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Climate Science Primer:

Tillamook Estuaries Trends and Projections

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Fishing boat in Tillamook Bay – born45 CC BY-SA2.0

Climate change is a global problem, yet the impacts and opportunities for action are locally based. As climate change accelerates with continued greenhouse gas emissions, local communities and organizations will need to be prepared for impacts and take action to protect people and the natural resources we depend on. Preparing for climate change is called Climate Change ***adaptation.*** Of course, the sooner emissions are substantially reduced, the better the outlook for avoiding long-term impacts. Reducing emissions in order to prevent the most catastrophic impacts of climate change is called climate change ***mitigation.*** Both are needed.

Coho salmon spawning - Bureau of Land Management CC BY 2.0

Purpose

The purpose of this climate change primer is to inform the development of a climate change risk assessment and adaptation strategy for five Tillamook County estuaries and their watersheds, commissioned by the Tillamook Estuaries Partnership (TEP). This document provides a short overview of climate science and projections specific to the region and resources of interest.

Numerous studies have detailed the impacts of climate change on Tillamook County and the surrounding area (OCCRI 2013, ODOT 2014, Weber 2015). This overview pulls from those reports and others to provide the latest information on historical changes in climate, future projections, and ongoing and expected impacts.

Assessing Risk

A risk assessment involves weighing the **probability** that an event will occur against the **cost** that will be incurred. We often invest in preparedness for events with low probabilities, such as earthquakes, because of the high potential cost.

While 97% of international scientists are in agreement on the science of climate change, many local leaders and residents have questions about and/or are skeptical of the model projections. Based on the risk approach, this process does not require individuals to overcome their doubts in order to effectively participate and develop sound adaptation strategies.

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
- Wetter winters ↑, drier summers ↓
- ↑ flooding and ↑ drought
- Sea level rise ↑ 2–5 ft. by 2100
- Ocean acidification ↑ doubled
- Higher winter ↑ and lower summer ↓ streamflow

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

Information from ice cores provides us a glimpse into CO_2 levels over hundreds of thousands of years. This data shows us that CO_2 has fluctuated between about 175 and 300ppm over the last 800,000 years. The current level of 400ppm 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.

All models have uncertainty, because complex processes are simplified and assumptions are made about how the earth's processes work. Thus, different models show very 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 (ie. 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 2013 report by the Oregon Climate Change Research Institute (OCCRI) assessed historic changes in climate for the Tillamook Bay Watershed. They found that warming has already occurred in the region, warming by 1° F from 1901–2009. This amount of warming is lower than the average warming of 2.6° F (Fig. 2) for the state of Oregon, likely because of coastal influence.

Precipitation – Precipitation has declined about 0.18 inches per decade, or 2 inches, from 1901–2011.

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.

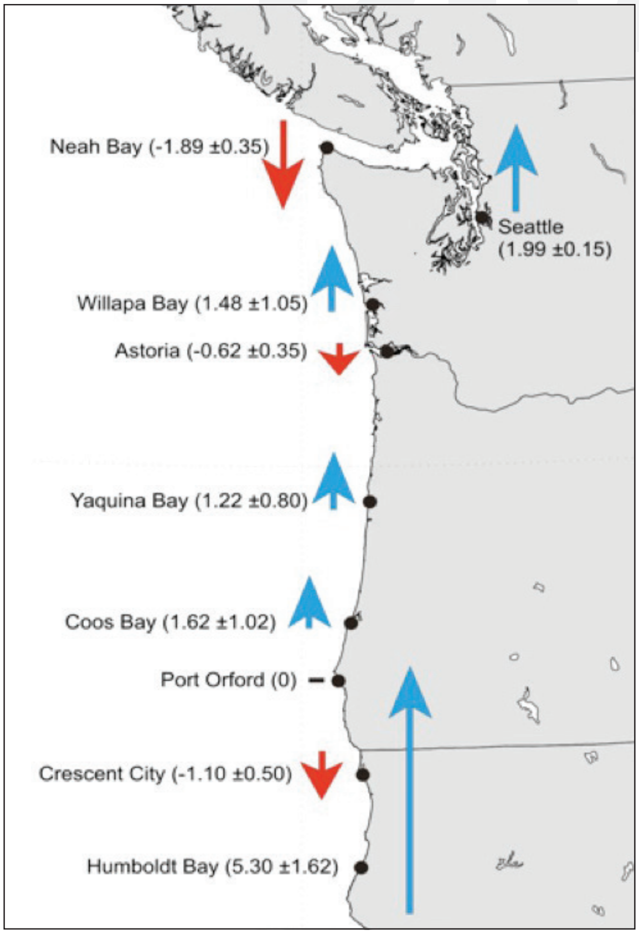

Figure 1 The net effect of sea level rise and land upheaval, over the last several decades, along the coast of CA, OR, and WA.[3]

Sea Level Rise – Sea level consists of two often opposing trends along the coast of Oregon – the global sea level and the elevation of the coastline. 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.[4]

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.[4]

Ocean Acidification – The oceans absorb a large proportion of our CO_2 emissions, causing them to becoming 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 Whisky Creek Shellfish Hatchery's ability to produce oyster larvae for commercial shellfish growers.

Stream flow – Mean annual stream flow across Oregon has decreased since the middle of the century, with the greatest decreases in the summer.[4]

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.[4] 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.[4]

Projected Future Trends

Most projections provided here 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).

