A refined tool to quantify the impact of changing oxygen and temperature on Puget Sound marine life

Previous efforts have evaluated when and where nutrients from human activities decrease dissolved oxygen levels. This research builds on those efforts to consider species-specific habitat use and oxygen thresholds. Marine life in Puget Sound and the Straits has evolved across a wide range of oxygen environments, so some species require consistently high oxygen, while others are more resilient. Additionally, the analysis considers the interdependent effects of temperature and oxygen since warming can reduce oxygen availability while simultaneously increasing how much oxygen species need. To meaningfully inform nutrient management, we need to understand not just when and where human-driven nutrients worsen oxygen conditions, but where those conditions may cause harm. Scientists at the University of Washington's Puget Sound Institute and School of Aquatic and Fishery Sciences applied an established framework to evaluate aerobic habitat compression for Dungeness crab, English sole, and Chinook salmon.

A digital copy of this factsheet with the hyperlinked sources is available at bit.ly/AerobicHabitatCompression

AQUATIC AND FISHERY SCIENCES
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Evaluating Dungeness crab, English sole, and Chinook aerobic habitat

The UW team evaluated aerobic habitat compression for Dungeness crab, English sole, and Chinook salmon – species selected for their economic, ecological, and cultural importance.

The analysis integrates:

1. **Species-specific oxygen thresholds:** the oxygen levels each species needs to sustain routine activities — like feeding and swimming— that are based on the best available science.[1] Although thresholds for reproduction and growth may be higher.
2. **The Salish Sea Model –** a well-characterized regional model that captures how oxygen and temperature vary across Puget Sound and the Straits through time in response to nutrient loadings and climate conditions.[2,3,4,5,6]
3. **An established framework** for evaluating aerobic habitat compression using the ratio of oxygen supply to demand, both of which depend on temperature and body size.[7]

Together, this analysis provides a spatially explicit, biologically grounded foundation to evaluate where low oxygen and warming may impact marine life — and to assess the benefits of nutrient management.

Monitoring reinforces the importance of temperature. Over the past century, warming caused most of the 0.3–0.9 mg/L decline in fall, bottom-water oxygen at several long-term monitoring sites in Puget Sound.[8]

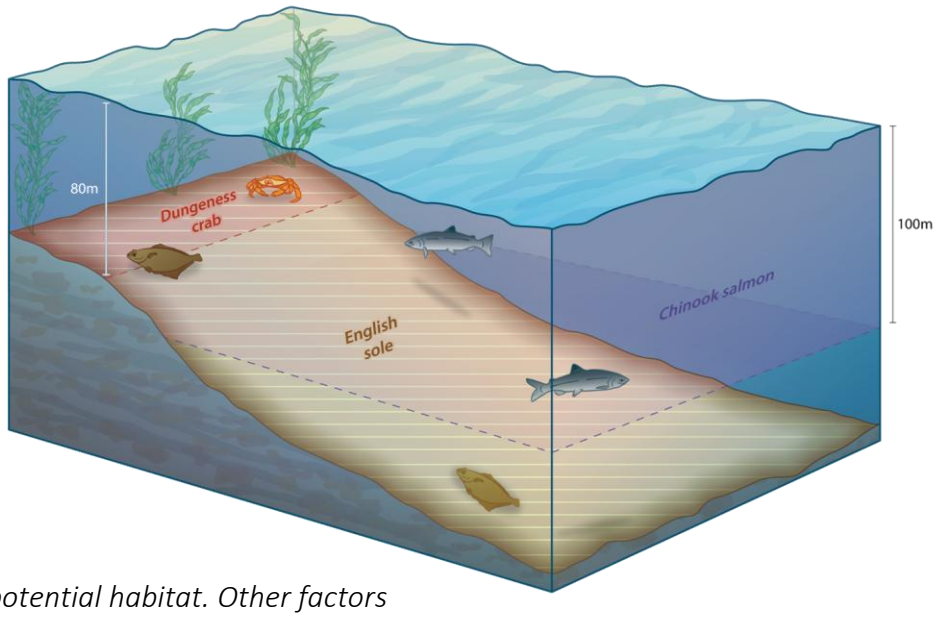
Considering each species' potential habitat

