers and land/water managers. TEP's role varies from project to project, but often includes identifying the questions that need to be answered, communicating among participating parties, and assisting in data collection.

Strategy: Identify and map at-risk coastal areas and wetlands – Numerous studies provide information on sea level rise, storm surge, king tides, and wave heights in the region. Projections of inundation for specific areas are available for **assessing risk to specific culverts, dikes, other infrastructure, and natural areas.**[42,43,44,45] Specific habitats such as **low salt marsh, high marsh, mudflats, freshwater wetlands, and nursery habitats should also be assessed** (e.g. using SLAMM modeling) and **future distributions mapped** to guide conservation and management. **Areas where infrastructure failures may affect conservation should be identified and mapped based on climate change projections** as well as infrastructure type and vulnerability. Potential partners include the cities of Tillamook, Netarts, Manzanita, Oceanside, and others;, Tillamook County; Oregon State University; and the Oregon Climate Change Research Institute (OCCRI).

▶ Addresses risks #23, #29, #44, #63

Strategy: Identify at-risk freshwater wetlands – Drought and increased evaporation rates are expected to especially threaten freshwater wetlands. **By assessing the vulnerability of freshwater wetlands, wetland restoration projects can be prioritized**. **Groundwater sources will need to be identified and protected**, although water rights could become an issue. TEP will need to work with the County to assess vulnerabilities. OWRD will need to be consulted over water rights issues.

▶ Addresses risks #26, #31, #42

Red = high priority action
Turquoise = medium priority action

Strategy: Assess future stream flow levels and freshwater inputs to estuaries – Use existing models and data to **assess likely changes to habitats, stream flow, salinity distribution, and water levels, 30 to 50 years in the future**. Identify areas in **headwater streams that may benefit from increased extreme precipitation events, more gravel deposition and LWD**, versus those that might be negatively affected by scouring. **Calculate the appropriate standard for planning infrastructure** needs based on climate change projections (e.g. determine whether sizing of culverts based on 100-year storm volumes is the appropriate standard).

▶ Addresses risks #20, #36, #63

Strategy: Identify other at-risk habitats and species – **At-risk species and habitats will need to be identified based on existing assessments and research**. Many resources are available to assist in this effort, including the Climate Change Sensitivity Database (Climate Impacts Group at University of Washington) and State Wildlife Action Plan. Potential partners include ODFW, USFWS, NOAA, and Audubon Society.

▶ Addresses risk #30

Strategy: Increase forest diversity and monitor resilience – As conditions change and catastrophic events occur, **the survival and resilience of tree species and other vegetation should be monitored and assessed**. Near-term planting and monitoring of a diversity of species and genotypes will provide information on long-term resilience and reestablishment after disturbance.

▶ Addresses risk #48

Strategy: Assess wildfire, fuels and efficacy of fuels management across the landscape – Wildfire frequency and extent are both projected to increase, but the **relationship among fuels, climate change, and wildfire needs to be assessed** in order to **determine appropriate management approaches that increase forest resilience**. Management may differ in the coastal areas as compared to drier inland areas as well. A **review of the appropriate riparian practices for areas affected by wildfire is also warranted**. Potential partners include Oregon Department of Forestry, private landowners, U.S. Forest Service, and University researchers.

▶ Addresses risks #28, #32, #39, #57

CAPACITY DEVELOPMENT

Strategy: Extend partnerships – TEP works with diverse partners to carry out conservation and restoration activities. As degradation of important habitats is exacerbated by climate change, the **number and type of partners will need to be expanded** to have greater reach.

▶ Addresses risk #8

Strategy: Increase Funding – TEP relies on foundation and agency grants to maintain ongoing capacity. The organization may need to **increase grant-writing efforts** to increase funding streams and **increase organizational capacity**. Grants are highly competitive, however, and funds are limited.

▶ Addresses risk #8

PLANNING AND POLICY

Strategy: Recommendations for conservation areas – As specific areas are identified as important for future habitat shifts, especially near tidal

Red = high priority action
Turquoise = medium priority action

marsh habitats or freshwater wetlands, TEP can **work with policy makers to ensure that those areas are conserved**. Potential conflicts between conservation and development exist, but conservation of areas likely to be at risk in the future can also protect infrastructure from climate impacts.

