Hood Canal: The Exposé

The waters of Puget Sound are like an insecure supermodel: beautiful on the surface, but a tumultuous wreck on the inside. While the people of the Sound were oblivious to the damage going on beneath the surface, they also continued to use the Sound as they saw fit. Hood Canal, due to its recent fish kills, dead zones, and sewage problems has recently garnered media attention for all the wrong reasons. A scientific expedition was sent out to the Puget Sound and beyond to investigate what causes Hood Canal to have low oxygen concentrations and if it is possible to revive her. We all know she is more beautiful without her problems.

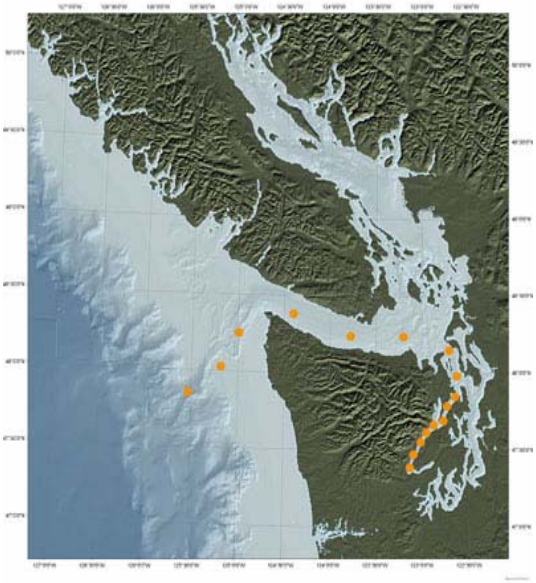
The Puget Sound basin is a fjord which has the general characteristics of steep sloping walls, greater relative depths within the middle of the basin and a sill on the seaward side. Barring water input from precipitation, water enters Puget Sound from river and stream runoff at the surface, and from ocean upwelling at the bottom. Water mostly exits on the surface, through the seaward end via Admiralty Inlet and the Strait of Juan de Fuca. Since there is one seaward entry, named Admiralty Inlet, into Puget Sound from the Strait of Juan de Fuca and the Pacific Ocean, seawater must enter through there at depth and water on the surface of the Sound exits through there as well.

The water from river and stream inputs is fresh less dense and more buoyant than seawater. This causes the input from the rivers and streams to stay at the surface. Seawater is denser because of the salt content so it flows closer to the bottom of the basin. Sills restrict the saltwater movement into the Sound from the Pacific because it has to stay near the lower layers of the water column.

The Scientific Group, made up of seniors from UW Oceanography, investigating the causes of Low Oxygen within Hood Canal.

Coastal wind patterns are also responsible for circulation within Puget Sound and the entry and exit of water through the Strait of Juan de Fuca. Southerly winds are prevalent in the late summer and early fall off of the Washington and Oregon coast. These winds, combined with the Coriolis force, bring surface water away from the Washington coast. The Coriolis force is an effect of the rotation of the earth and causes large things that move over large distances to drift to the right in the northern hemisphere. It acts on wind and ocean currents and water movement. So when a wind is pushing on the

water trying to move it south, the water ends up moving west away from the coastline. Thus, the water level is lower near the coast, so deep water must upwell to replace the surface water that has moved away. As this water upwells into the Strait of Juan de Fuca, it can flow over the sill and into Puget Sound. Since this water is still very dense compared to the surface water, it continues to remain deep in the water column. As water flows over a sill it mixes depending on the tides. Mixing of the bottom water over the sill is favorable during the event of a neap tide and bottom gravitational circulation can develop potential consequence of this deep water upwelling is the transport of water into the Sound that has lower dissolved oxygen concentrations. (Newton et al., pg. 15).