Since different species have unique oxygen needs and mobility, focusing on a species' potential aerobic habitat* considers where low oxygen and temperature may truly affect them. For example, low oxygen in deep parts of the Main Basin won't impact Dungeness crab since they generally occupy shallower parts of the seafloor. Chinook salmon, on the other hand, typically live in the top 100 m of the Sound.

Dungeness crab: Area along the bottom of the Sound if < 80 m

English sole: Area along the bottom of the Sound

Chinook salmon: Volume in the top 100 m of the water column



**This UW analysis only considers depth to define potential habitat. Other factors (e.g., substrate, food availability, etc.) may also limit a species' available habitat.*

Photo courtesy of King County.
Graphic: Emily Eng for PSI

Seasonal habitat compression in Hood Canal & embayments

Analyzing 2014 model outputs throughout Puget Sound & the Straits found:

Seasonal habitat compression during the summer and fall was typically less than 2% of each species' aerobic habitat across Hood Canal and several embayments.

During this seasonal compression, there is sufficient oxygen in more than 98% of Dungeness crab, English sole, and Chinook salmon's aerobic habitat to support routine activities.

Hood Canal experienced the largest habitat compression, which also extended into winter.

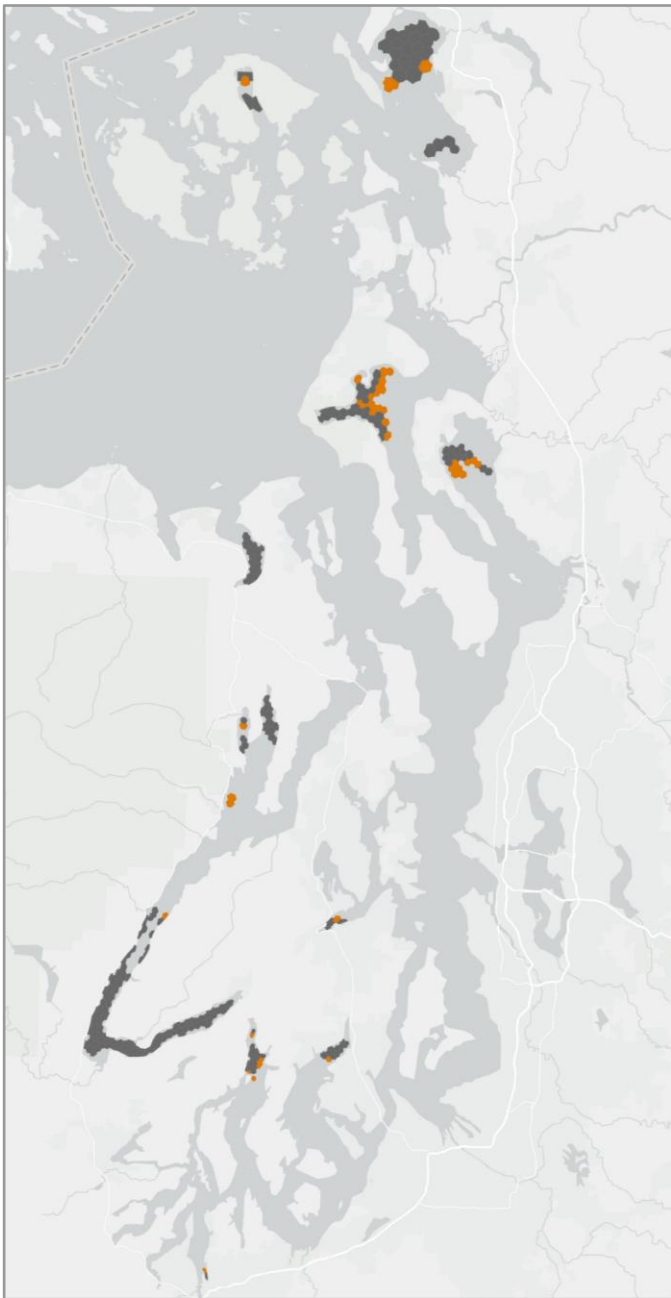
Nutrients from human activities in Washington compressed less than 1% of aerobic habitat for each species — even on the worst day of the year.