▶ Addresses risks #29

Strategy: Recommendations for policy on new estuarine barriers – With higher sea level, storm surge, king tides, and wave heights, it will be increasingly important to **influence local policy on the installation of barriers**. Increased installation of barriers, including sea walls, dikes and levees, and even rip rap, could make estuary protection more difficult to implement. Partnerships and collaboration with City and County governments could reduce the potential for competition between development and conservation.

▶ Addresses risk #23

Strategy: Develop farm water quality plans – Partnering with NRCS and/or OSU Extension, TEP can **help to develop farm management plans** with select farms to limit nutrient inputs to estuaries and protect shellfish, crabbing, and fishing industries. Appropriately sized animal waste holding facilities will minimize or even eliminate emergency discharges that can pollute downstream water bodies and threaten water supplies and shellfishing operations.

▶ Addresses risks #9, #24

Strategy: County-level policy on water quality – County-level policy that limits nutrient inputs to estuaries and protects shellfish, crabbing, and fishing industries is needed. **Investment in municipal sewage infrastructure** can help to limit nutrient inputs.

▶ Addresses risks #9, #24

Strategy: Improve land management practices through policy change – **Ground cover policy for steep slopes will need to be updated** to increase the retention of cover and re-planting.

▶ Addresses risks #20, #57

ACCEPT

Strategy: Accept inevitable impacts of climate change – Some of the vulnerabilities that were identified are difficult to rectify using management strategies. These include ongoing changes in the distribution and boundaries of tidal marsh habitats, species distributions, and nutrient cycles due to changes in ocean chemistry, hydrology, and salinity profiles. When there are few or no adaptation strategies to address such impacts, or if addressing them would cause significant harm or degradation of other resources, there may be little recourse except to accept the impacts. Also included in the Accept category were risks associated with rising sea levels and storm surge, such as limits on commercial and recreational uses during extreme conditions.

▶ Addresses risks #22, #29, #65, #72

TRANSFER

Strategy: Other entities mitigate risks – Many identified risks need to be addressed, yet they are outside the usual purview of TEP's scope. Some of these included impacts to agriculture, such as changes to flood risk designations by FEMA, issues with manure buildup from changes in the timing of precipitation, the types of grasses or cover crops to be planted, saltwater intrusion into freshwater

Red = high priority action
Turquoise = medium priority action

wells, potential overdraft of rivers and streams, and difficulty for many landowners in meeting water quality targets. Other risks to be transferred to other entities included increased costs for wastewater treatment, the re-distribution of toxic hotspots, potential declines in tourism, reduced beach and shore access, increased disease risk to native fish, the loss of angling opportunities, increased risk of landslides, erosion and sedimentation near steep slopes, and increasing difficulty for numerous entities in meeting water quality targets.

- ▶ Addresses risks #4, #7, #13, #15, #16, #18, #21, #27, #33, #34, #35, #41, #43, #45, #49, #50, #51, #52, #58, #61, #62, #64, #68, #69, #72, #73, #74

Table 5 Strategies and actions developed to address the risks to TEP's goals, identified in the Vulnerability Assessment (see Appendices B and D for a list of all numbered risks). Strategies and actions are sorted in order by priority. Individual risks are listed by number, which corresponds to the full list in the Vulnerability Assessment. Risks that were ranked as highest priority for TEP to address in the Vulnerability Assessment are shown in red, but do not always correspond with the highest priority actions because of the criteria used in the ranking process.