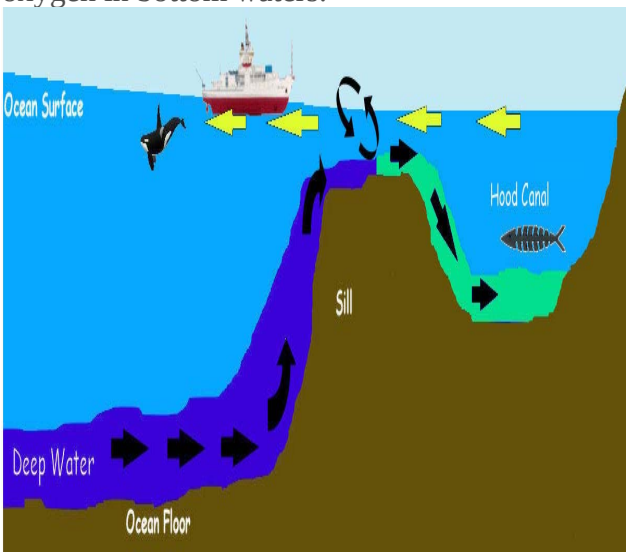


Water entering Hood Canal mixes homogenously as it moves over the sill and helps to drive its two layer circulation (Newton et al., pg. 4). River flow may also help drive the circulation but if it's low then that will decrease stratification and enhance mixing. However, it would also slow down the density driven estuarine circulation by decreasing movement of water in and out of the canal. This is one of the main causes of Hood Canal's sluggish flow and regions of stagnant water.

The residence time, or the time it takes for the water in Hood Canal to fully exchange with water outside the canal, may be several months to over a year (Newton et al., pg. 13). Flow reversals reduce the transport which in turn increases the residence time and under these conditions it may be characterized as a three layer flow (Cannon, pg. 38). A three layer flow occurs when the bottom, middle and surface waters move in alternating directions due to flow reversals, for example when bottom water in Hood Canal moves south, the middle water moves north and the wind causes surface water to move south as well.

Oxygen finds its way into the water from either photosynthesis (plants and algae use carbon dioxide and water to make sugar and oxygen) or the physical diffusion from the air at the sea surface. Surface waters are abundant with oxygen, since phytoplankton, who photosynthesize and release oxygen, require sunlight to grow. Water that is under the sunlit layer loses oxygen through respiration. If an area whose bottom is covered with dead plants or phytoplankton which are a source of food to bacteria also feature a strong density gradient, or a sharp boundary between fresher and saltier water,

which prevents mixing with the overlying water column, then the oxygen at the bottom can soon become exhausted, leading to the death of animal communities. Such density gradients can also stem from large temperature or salinity differences in the water at various depths. Poorly flushed estuaries, for example are particularly vulnerable to the effects of eutrophication such as these zones of low oxygen, because low water flows lead to slow replenishment of oxygen in bottom waters.

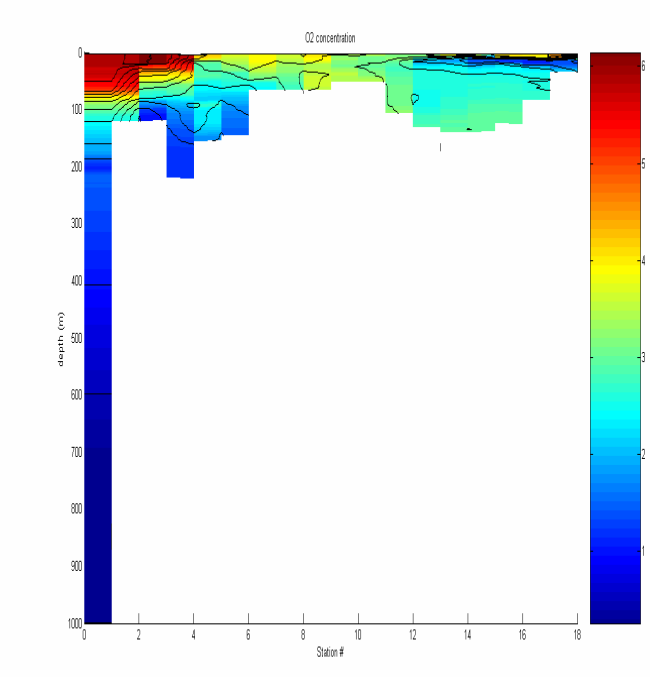


The winds causes upwelling of deep ocean water into the Puget Sound. The water then mixes along the sill before being able to move into Hood Canal.

Phytoplankton, or floating algae and other microscopic photosynthesizers, make up the base for most marine food webs. A certain level of nutrients in the water column is required for phytoplankton health and the growth of the rest of the organisms within their ecosystem. Most of the oceanic regimes globally are limited by nitrogen and phosphorus additions. The addition of these nutrients into sunlit waters greatly accelerates primary production (growth of phytoplankton), leading to disruptive algal blooms and a phenomenon called eutrophication. Eutrophication is basically the additional input of nutrients beyond the level that organisms in the water can use. The growth of phytoplankton en masse leads to the coloration of the water to green or brown, and the shade they cast deprives other plants living below them of essential sunlight. Another undesirable effect is that lower oxygen concentrations appear when bacteria consume oxygen to break down the masses of organic material that result from dead, sinking phytoplankton and animal wastes. Most of this matter accumulates on the seafloor, where oxygen is relatively scarce to begin with, thus the area becomes extremely susceptible and prone to the formation of a dead zone especially if the area is like Hood Canal and has poor circulation.