Exploring the influence of nutrients from human activities

While the aerobic habitat for each species naturally compresses during late summer and fall, species have likely adapted to this over generations.

However, the small proportion of nutrients from human sources in Washington is predicted to extend aerobic habitat compression in Hood Canal and some shallow embayments.

The UW team evaluated the difference between Salish Sea Model predictions for 2014 'existing' and 'reference' conditions to **quantify how much aerobic habitat is lost due to nutrients from human activities in Washington.**



Dungeness crab aerobic habitat compressed for at least one day in 2014

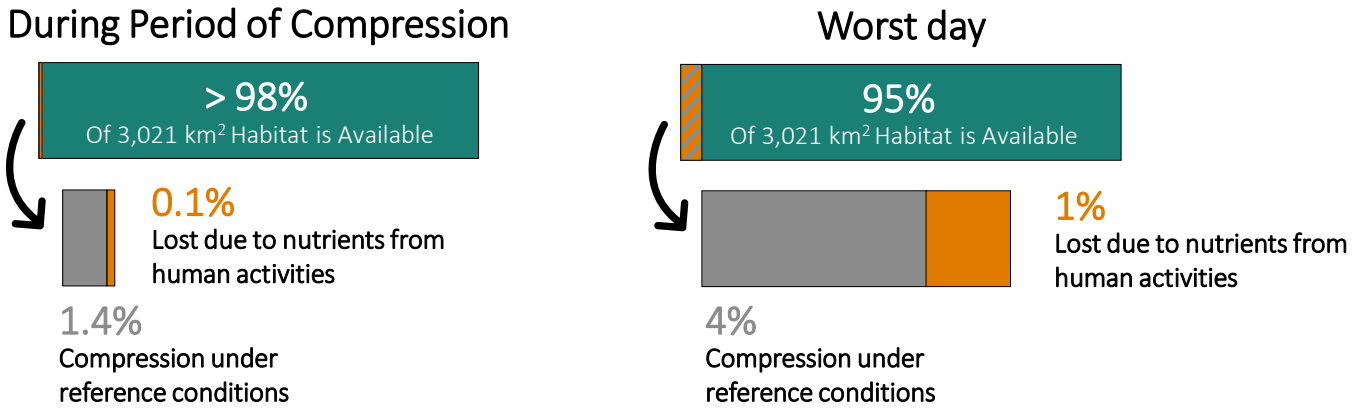
- Habitat compression under both 'reference' and 'existing' conditions
- Habitat loss due to nutrients from human activities in Washington

Climate is held constant between existing and reference conditions. The UW Team plans to analyze how climate change may impact habitat compression in the next phase.

Nutrients from human activities have a small impact on the aerobic habitat for Dungeness crab, English sole, and Chinook salmon