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
1	Strategy: Limit nutrient inputs							
High	Point source identification	38, 46, 47	Fisheries and shellfisheries		DEQ, ODA	Medium	Medium	High
High	Storm water management	9, 24	Water quality	Cost of infrastructure improvements	City/County, DEQ	High	Medium	High
High	Bacterial DNA identifica-tion to identify source	38, 46, 47	Fisheries and shellfisheries	Cost	DEQ, ODA	Medium	Medium	Medium
High	Domestic sewage - septic system improvements or upgrades	9, 24	Water quality	Cost of infrastructure improvements	City/County, private landowners, DEQ	High	Medium	High
High	Farm water quality plans	9, 24	Water quality	Impact on agriculture	NRCS/OSU Extension, DEQ, OR ODA, Soil and Water Cons. District	High	Medium	Low
High	Water quality monitoring and assessment (for quicker response)	9, 24	Water quality		DEQ, EPA, ODA	Medium	High	High
Medium	Municipal sewage – wastewater treatment plant upgrades	9, 24	Water quality	Cost of infrastructure improvements	Cities and Districts, DEQ	High	Medium	High
Low	County level ordinance or rulemaking	9, 24	Water quality		County, DEQ	High	Medium	High
2	Strategy: Agricultural management							
High	Animal exclusion fencing	55	Riparian habitat improvements	Infringement on use of ag lands	Landowners, ODA, Soil and Water Cons Dist, NRCS	High	High	Medium
High	Off channel watering	55	Riparian habitat improvements	Private landowners, ODA regulatations, Farm Mgmt Plans	Landowners, ODA, Soil and Water Cons Dist, NRCS	High	Medium	High
High	Education and outreach on manure management	38, 46, 47	Fisheries and shellfisheries		DEQ, ODA	Medium	Medium	Medium
High	Manure management	38, 46, 47	Fisheries and shellfisheries		DEQ, ODA	High	Medium	Medium

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
Medium	Promote (construct) livestock crossings at bridge/hardened fords	55		Doesn't address nutrients and bacteria, Permits	Landowners, ODA, Soil and Water Cons Dist, NRCS	Medium	Medium	High
Medium	Improve drainage function of lower tidal wetlands through restoration, thereby improving productivity of upland agricultural areas	47	Biodiversity and habitat	Permitting, landowner participation, cost, offsite impacts (or perceptions of)	ODA, Tillamook County, FEMA, ODFW, NRCS, NOAA, USFWS, Landowners, Local govts.	High	High	High
Medium	Rainwater collection off barn/ storage roofs for watering	55	Riparian habitat improvements	Private landowners, ODA regulatations, Farm Mgmt Plans	Landowners, ODA, Soil and Water Cons Dist, NRCS	High	Low	Medium
3	Strategy: Improvements to infrastructure							
High	Improvements to septic systems	71, 38, 46, 47	Fisheries and shellfisheries	Cost, landowners	Landowners, County, Municipalities, DEQ	High	Medium	High
High	Identify culverts and roads most at risk of failure from high flows (esp. those culverts with insufficient capacity)	12, 57		Access to culverts and roads on private lands	NRCS, County, Cities, ODF, USFS, BLM, Landowners, ODOT	Medium	High	Low
High	Replace or remove culverts and roads most at risk	12, 57	Safety and access benefits	Cost, regulatory components, waste disposal, land availability for relocation	Wastewater treatment plants (special districts), EPA, DEQ, Tillamook County (as permitter)	High	Medium	High
Medium	Improvements to stormwater infrastructure (including stormwater retention)	71, 38, 46, 47	Fisheries and shellfisheries	Cost	Landowners, County, Municipalities, DOT, DEQ, ODA	High	Medium	High
Medium	Move/improve (lagoon -> cistern) wastewater treatment lagoons (a few in Nehalem, Bay City, Cloverdale) to reduce risk from overflowing	12, 57	Fisheries and shellfisheries	Cost, landowner participation, re-routing traffic, regulatory components	Municipalities, special districts, Oregon health authority, DEQ	High	Medium	High
Medium	Reduce miles of unmaintained forest roads by fully decom-missioning (remove culverts, pull back unstable slopes, reduce landslide risk)	28, 32, 57	Reduce future maintenance costs	Access to private lands	ODF, Private landowners, USFS	High	Medium	High
4	Strategy: Identify and prioritize areas for restoration							
High	Identify sites where gravel deposits and downed wood might enhance fish habitat	20		Land ownership	Landowners, USFS, BLM	Medium	Medium	Medium
High	Identify areas and prioritize by estuarine and freshwater type. Freshwater wetlands expected to be more vulnerable under drought scenarios.	26, 31, 42		Potentially creates conflicts between conservation and development	County, state, federal, city land managers and owners, NGOs	High	High	Medium
5	Strategy: Protect existing habitat							
High	Protect existing healthy riparian vegetation, which provides shade	1, 2, 3, 5, 6, 11, 14, 17, 19, 56, 63	Biodiversity and habitat	Property/ landowner concerns and rights, limitations on use and perceived use	USFWS, ODFW, NOAA, Landowners, Municipal, county governments	High	High	Low