Poor circulation and high nutrients, two things essential to eutrophication, has led to the development the hypoxia in Hood Canal. Many scientists and ocean researchers think that human activities have negatively impacted the area through eutrophication. In Hood Canal, the blooms occur in the spring to summer months, and by the end the large amounts of biomass produced fall to the

bottom of the Canal. This is how, in Hood Canal, excess nutrients leads to eutrophication which therefore leads to low oxygen in the bottom waters.



Dissolved Oxygen oxygen concentrations as our journey progressed. The lowest oxygen concentrations were found in the deep ocean stations(1-3) and in the midsurface layers in Hood Canal (Stations 8-18).

Just after the 2006 fish kill event, our team sampled for nutrient concentrations from the ocean waters that may enter Hood Canal and inside the basin. Our team journeyed from outside of Puget Sound and made our way through Hood Canal. By taking nutrient samples at regular intervals we saw that phosphate, silicate and nitrogen concentrations (which are the most important macronutrients for phytoplankton growth) were highest in Hood Canal. Typically, concentrations of these nutrients should be lowest at the surface and increase with depth because phytoplankton are constantly using most of the nutrients available in the sunlit layers. This was the case outside of Hood Canal. However, inside Hood Canal, the highest nutrient concentrations were at around 10-20 meters deep. Nutrient concentrations were higher at the southern portion of Hood Canal (furthest from the entrance) and lowest near the northern entrance. This suggests that there is a large input of nutrients from rivers and human sources. The fact that most of the nutrients are found closer to the surface implies that the water at that depth has recently been upwelled from the bottom.

Due to its sluggish circulation, Hood Canal has dense water kept at the bottom of the basin for longer periods, and because of the high amounts of nutrients, eutrophication may lead to greater oxygen depletion over time as the water continues to stay put. As it is finally moved out of the bottom layer, it can be mixed to become more oxygenated or phytoplankton can produce more oxygen in the water mass if it is in the sunlit zone, and then the new bottom water starts getting depleted. Upwelling of deep water does not appear to create low oxygen zones in Hood Canal even though deep waters are also depleted of oxygen. Our investigation showed that mixing over the sills tends to increase the oxygen level of new water coming into the basin above the levels seen in the oxygen

depleted zone in Hood Canal. Therefore, the process resulting in low oxygen zones in Hood Canal must be localized, and may be affected by human activities.

If it is in fact the case that Hood Canal residents and other humans are a large source of nutrients that are causing hypoxia in this region, there are many potential sources including fertilizer runoff into rivers, septic tank leaking and many other sources. The Washington State Sea Grant Program has a list of recommendations of what people living near Hood Canal can do to lessen their impact on this fragile ecosystem. They suggest checking septic systems and try to prevent fertilizers, pesticides, detergents, and other organic waste such as lawn clippings from entering streams, groundwater and other water sources. We don't know yet how large of an impact humans have on Hood Canal, but these efforts may help reduce the severity of the oxygen problems in Hood Canal. Other human-caused dead zones, such as in the Black Sea, have been revived through local actions so there is still hope for our revered and adored supermodel.

Vocab:

- ***fjord:*** a long, narrow arm of the sea bordered by steep cliffs: usually formed by glacial erosion.
- ***eutrophication***: characterized by an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes the waters of oxygen
- ***Coriolis force***: the apparent deflection (Coriolis acceleration) of a body in motion with respect to the earth, as seen by an observer on the earth, attributed to a fictitious force (Coriolis force) but actually caused by the rotation of the earth and appearing as a deflection to the right in the Northern Hemisphere and a deflection to the left in the Southern Hemisphere.
- ***hypoxia***: lack of oxygen in an environment
- ***upwelling***: The vertical movement of water from depth to the surface.

For more information try these as a start!

"The Dissolved Oxygen Issue." Hood Canal Dissolved Oxygen Program. http://www.hoodcanal.washington.edu/aboutHC/brochure.html

Newton, J. et al. "How To Create Sustainable Futures." http://www.uwei.washington.edu/hoodcanal_qa.pdf