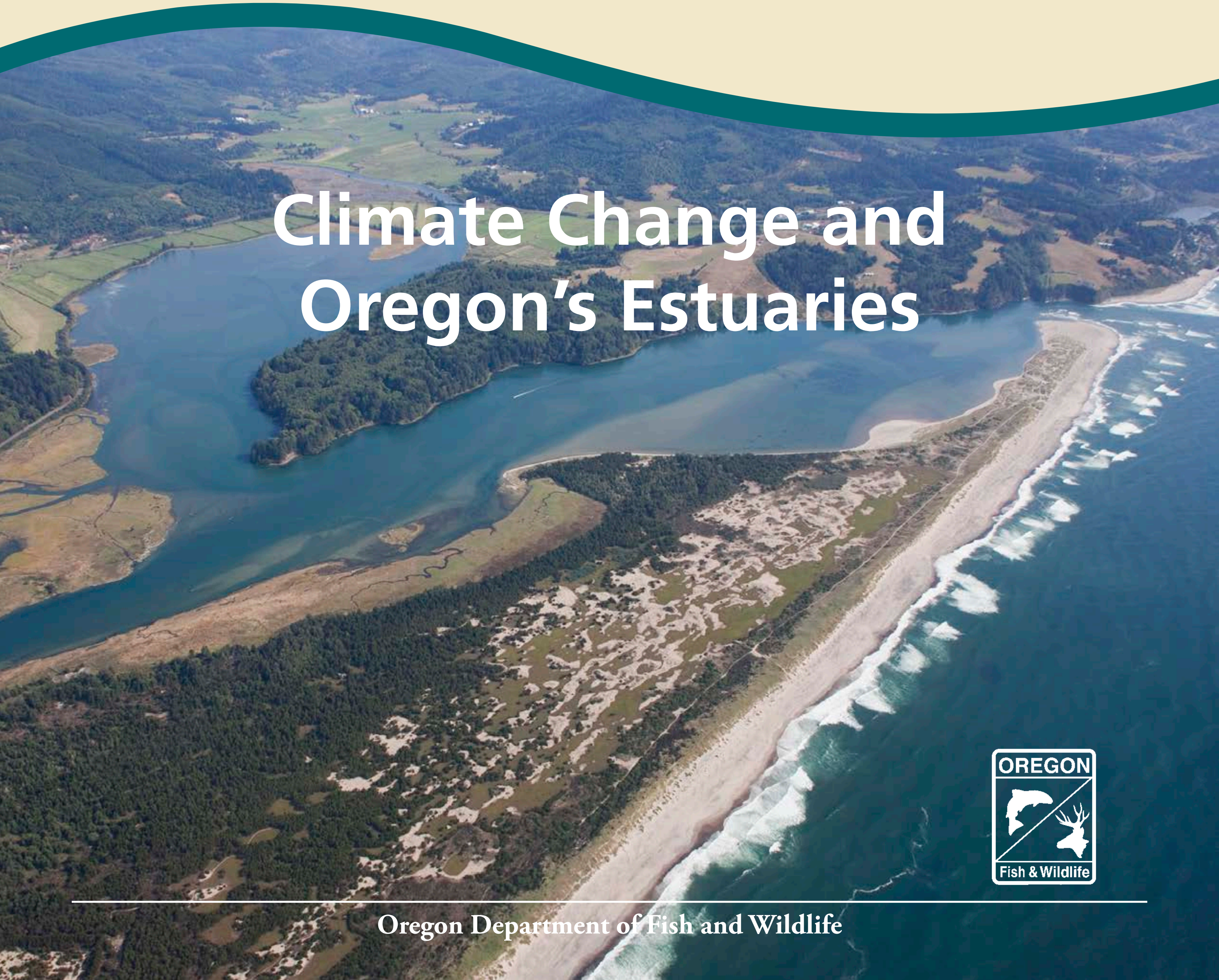
the OREGON CONSERVATION STRATEGY

FACT SHEET



Climate Change and Oregon's Estuaries

Oregon Department of Fish and Wildlife

Estuaries are complex and highly productive ecosystems that occur where freshwater rivers meet the ocean. Oregon's estuaries provide many benefits. They:

- Provide wintering habitat for waterfowl, stopover feeding areas for migrating shorebirds, and year-round habitat for many other fish, wildlife, and aquatic plant species;
- Serve as breeding and nursery grounds for many rockfish species and as refuge and feeding grounds for a wide variety of crustaceans, mollusks, and fish, including juvenile salmon on their way to the ocean and perhaps three-quarters of Oregon's harvested fish species;[1]
- Buffer wave damage during storms and help stabilize shorelines; and
- Improve water quality by filtering out sediment and nutrients, and by removing pathogens and other contaminants.[2]

Estuary systems already face a number of threats. Development, diking, and drainage in coastal areas have resulted in the loss of over 20 percent of Oregon's estuary habitat, with much higher losses in specific estuaries (such as Nestucca Bay at 65 percent and the Salmon River estuary at 42 percent) and in particular habitat types (including 68 percent of tidal marshes and swamps).[3] Sediment and pollution from upstream activities and dredging have diminished eelgrass beds. Upstream water diversions have also changed the amount, timing, and quality of freshwater inflows, which are critical to estuary health. Non-native plant and animal species have invaded many Oregon estuaries.

Rapid climate change will bring new threats to Oregon's estuaries and may intensify many of the existing problems. Warming temperatures, rising sea levels, changing precipitation patterns, and ocean acidification will all play major roles in shaping estuarine ecosystems for many decades or even centuries to come.

The Oregon Department Fish and Wildlife and its conservation partners are working to develop new approaches to conserving estuaries and their ecological values in the face of rapid climate change. These include:

- Protecting land upstream of important estuaries from development to allow these areas of habitat to move in response to climate change;
- Improving management of watersheds that feed sediment and fresh water into estuaries to help counteract the effects of climate-related changes; and
- Educating the public and decision-makers about the importance of limiting bulkheading and other kinds of shoreline armoring that limit the inland migration of estuaries in response to sea-level rise.

Using these and other climate change adaptation strategies, we can help estuary habitats and the fish and wildlife that live there adjust to changing conditions and be more resilient to current and future threats.

Overview of climate change impacts

Warming temperatures: During the last century, the Pacific Northwest experienced overall warming of about 1.5° F. This trend is expected to continue and to accelerate through at least this century, although temperatures beyond the year 2050 will be highly dependent on future greenhouse gas emissions. Recent models indicate additional increases in average annual temperature of 3.2°F by the 2040s and 5.3°F by the 2080s for the Pacific Northwest.[4] Coastal sea surface temperatures in the region are projected to increase about 2.2°F by the 2040s, when compared to the period between 1970 and 1999.

Cover photos: Nestucca Bay. Photo Roy W. Lowe, USFWS. Western sandpiper. Photo Wikipedia. Poole Slough Yaquina Bay. Photo Bruce Taylor.

Sea level rise: Warming temperatures are driving rising sea levels in two ways: indirectly, by melting glaciers and ice caps that add freshwater to the ocean, and directly, through the expansion of water as the oceans warm. (Warm water takes up a greater volume than cold water.) After 2000 years of relative stability, average global sea levels have risen about 8 inches in the last 100 years.[6] Recent research suggests that a global sea-level rise of 3 to 4 feet by the end of the century is likely if greenhouse gas emissions continue on their current path.[7] Along the Oregon coast, the amount of local sea-level rise will vary considerably because of local land subsidence and uplift processes.[8]

Coastal storms and wave height: Climate change is expected to increase the intensity and possibly also the frequency of coastal storms.[9] In recent decades, there has been an increase in storm intensity and wave height across the Pacific Northwest, which may be associated with global climate change, regional climate variability, or a combination of the two.[10] Each of these trends will tend to increase the effects of sea-level rise on coastal areas as storm events cause shoreline erosion and reshape estuaries.[11]

Changes in precipitation and freshwater runoff: Over the next century, annual precipitation in the Pacific Northwest is expected to stay within the range of natural variability. However, we are likely to see a moderate increase in winter precipitation and a decrease in summer precipitation.[12] Precipitation could also be less frequent but more intense in the future: There has been a widespread, long-term trend toward more heavy precipitation events, and that trend is expected to continue.[13]

As temperatures warm, more of our winter precipitation will fall as rain instead of snow, reducing snowpack and changing the timing and amount of flow in rivers and streams that are primarily fed by snowmelt.[14] The Columbia River estuary is the Oregon estuary most affected by this shift, as most others are already influenced more by rain than snow events. Many of the tributary watersheds to the Columbia River have already seen a 60 percent or greater decrease in April 1st snow water equivalent over the past 50 years; projected decreases are even greater.