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. Most models agree on more intense storms, wetter winters, drier summers, and more frequent extreme heat and wildfire.

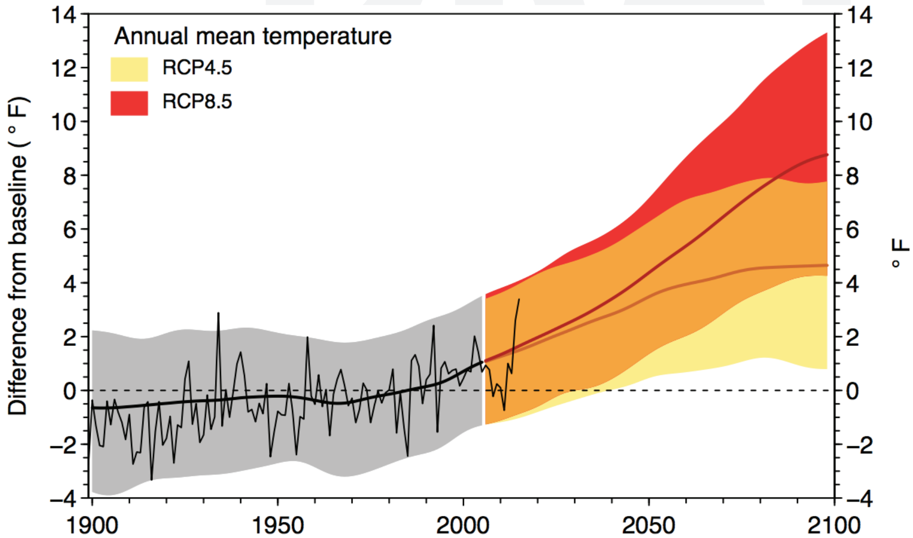

Figure 2 Historic and future warming across the state of Oregon, based on observational data (black lines) and ensemble model projections. RCP4.5 (yellow and orange) assume lower emissions and RCP8.5 assumes continued higher emissions of greenhouse gases.[3]

Temperature – 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.[3]

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.[3] Summer precipitation is expected to decline by 14–19%. Winter precipitation is expected to increase by 7–13%.

Extreme events – The number of days above 90° F is expected to increase throughout the century, especially in the eastern portion of the watershed (Table 1). 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.[3]

Sea Level Rise – Numerous studies on sea level rise are available, with slightly different projections. Here we present the National Research Council's projections from their 2012 report[1] for the Oregon Coast, which have an overall wider range than some other projections.[3]

Table 1 Projected changes in extreme events for Tillamook Bay Watershed, based on estimates from graphs in OCCRI 2013.

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

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.

Ocean Acidification – The ocean's acidity is expected to double by the end of the century, if emissions are not reduced.[2] Along the Oregon coast, by 2050 the nearshore domain may see an annual mean pH as low as 7.82 ± 0.04 (compared to a pre-industrial value of 8.03 ± 0.03).[3] By 2030, mean annual surface seawater aragonite satu-

Table 2 Projected sea level rise in Oregon.[5] 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)

ration state off the Oregon coast is projected to reach a threshold known to disrupt calcification and development in larval bivalves.[4] 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 – Future changes in mean annual stream flow are expected to be small, as increases in precipitation in winter are balanced by decreases in the warm season.[5] Higher winter and lower summer stream flows can have significant impacts, however. Lower summer flows are expected to be accompanied by warmer water temperatures, 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, or 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.[6] 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.[11]

Oyster at Whisky Creek Shellfish Hatchery -Oregon State University CC BY-SA2.0

What does climate change mean for the Tillamook Estuaries and their watersheds?

Climate is place. The climate is what defines any given locality and, for many of us, makes it home. Changes in climate will cause Tillamook estuaries and their watersheds to more closely resemble coastal California, which is a big change. There are many vulnerabilities associated with climate change, some more predictable than others. Some predicted impacts of continued climate change in Tillamook County include:

- Changes in the abundance and distribution of plant and animal species and habitats.[7]
- Shift from coniferous forest to mixed forest type.[11]
- Increases in diseases and invasive species, and insect, animal, and plant pests.[12]
- Loss of wetland ecosystems and ecosystem services.[12]
- Increased incidence of extreme precipitation and damaging floods.[12]
- Increased potential for landslides with possible impacts to roads, tunnels, and other infrastructure.[12]
- People, homes, and roads at risk of inundation during annual flood events.[4]
- Increased wildfire, including declines in air quality and associated health problems.[12]
- Increased drought stress to vegetation due to longer, hotter summers. Potential loss of vegetation and specialized habitats.[8]
- Potential buckling and degradation to infrastructure such as train tracks and roadways with heat over 90° F.[13]
- Erosion of beaches and dunes with major storms.[13]
- Challenges to managing reservoir timing for water supply, hydroelectric production, and flood risk.[4]
- Stream temperatures lethal to many fish species; also increasing variability making it difficult to recover species such as Chinook.[4]
- More extreme El Nino-Southern Oscillation (ENSO) events, amplifying wave energy and coastal erosion.[4]
- More hypoxia events; impacts to plankton, fish, shellfish, and other marine organisms leading to irreversible changes to species assemblages.[4]
- Impacts to the coastal economy, local communities, and indigenous populations.[4]

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