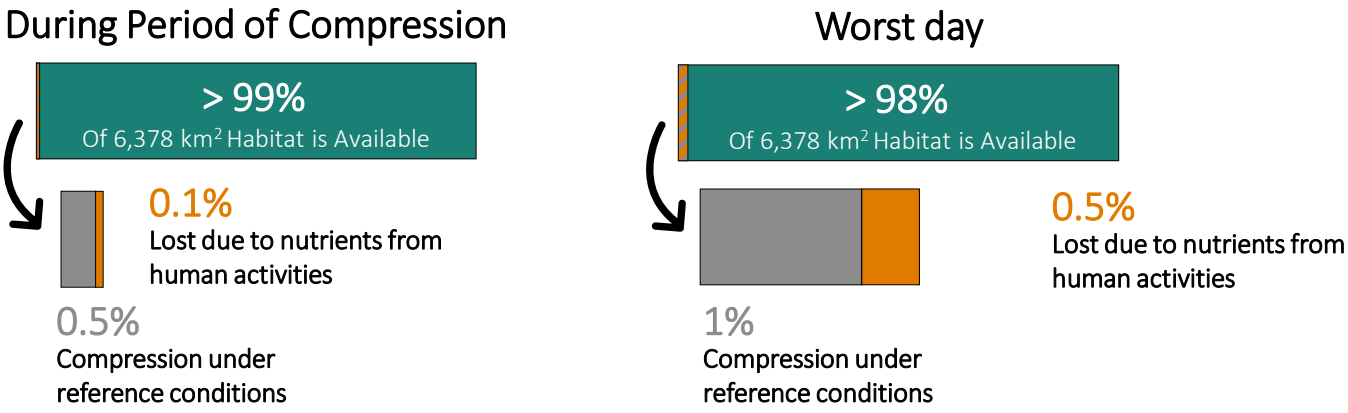
Dungeness crab

Throughout Puget Sound & the Straits, nutrients from human activities caused an average habitat loss of about 0.1% (4 km^2) during the period of compression and up to 1% (33 km^2) on the worst day.



English sole

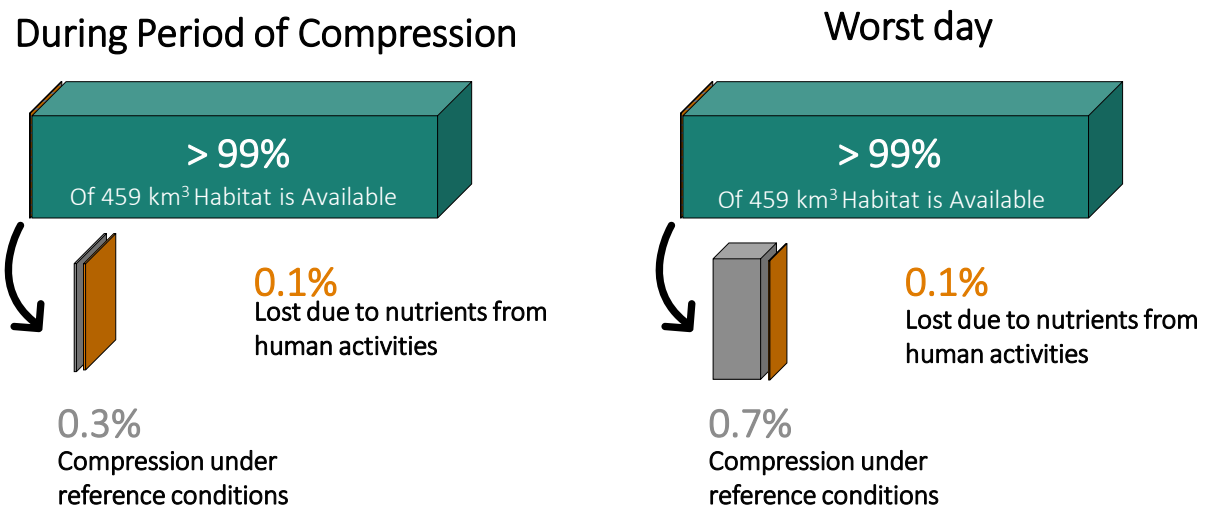
Throughout Puget Sound & the Straits, nutrients from human activities caused an average habitat loss of about 0.1% (7 km^2) during the period of compression and up to 0.5% (30km^2) on the worst day.