Ocean acidification: Human activities increase the amount of carbon dioxide (CO_2) in the atmosphere, and oceans absorb a significant fraction of this gas. Absorption of CO2 helps buffer the earth from some of the effects of increased carbon emissions, but it also makes ocean waters more acidic (that is, the pH is lowered). Since 1750, the pH of seawater has dropped significantly (about 0.1 globally).[15] That means water is about 1 ¼ times more acidic today. In the future, surface-water pH could decrease by an additional 0.4 (2 ½ times more acidic) by the end of this century. The extra acidity interferes with marine creatures' ability to build shells, putting marine ecosystems at risk and causing economic losses in communities that depend on shellfish production and harvesting.[16] For perspective, there is no evidence that ocean pH has been lower than 0.5 below present values for at least the past 300 million years.[17] These changes are expected to persist for centuries, even if atmospheric carbon dioxide concentrations return to pre-industrial levels.

Implications for Oregon's estuaries

Coastal inundation and erosion: Coastal wetlands have persisted through past changes in ocean levels because of the natural build-up of sediment and organic matter, which raises the elevation of the wetland floor over time as the sea level rises. However, in some estuary systems future ocean levels may rise too quickly to allow wetlands to keep pace with sea-level rise. In that case, these habitats will be flooded or lost (that is, converted to open water habitat) unless they have room to "migrate" upslope to adjust to rising water levels.[18]

In many developed areas of the coast, sea walls, bulkheading, rip rapping, and other kinds of shoreline armoring prevent landward migration of estuary systems. Today, as sea-level and erosion trends become visible on the coastline, state agencies are seeing an increase in requests for shoreline armoring permits.

Chinook salmon. Photo Wikipedia.

Unfortunately, armoring comes with a price for estuaries. Coastal armoring and some upstream land uses can reduce sediment supply, making it less likely that sediment build-up will keep pace with sea-level rise.

As a result, estuaries where migration and sedimentation are constrained by development or upstream land uses are the most likely to convert to open water marine habitat as sea levels rise.

Some studies have suggested that rates of coastal erosion may be more impacted by coastal protection strategies – in other words, how we choose to react to rising sea levels – and by the changes in storm intensity and frequency described above than by the direct results of sea-level rise.[19]

Changes in biological, chemical, and physical processes: The key processes that drive the productivity of estuaries are complex and often interrelated. These processes determine the plant and animal species found there, and affect the benefits they provide us. As a result, predicting the exact ecological outcomes of climate change on these systems is difficult.[20] However, important factors, such as the salinity of estuarine waters, the amount of sediment in the water and on the estuary floor, how much sunlight reaches plants, and the chemical composition of water, are all very likely to be affected by climate change.

