Study tests resilience of the Salish Sea to climate change impacts

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Credit: Pacific Northwest National Laboratory

What will the ecology of the Salish Sea look like in the year 2095?

It's an important question for millions of people who live along and near the shores of this intricate, interconnected network of coastal waterways, inlets, bays, and estuaries that encompasses Puget Sound in Washington state and the deep waters of southwest British Columbia.

A research team from PNNL found that the inner Salish Sea is resilient, and that future response to climate change—while significant—will be less severe than the open ocean.

Building a picture of Salish Sea ecology

Climate change is a global issue from the tropics to the polar regions, but impacts are often of greatest concern locally. It's why the Climate Preparedness and Resilience Program of the U.S. Army Corps of Engineers funded PNNL to develop a better understanding of the Salish Sea's future—how its ecology will respond to increasing temperatures, rising sea levels, and growing nutrient loads.

The research focused on key parameters, such as algal blooms, ocean acidification, and annual occurrences of hypoxia—a condition characterized by low levels of dissolved oxygen. These are all ecological issues of concern in the Salish Sea today and in the decades to come.

Researchers used the Salish Sea Model, which was developed by PNNL in collaboration with the Washington State Department of Ecology and through U.S. Environmental Protection Agency grant support. The model is a predictive ocean-modeling tool for coastal estuarine research, restoration planning, water-quality management, and climate change response assessment. In 2018, PNNL scientists used it to accurately simulate the Salish Sea's responsiveness to anthropogenic nutrient loads, such as fertilizer runoff and wastewater discharges (Khangaonkar et al., 2018).

According to PNNL program manager Tarang Khangaonkar, that milestone 2018 achievement—successful prediction of Salish Sea biogeochemical cycles including occurrence, timing, and duration of hypoxia at sites historically known for poor quality and fish kills—helped make possible the most recent study. "That research established that our model was working in a robust manner, so we were able to apply it to answer new questions—to find out how this body of water will change with climate change," he said.

The domain of the Salish Sea Model stretches from British Columbia south to Newport, Oregon. Credit: Pacific Northwest National Laboratory

To take on the challenge, PNNL researchers applied downscaled outputs from the National Center for Atmospheric Research's Community Earth System Model, a well-known and frequently applied global climate model, to drive the Salish Sea Model. The team simulated a single projection of 95?year change under the representative concentration pathway 8.5 (RCP8.5) greenhouse gas emissions scenario, relative to the year 2000. This corresponds to a high emissions scenario in the Intergovernmental Panel on Climate Change (IPCC) 5th assessment report corresponding to unchecked greenhouse gas emissions. The Department of Ecology collaborated by providing input data, such as watershed and wastewater effluent loads into the sea, taking into account future land-use change and population growth.

Study results: The Salish Sea in 2095

Published in the journal JGR Oceans, "Salish Sea Response to Global Climate Change, Sea Level Rise, and Future Nutrient Loads" (Khangaonkar T, A Nugraha, W Xu, and K Balaguru, 2019) projects impacts to the Salish Sea by 2095, including higher water temperature (+1.5°C), higher sea levels (+1.5 meters), greater acidification, and decreased dissolved oxygen levels.

A region of annually recurring hypoxia in this 6,900-square-mile body of water is projected to increase from less than 1 percent of the total area today to about 16 percent by 2095.

The fast-growing population of the greater Seattle and Vancouver, BC, metropolitan areas—along with rising water temperatures—also play a role in the future state of the waters. With more people come greater nutrient loads that contribute to algal growth, with biomass projected to increase by about 23 percent. Moreover, that biomass may shift from communities dominated by diatoms to ones dominated by dinoflagellates.

"These changes have a significant effect on the composition of phytoplankton species. Some species such as dinoflagellates may benefit and others such as diatoms will not. It is the species that favor warmer water that will become more dominant," Khangaonkar said, noting that the findings are based on mathematical assessments that do not make allowances for biological adaptation.

A resilient body of water

Despite significant forecasted change, the study indicates that future response to climate change in the Salish Sea would be less severe relative to change predicted in the open ocean. Greater resilience may be attributed to strong vertical circulation and mixing of surface layers with deep water that provides a physical buffer to keep the Salish Sea's waters cooler, more oxygenated, and less acidic.

PNNL's Marine Sciences Laboratory on the shores of Puget Sound in Sequim, Washington. Credit: Pacific Northwest National Laboratory

"One of the reasons we started this study was to learn what climate change will mean for our nearshore areas of the Salish Sea," Khangaonkar said. "Will it be impacted more than the coastal Pacific Ocean waters? Will it be less?"

The research team found that mixing and deep-water circulation within the Salish Sea provide relief from much stronger global climate change impacts. While average temperatures at the open ocean shelf boundary are projected to increase by 2.6°C, the Salish Sea average is projected to rise 1.5°C. Similarly, average dissolved oxygen at the open ocean shelf boundary is projected to decrease by 1.7 milligrams per liter, inside the Salish Sea, the average level of dissolved oxygen drops half that amount.

Circulation is important for water quality. "When people think of climate change," explained Khangaonkar, "their first assumptions are that of higher temperatures and rising sea levels, and that it will change current patterns and tidal movements significantly. But we found that this was not the case for the Salish Sea."

The research team used the model to examine the volume flux (exchange flow) of water moving into the Salish Sea from the Pacific Ocean. Would this quantity that is nearly 20 times as large as all freshwater inflow combined change? And if so, will it impact flushing and water quality? The study results showed that two factors appear to counteract one another to make circulation change insignificant.

Melting polar ice affects the ocean's salinity and reduces estuarine circulation strength driven by salinity gradients. At the same time, sea-level rise increases circulation strength and the two factors essentially cancel each other out for the deep fjord-like waters of the Salish Sea.

Khangaonkar cautions that the resiliency of the Salish Sea is limited to the deeper estuarine mixing region between the continental shelf and rivers. "Once we go into the intertidal areas and upriver, we find that the impacts of climate change are higher," he said.

For example, the intertidal reaches of the Snohomish River Estuary, which is an inner Salish Sea subbasin, is predicted to experience up to 3°C annual mean surface temperature increase. Similarly, as a result of sea-level rise, the salinity intrusion is predicted to extend as far upstream as 18 km from the river mouth relative to 7 km in historical conditions for the Snohomish estuary.

Bringing the Salish Sea Model to the world

PNNL conducts numerous applications of the Salish Sea Model to assist with nearshore habitat restoration planning and design, analysis in support of re-establishment of fish migration pathways, and assessment of basin-wide water quality impacts. The methods, models, and procedures used for downscaling global climate change projections for the Salish Sea region, could be applied for similar analysis in other regions. The Salish Sea Model application results and solution files are routinely made available to collaborators upon request.

More information: Tarang Khangaonkar et al. Salish Sea Response to Global Climate Change, Sea Level Rise, and Future Nutrient Loads, *Journal of Geophysical Research: Oceans* (2019). DOI: 10.1029/2018JC014670

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