Read the report for more information at
bit.ly/AerobicHabitatCompressionReport

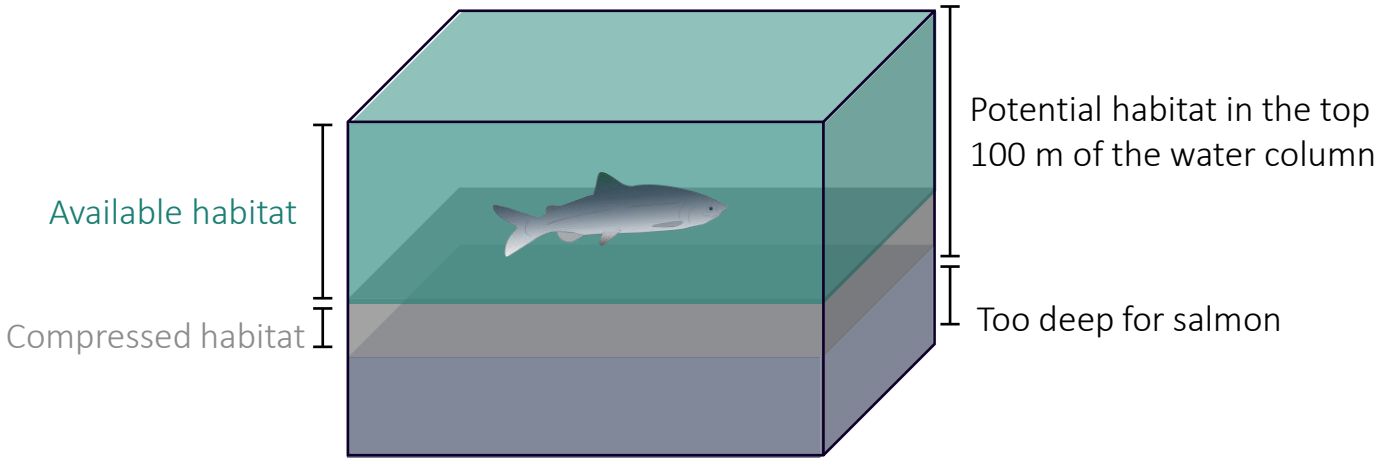
Chinook salmon

Throughout Puget Sound & the Straits, nutrients from human activities caused an average habitat loss of about 0.1% (0.2 km^3 & 0.5 km^3) during the period of compression and on the worst day.



Chinook salmon always had access to well oxygenated upper waters

Chinook salmon can move up and down within the water column, allowing them to avoid low oxygen in deeper waters. Results show **they always had access to sufficient oxygen somewhere in the water column.**



Future research is needed to better evaluate how episodic vertical habitat compression may affect Chinook salmon's routine activities and responses.

Building on previous efforts

Washington is taking important steps to manage nutrient pollution in Puget Sound to protect marine life from low dissolved oxygen.

Previous efforts have evaluated when and where nutrients from human activities decrease dissolved oxygen levels. This research builds on those efforts to evaluate when those changes may impact Dungeness crab, English sole, and Chinook salmon through aerobic habitat compression.

Considering temperature and oxygen together, over half the area predicted not to meet water quality standards[3] would still support routine activity for Dungeness crab.

Incorporating supporting lines of evidence that account for **species-specific habitat use and oxygen thresholds** can improve even traditional dissolved oxygen analyses by providing a clearer picture of where oxygen levels may affect marine life. Additionally, considering the **combined effects of warming waters** from climate change **and reduced oxygen** associated with human-driven nutrient inputs can add further nuance to assessments of oxygen stress.

Keep in mind that nutrients from human activities may also contribute to harmful algal blooms, reduced eelgrass habitat, shifts in food-web structure, and ocean acidification.

Photo courtesy of David Ayers/USGS
Photos on the front page courtesy of: Conrad Gowell, WFC; Kathleen Reed; and J Brew.