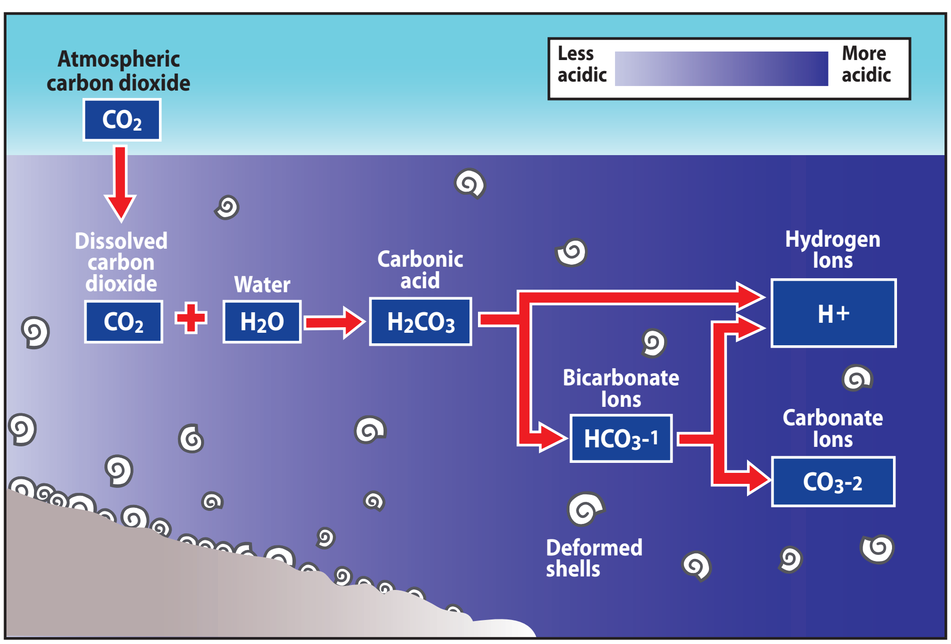
Temperature increases can affect a wide variety of biological and chemical processes in estuarine systems, including the amount of light, dissolved oxygen, and carbon available to estuarine species, the occurrence of harmful algae blooms, and rates of nitrogen fixation and denitrification.[21]

Hydrological cycles on land also greatly affect the functioning of estuary systems by determining the quantity and timing of freshwater inflows and the sediments, nutrients, and contaminants that come with them.[22] For example, changes in snowmelt are expected to result in increased winter flow and decreased summer flow.[23] Increasing temperatures, combined with continually increasing human use of water, are very likely to decrease the overall freshwater input to estuaries, affecting sediment inputs, water movement, water quality, and salinity. These changes can in turn cause stress to plant and animal populations and may even cause a major shift in vegetation communities in an estuary.[24] Reduced freshwater flows into estuaries may further exacerbate the increases in salinity that are expected to result from sea-level rise.

Warmer, wetter winters and more extreme precipitation events would also increase the likelihood of winter flooding in western Oregon streams and rivers, which may in turn lead to large pulses of freshwater and sediment input in estuaries.[25] Activities such as road building and timber harvest can diminish the capacity of natural systems to buffer these events.[26]

The absorption of carbon dioxide from the atmosphere reduces the availability of carbonate ions through a chemical reaction with seawater. These ions are necessary for the formation of skeletons and shells in many marine organisms. As more carbon dioxide is absorbed from the atmosphere, oceans will become more acidic.

OCEAN ACIDIFICATION



China rockfish. Photo Brandon Ford.

Shifts in species and biodiversity loss: All of the changes described here are likely to cause a shift in the plant and animal species found in Oregon estuaries. Researchers have already documented a northern shift in the ranges of many species in the northern hemisphere. One study found an average pole-ward range shift of 3.8 miles per decade for terrestrial species globally.[27] Much larger shifts, up to hundreds of miles, have been documented for some marine species.[28] Some species also move in response to variables other than direct warming, such as the availability of food or moisture, water depth, salinity, or water chemistry. Differences in the way species, populations, and individuals respond to climate change are expected to create completely new ecological communities.[29] Some species will not be able to adapt by moving as the climate changes, because suitable habitat is not available or accessible, or because the species is unable to move far enough or fast enough to respond to rapid changes. In some species, higher temperatures and other changes can disrupt reproduction or cause mismatches in the timing of life events between interdependent species.[30] Higher temperatures may also increase the frequency and severity of outbreaks of nonnative invasive species and lead to increased rates of disease and parasitism, creating new stresses on native species.[31]

Ocean acidification presents a unique challenge for coastal and marine food webs. When carbon dioxide reacts with seawater, it reduces the availability of the carbonate ions that species such as shellfish, marine plankton, and corals use to build their skeletons and shells.[32] There is also evidence that increased acidity lowers the metabolic and growth rates of some marine life, especially invertebrates.[33] Shell or skeletal material builds more slowly and eventually begins to dissolve as waters become more acidic. While the current impact of ocean acidification on these species is poorly understood, significant changes are expected within decades.[34] Any harm to invertebrate life is likely to have cascading effects throughout marine and coastal food webs, with implications for both marine and human communities, because pH-sensitive invertebrates in estuaries form the food base for many ecologically and economically important species.