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
6	Strategy: Improve land management practices in high risk areas							
Medium	Change policy on ground cover retention on steep slopes to increase cover and re-plant	20, 57	Water quality		Private land owners, USFS, BLM, ODF	Medium	Medium	Low
7	Strategy: Restore wetlands and floodplains							
High	Restore floodplain connectivity for freshwater and tidally influenced wetlands and examine underlying influences on hydrology	26, 30, 31, 42	Biodiversity and habitat	Potentially creates conflicts between conservation and development	County, state, federal, city, private land managers and owners, NGOs	High	High	High
High	Riparian restoration in stream related wetlands	26, 42	Flood abatement; Water quality	Potential loss or conversion of ag lands	ALL	High	High	High
Medium	Planting and restoration of wetlands with species that are better adapted to climate variability	26, 30, 31, 42	Biodiversity and habitat	Species may not be native to the region	County, state, federal, city, private land managers and owners, NGOs	High	High	High
8	Strategy: Habitat improvement							
High	Large woody debris (LWD) to collect gravels for more subsurface flow and assist catching landslide material	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Reduce water temperatures	Costs	ALL	High	High	High
High	Riparian plantings	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Biodiversity and habitat		Watershed councils, Land trusts	High	High	High
High	Floodplain habitat restoration	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Flood abatement	Perceived conflicts among conserva-tion, other land uses; permits	ALL	High	High	High
High	Reconnect springs, wetlands, floodplains that can serve as cold water refugia	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Flood abatement	Difficult to show success of restoration via monitoring	Watershed councils	High	High	High
Medium	Increase diversity of habitat to create more salmonid life history options	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Biodiversity and habitat		ALL	Medium	High	Medium
Medium	Increase off-channel habitat	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Flood abatement	Space availability, costs, permits	ALL	High	High	High
Medium	Stream channel restoration to create more channel complexity	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Flood abatement	Difficult to show success of restoration projects via monitoring	ALL	High	High	High
Medium	Expand conservation and restoration activities to ensure maintenance of specific types of wildlife habitat	70	Ecosystem services		Watershed councils, TNC, USFWS	High	High	High

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
Medium	Large scale, holistic floodplain management to maintain and enhance complexity and function	40	Flood abatement	Perceived conflicts between conservation and development/other land uses, permits	ALL	High	High	High
Medium	Address warming caused by inline impoundments	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Water quality	Balance water need with flow requirements for cooling	Private landowners USFW, ODFW, NOAA, ODA, OWRD	Low	Low	High
Medium	Forest management strategy to balance water absorption	1, 2, 3, 5, 6, 11, 14, 17, 19, 20, 56, 63	Biodiversity and habitat	Forest practices	Private landowners USFW, ODFW, NOAA, ODA, OWRD	Medium	Medium	High
Low	Set back dikes to increase channel width and improve floodplain function	60	Biodiversity and habitat, flood abatement	Landowners' expectations, remove land from management and taxation	Landowners and granting agencies	High	Medium	High
9	Strategy: Increase natural upland water storage							
Medium	Promote beaver habitat in the uplands	1, 2, 3, 5, 6, 9, 11, 14, 17, 19, 38, 48, 56, 63, 71	Biodiversity and habitat	Loss of riparian vegetation and warming water in ponds, potential misperception, landowner concerns	USFWS, ODFW	Unknown	Medium	Medium
10	Strategy: Reduce impacts of new and existing development on estuaries							
High	Replace/remove/remediate existing infrastructure and development vital to estuary conservation and ecological functioning over long time frames	23	Water quality; lower risk to infrastructure	Loss of property. Potential conflict between conservation and development	State, Feds, NGOs	Medium	Medium	High
Medium	Make recommendations to County and Planning Department for policies, related to new development, that support estuary conservation and habitat migration	23	Lower risk to new infrastructure; potentially lower insurance costs	Potential conflict between conservation and development	County/City	Medium	Medium	Low
11	Strategy: Assess and manage for projected change							
High	Using sea level rise study/report, assess culverts, dikes, other infrastructure, and natural areas at risk	44			Tillamook County/Cities	High	High	Low
High	Protect/restore/conserve areas that will become new habitat with sea level rise	29		Potential conflicts between development and conservation	Federal, state, local agencies, NGOs, general public	High	High	High
Medium	Develop/use models to view stream and estuary conditions 50-100 years out (for planning current and near future actions)	63	Inform many other plans and projects	Landowner concerns/rights, limitations on use and perceived use; Model development	Universities or govt. agencies	Medium	Medium	Medium
Medium	Education and outreach to promote appropriate standards to all groups (landowners, agencies, Counties, etc.)	36	Access during wildfire; Fish passage improvement; Water quality improvements	Short-term disturbance associated with repair and upgrades	Land managers, Watershed councils	High	Medium	Low

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
Medium	Identify at risk habitats, birds, and species	30			ODFW, USFWS, NOAA, Audubon	High	Medium	Medium
Medium	Assess precipitation standards for culverts and roads (e.g. 100-year storms) based on climate projections and review current standards	36			Stimson lumber, other landowners, state or federal agencies, Universities	Medium	Medium	Medium
Medium	Prioritize, replace, remove, and remediate based on the results of the study	44		Could create conflict between conservation vs. development	ODOT, ODFW, Feds, NGOs	High	Medium	High
Medium	Re-map estuarine sediments and habitats	29			Federal, state, local agencies, NGOs, general public	High	High	High
Low	Revise management units to protect estuarine fringe	29		Political challenges to revising management units	Federal, state, local agencies, NGOs, general public	High	Medium	High
Low	Accept loss of current boundaries	29			Federal, state, local agencies, NGOs, general public	Low	Low	Low
12	Strategy: Expand organizational capacity							
High	Write grant proposals	8		Competition for potential money/ grant funds	Many different agencies, groups, private individual, local businessess, and others	High	High	Medium
Medium	Extend partnerships	8	Building capacity, greater community engagement		Many different agencies, groups, private individuals, local businesses, and others	High	High	Low
Medium	Expand capacity	8			Many different agencies, groups, private individuals, local businesses, and others	High	High	Medium
13	Strategy: Manage streamflow							
Medium	Sustainable water storage and release	1, 2, 3, 5, 6, 9, 11, 14, 17, 19, 38, 48, 56, 63, 71	Water quality	Water rights, costs, permits	ALL	Medium	Medium	High
14	Strategy: Reduce water demand							
High	Education and outreach on water conservation	6, 56			Watershed councils, municipalities, media, water districts	High	High	Medium
15	Strategy: Protect groundwater sources							
Medium	TBD - protect groundwater sources	26, 42		Water rights and use	OWRD	High	Medium	High

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
16	Strategy: Increase strategy for invasive management							
Medium	Aggressive PRISM approach	70				High	High	Medium
Low	Herbicide use for control	70		Increased herbicide use		Medium	High	Medium
17	Strategy: Improve riparian planting survival							
High	Plant diverse species in riparian areas	10, 25, 53	Water quality		Watershed councils, Land trusts	High	High	Medium
High	Replant riparian areas as needed	10, 25, 53	Water quality		Watershed councils, Land trusts	High	High	Medium
High	Monitor riparian planting survival	10, 25, 53			Watershed councils, Land trusts	High	High	Medium
18	Strategy: Increase forest diversity and resilience							
High	Replant with multiple tree species to preserve and enhance diversity	48	Biodiversity and habitat	Native versus non-native species issues	Private landowners, federal and state agencies, Universities	Medium	Low	Medium
Medium	Assess establishment and survivial of tree species post-disturbance and over longer time periods to determine the most suitable species for planting	48	Biodiversity and habitat	Long term monitoring needed	Private landowners, federal and state agencies, Universities	High	Medium	Medium
19	Strategy: Reduce greenhouse gas emissions							
Medium	TBD - reduce GHG emissons across the County	9, 24, ALL	Help meet state GHG targets			Low	Medium	Medium
20	Strategy: Develop appropriate vegetation management actions if changes are detected							
Medium	Change in the type of vegetation used in riparian restoration activities	54, 70			All landowners, OSU Research, USFW, ODFW, NOAA	High	High	Low
21	Strategy: Continue with current management strategies and monitor for changes							
High	Continue water quality monitoring	69				Medium	High	Medium
Medium	Monitor for changes in vegetation	54, 70			USFW, ODFW, NOAA, Farm Bureau, ODA, TNC, ODF	High	High	Medium
Medium	Maintain Riparian Management Areas (RMAs) strategies	54, 70			USFW, ODFW, NOAA, Farm Bureau, ODA, TNC, ODF	High	High	Medium
22	Strategy: Improve understanding of risks related to wildfire, forest management and climate change							
Medium	Assess fuels across landscape (wetter coast to drier inland) and manage appropriately	28, 32, 39, 57			ODF, Private landowners, USFS	Medium	High	Low
Medium	Review riparian practices for areas affected by wildfire	39				Medium	Medium	Low
Medium	Based on the results of the assessment, manage fuels for reduced wildfire severity while maintaining ecological values and function.	28, 39, 57	Safety and emergency preparedness	Access to private lands, Needs ongoing and continuous effort to be effective	ODF, Private landowners, USFS	Medium	Medium	High