Managing for climate-adaptive estuaries

The trends described here – warming temperatures, rising sea levels, changing precipitation and hydrologic patterns, and acidifying oceans – are expected not only to continue for many decades or centuries but also to accelerate until human-generated greenhouse gas emissions are reduced. For each of these trends, there is enough evidence and certainty now to allow us to start making management decisions with likely future climate conditions in mind.

Sea-level rise is one of the climate change impacts about which we have the most certainty. We know that sea levels will continue to rise, although we cannot know exactly how high they will rise or how soon. In the face of these changes, coastal communities will have two options: try to hold back the sea or let the shoreline retreat.[35] The decisions coastal communities make about when and where to build protective structures will have a significant impact on the future health and productivity of estuary habitats.

In the face of rapid sea-level rise, it is very likely that many estuaries that are blocked from moving inland will be inundated and will change to open water habitat. Land use decisions about how and when to retreat from shore-lines and where to allow or preclude coastal development will play a critical role in estuary conservation for at least the next century.

Efforts to protect and restore estuaries should focus on areas where this upstream migration remains possible. Models that predict local sea levels can identify the systems most likely to be at risk, and, together with maps of coastal infrastructure and other barriers, can help prioritize areas for protection.

Responding to many of the other climate change impacts outlined here will be more complex. Allowing species, populations, and individuals to shift in response to climate

change is important and will require conservation areas to be large, numerous, and connected enough to accommodate these shifts. However, in some cases, more suitable habitat will not be available or accessible, and those estuaries will be lost or diminished.

In these cases, management actions will have to focus, at least in the short term, on reducing the non-climate threats that climate change intensifies. For example, improving the complexity and health of upstream riparian areas can help cool water temperatures and improve water quantity and quality in estuaries. This type of restoration and management will help buffer estuaries from the effects of changing temperature and precipitation regimes. Likewise, reducing the flow of excess nutrients, sediment, and pollutants into estuaries will help buffer species from some of the negative effects of acidification. These kinds of strategies are often referred to as "no regrets" strategies, because they are likely to improve ecosystem health regardless of future climate conditions.

Climate change is fast becoming a reality in fish and wildlife management. Planning and adaptive management actions must consider the best available science on future climate conditions and focus on strategies that are likely to meet management goals in a warmer and less predictable world. Protecting estuaries and their fish, wildlife, and plant species can help build the resilience of both human and natural communities to the changes to come.

Siuslaw estuary. Photo USFWS.

Oregon's shorebirds in a changing world

Flocks of migrating western sandpipers (*Calidris mauri*) provide the Oregon coast with one of its most spectacular sights. These small shorebirds visit Oregon estuaries in spring and fall as they travel between their Alaskan breeding grounds and their wintering grounds to the south, often collecting in groups of many thousands of birds. As many as 100,000 western sandpipers have been observed in Tillamook Bay at one time during migration periods. Smaller numbers of these birds also spend the winter in Oregon.

Western sandpipers migrate between points as far north as the North Slope of Alaska, and as far south as the coast of Peru. In order to make these long migrations successfully, they generally stop several times along the way to feed for a few days and then continue their migration. In Oregon, both migrating and winter resident western sandpipers depend heavily on tidal mud flats. These very productive areas provide a ready supply of sandpipers' main food sources: invertebrates, such as crustaceans, worms, and small clams, and biofilm, a very thin layer of slime made of microbes, organic matter, and sediment. As a result, Oregon estuaries provide a critical food source for western sandpipers and other similar shorebirds during their long spring and fall migrations. The birds' ability to complete migration, as well as to breed successfully when they reach their destination, depends very much on the availability of suitable feeding habitat along their migration routes.