Priority	Potential Actions	Specific risks	Co-benefits	Potential barriers or conflicts	Partners	Effective-ness	TEP influence	Relative cost
Low	Review salvage logging practices for better understanding of how this risk affects the region	32			ODF, Private landowners, USFS	Medium	High	Low
23	Strategy: Reduce visitor impacts to bays and rivers							
High	Education and outreach to share water quality info with stakeholders and users	69			Watershed Councils	Medium	High	Low
High	Education and outreach on visitor impacts	66	Combine with other outreach efforts; TEP visibility		Watershed councils, municipalities, media	High	High	Medium
High	Education and outreach to keep users away from stressed areas	69	Biodiversity and habitat	Difficult to affect people's behavior; no enforcement	Many education partners, Community volunteers	High	Medium	Medium

Many climate change risks to the region's natural resources are exacerbated by other stressors, including pollution, water demand, logging, land use practices, flood control barriers, and other common practices. The positive news is that adaptation strategies and actions that reduce these other stressors can result in an increase in overall resilience for many species and resources. For example, reducing water withdrawals during low flows will allow freshwater species to become more resilient in the face of increasing drought and water temperatures as climate change advances.

An exception is the impact of ocean acidification to shellfish and other marine organisms. The coastal waters of the Pacific Northwest are experiencing some of the most rapid rates of ocean acidification around the globe, and little can be done to slow this increasingly severe impact to shellfish and other marine species. Reducing nutrient loading could reduce eutrophication (which enhances acidification), but because upwelling is the primary driver of acidification in this region, results will be limited. Many of the impacts associated with ocean acidification were assigned to the "Accept" category because of the lack of specific actions that TEP can take to reduce this risk. It is acknowledged that the most effective strategy to address ocean acidification will be to reduce greenhouse gas emissions, thereby limiting the overall magnitude of climate change and the impacts associated with it.

In addition to reducing greenhouse gas emissions, the socioeconomic vulnerability of the region to ocean acidification can be addressed in numerous ways. Some options include diversifying fishery harvest portfolios, increasing availability of science, scientists, and research to fisheries and hatcheries, changing the timing and breeds used in hatcheries, and others.[16]

Garibaldi Harbor, Tillamook Bay

Tillamook Bay — Don Best / Tillamook Estuaries Partnership

The Need for Coordination and Collaboration

Numerous entities are working on climate change adaptation in the Tillamook region. As climate change continues to shape this already dynamic system, close communication and coordination among these entities will be needed. Without coordination and communication, strategies to increase resilience in one sector could create negative impacts or reduce resilience in other sectors, thereby simply shifting the climate-related risks from sector to sector.

TEP has a strong reputation and history in the region as an organization focused on building partnerships across a variety of sectors from throughout the local communities. TEP works with government agencies, NGOs, scientists, private landowners, local governments, industry, and active community members. These existing relationships position TEP favorably for taking a leadership role in coordinating climate action across communities, groups, and individuals.

Many of the recommended strategies and actions in this report include research, monitoring, and data assessment that can benefit diverse sectors of the local community. For instance, an assessment of the most vulnerable coastal resources and areas would inform land use planning, hazard mitigation efforts, insurance rates, and natural resource management and conservation. Some initial mapping of vulnerabilities of coastal areas to erosion and inundation has been done (such as DOGAMI's flood, tsunami, and coastal erosion maps), as have culvert inventories in some areas, while other efforts are underway for hazard mitigation and transportation planning (such as FEMA's RiskMap project and ODOT's adaptation planning efforts). The Oregon Department of Forestry also has completed wildfire mapping that could inform adaptation planning for the region.