Western sandpipers are the most common shorebird along the Pacific coast, and they are not currently threatened or endangered. However, these charismatic birds have been affected by degradation of estuaries, and climate change is likely to cause them further problems. In Oregon, rising sea levels are expected to convert many current tidal flats into open water over the next 50-100 years, and where these habitats are hemmed in by diking or development, they are unlikely to be able to shift inland. The loss of this productive feeding habitat may cause problems for migrating western sandpipers. Other changes in estuaries that affect vegetation and invertebrate communities may also decrease food availability. Maintaining high-quality stopover sites in the face of rising seas should be a priority in future efforts to conserve these birds.

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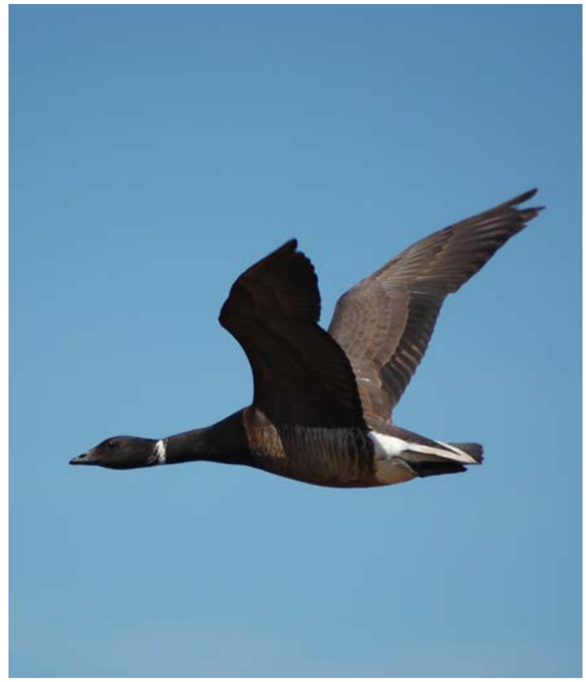

Black brant. Photo Don Becker, USGS.

Western sandpiper. Photo Dave Herr, USFWS.

Blue heron. Photo Nick Myatt.

Eelgrass meadows: a "coastal canary"?

Eelgrass (Zostera marina) is a seagrass that forms extensive, highly productive meadows in many Pacific Northwest estuaries. Eelgrass and other seagrass species act as important "ecological engineers," stabilizing sediment, producing organic carbon, cycling nutrients, and providing food and refuge for a wide diversity of species. Eelgrass is often considered an indicator of estuary health, in part because it serves as a key habitat for large numbers of fish, especially during their early life cycles. Eelgrass meadows are particularly recognized as important nursery and feeding areas for juvenile salmon and Dungeness crab, and they also provide important feeding areas for charismatic shorebird species such as blue herons, as well as mammals and raptors. As with other species affected by climate change, eelgrass is also subject to non-climate stressors, including shoreline development, dredging, eutrophication (abnormally high nutrient levels that can lead to the depletion of oxygen in the water and other negative impacts), and damage from ship wakes and recreational use.

The health of eelgrass systems is dependent on many factors, including the level of light they receive, the temperature, salinity, and nutrient level of estuaries, and the action of waves, currents, and tides. A study of the effect of changes in temperature and salinity on eelgrass found that it could be negatively affected by some of the trends associated with global climate change. Eelgrass is sensitive to the decreased levels of light found in deeper water, so rising sea levels may cause a shift in their distribution. Any increase in the amount of sediment in estuarine waters resulting from changing precipitation patterns or other causes might also force a landward shift by decreasing the amount of light available at current elevations. Eelgrass is most successful within a very narrow water temperature range (41-46°F) and is stressed by higher temperatures.

Scientists have been tracking an apparent global decline in seagrasses that is most likely due to a combination of climate and other stressors. The important role eelgrass plays in the health and productivity of Oregon's estuaries – and the fish and wildlife that depend on them – argues for closely tracking its distribution and response to climate change and other human-caused threats. Mitigating these other impacts may help eelgrass meadows respond adaptively to unavoidable changes in temperature, light, and sea level.

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Shorebirds. Photo David Ledig, USFWS.

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Tillamook Bay. Photo Kathy Munsel.

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