Updates to Oregon's transportation infrastructure to reduce climate change risks are already underway, and numerous adaptation strategies have been identified.[41] Coordinating with these and other adaptation actions will allow TEP, at a minimum, to mitigate negative impacts of other adaptation actions to natural resources and, at best, to work in collaboration with such efforts to implement resource restoration and resilience measures as part of infrastructure adaptation strategies.

Crabbing off the coast of N. Oregon

Sand Lake Estuary Don Best/Tillamook Estuaries Partnership

Conclusions

TEP works closely with many partners in the region to balance the diverse needs of the local community, including cultural, social, economic, and natural resource sectors. Healthy and functioning natural systems are a vital component of all of these sectors. TEP and its partners are committed to sustaining those natural systems as well as the communities that rely on them. The need for balance drives multiple organizations, businesses, and individuals to all work together to create a sustainable landscape.

Climate change poses a significant threat to the resources of Tillamook County, and fundamentally changes how they need to be managed over time. The Vulnerability Assessment revealed that many of the risks to the region's forests, wildlife, water, and fish were not foreseen in 1999 and, therefore, were not addressed within TEP's original CCMP. Other risks were addressed in the original CCMP, yet their impacts have become greatly exacerbated by climate change, and the current goals may be inadequate to address them. The updated CCMP will address many current and future impacts and trends associated with climate change. The CCMP shall be revisited every five years thereby allowing new information on climate change trajectories and impacts to the region to be incorporated into TEP's strategies and priorities.

The climate change adaptation strategies laid out in this report describe actions and activities that will reduce the vulnerability of many of the region's resources to climate change impacts. Together, these actions will increase the overall resilience of Tillamook County's natural resources. Many of the identified adaptation strategies are already underway, demonstrating the relevance and importance of the restoration, conservation, and outreach efforts that TEP historically has led. Other adaptation actions will be implemented in the near future. Still others are long-term actions that depend on additional research, scientific information, or understanding of the local trajectory and/or magnitude of climate change.

All adaptation actions in this report have significant co-benefits that will result in positive impacts to people and resources of the region, regardless of the trajectory or magnitude of climate change. Increased planting and restoration of riparian vegetation, for example, will provide important habitat for fish and wildlife while also cooling waterways by providing more shade. This, in turn, will reduce the potential for harmful algae and bacteria, which can affect recreational opportunities and human health. Another example of co-benefits is the restoration of beavers at higher elevations, which build ponds that store water during winter, allowing for continued streamflow into summer months. Beaver ponds and dams can also provide flood abatement for communities downstream, as well as complex wildlife habitat that supports biodiversity.

Climate change is an important lens through which to assess and prioritize conservation management actions. And yet specific adaptation strategies can be implemented with diverse partners and for a variety of reasons. While many of the actions described in this report will increase overall resilience in the near- and mid-terms, over longer time frames these actions may still fail to protect the important resources of the region, especially if greenhouse gases continue to be released at current levels. The sequestration of carbon in forest, riparian, and estuarine vegetation and soils is essential to reducing carbon in the atmosphere and is the expected outcome of many of the actions identified as high and medium priorities in this adaptation strategy. Thus, focus on actions that directly or indirectly mitigate the impact of greenhouse gases on the environment will become increasingly important.

Implementation of the adaptation strategies described herein provides numerous opportunities for communicating with the public, TEP partners, stakeholders, private landowners, and others about the importance of local action on climate change. TEP's focus on community education and engagement to promote environmental literacy shall include positive approaches toward reducing emissions and sequestering carbon as well as the co-benefits of these actions, such as improving people's health, reducing natural hazards, saving money, and/or reducing pollution.

The Tillamook region's culture of collaboration around natural resource management and conservation provides a sound base for addressing future change. As people and nature experience shifts in species, loss of important resources and natural function, and increased frequency and severity of extreme events, this culture will become increasingly vital for maintaining resilience. Joint efforts among diverse interests and sectors to maintain ecosystem function and biological diversity is the key to future resilience to climate impacts, and TEP is well-positioned for helping to ensure that natural resource function is a priority consideration in all efforts going forward.

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