

The State of the Sound: Oxygen, Phytoplankton, and Zooplankton

A few months ago, residents of Hood Canal were dismayed to find scores of dead fish washing up on their beaches. The kill, which occurred on September 19, 2006, suffocated over 30 species of fish and crabs, with carnage estimated to be even greater than widespread kills that occurred in the area in 2003. Robert McLure of the Seattle Post-Intelligencer reported that the event started with dead shrimp, Dungeness crab, lingcod, flounder, sand lance and other fish (Seattle P-I, September 20, 2006). The kill stretched for about six miles at the southernmost tip of Hood Canal.

"What we don't know is why it happened so quickly," said Brad Ack, director of the Puget Sound Action Team told McClure in September. "It focuses our attention again that we have a serious problem in Hood Canal, and just because the last couple of years haven't seen these kinds of fish kills doesn't mean that the problems have gone away."

To residents today, the canal appears to have returned to normal. But scientists have traced the levels of dissolved oxygen in the water since the kill and have found little change. Now they are trying to answer the question: will Hood Canal be able to recover on its own? What, if anything, should be done to help it? What are the implications for residents of the area and the fish and other organisms in the canal?

A study by a group of undergraduate students from the University of Washington conducted shortly after the fish kill attempted to answer some of these questions. The study focused on the microorganisms and the amount of dissolved oxygen in the canal during what should be a recovery phase for the area.

Dissolved Oxygen Content

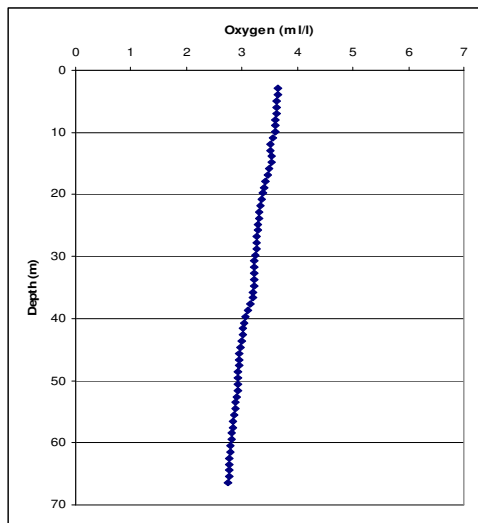
Hood canal is an area with sluggish water because it is obstructed by the shallow-water sill at the mouth of the canal. This aids in the entrapment of low oxygen water within Hood Canal.

Scientists have suggested the cause of the kill may have been deep water that was upwelled on the Washington coast. This incoming ocean water is denser than the resident oxygen-depleted bottom water of Hood Canal, so it sinks, wedging itself beneath the bottom water, which is pushed up toward the surface.

For the oxygen-dependent marine organisms living in the water column, this upwelling means they have a smaller volume of oxygen-rich water to live in. With the same number of organisms now living in a smaller volume, the oxygen is depleted even more. Eventually, there is not enough oxygen to support the larger animals and they suffocate, resulting in a fish kill.

Even a month after the fish kill, the water in Hood Canal was still quite low in oxygen compared to the open ocean and in the Strait of Juan de Fuca. Hood Canal's water had so little dissolved oxygen, in fact, that even the highest concentrations of oxygen found in the canal were lower than the lowest values at the ocean stations.

When compiling a profile of oxygen content from the surface to the bottom of the ocean, there should be a layer of water near the surface with a high oxygen content—this is where fish, smaller organisms like zooplankton, and microorganisms like phytoplankton live. Hood Canal's



Example of a dissolved oxygen profile from northern Hood Canal

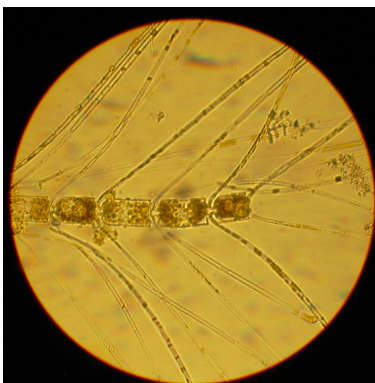
oxygen profiles showed no such layer.

Instead, the profiles from the northernmost part of Hood Canal show a straight line from the surface to the bottom, with little differentiation, indicating that the oxygen content of the water is the same from the surface to the bottom. These stations were located along the sill at the entrance to Hood Canal, so it is actually not surprising that they were very well-mixed. Extending further south in

Hood Canal, the range of oxygen concentration continued to drop. At the southernmost part of Hood Canal, where the fish kills have typically occurred, there was a slight oxygen maximum at the surface, but there was a sharp and distinct oxygen minimum, depleted almost to anoxia. In general, these southernmost stations displayed oxygen profiles that might have been expected in very deep water which has been stagnant for quite some time, but here it lay at the surface. This layer of severely oxygen-deprived water is probably a remnant of the severe hypoxia observed in September and what most likely caused the fish kills that occurred simultaneously.

Phytoplankton

Dissolved oxygen and phytoplankton are two of the best indicators for the health of water. Like plants found on land and algae residing in lakes and ponds, energy needed to sustain phytoplankton growth and foster reproduction comes from photosynthesis. The success of photosynthesis is proportional to the available sunlight and nutrients in the water column. Phytoplankton, the base of any oceanic or estuarine food web, maintain large numbers to allow their survival in the face of continuous predation from zooplankton.



Chaetoceros sp.

In the month immediately following the fish kills, there was one species of phytoplankton that was not simply surviving in the anoxic water—it was thriving. *Chaetoceros concavicornis* was so plentiful, in fact, that it was clogging scientists' sample collection nets.

The presence of the bloom would indicate that low oxygen have no detrimental effect on phytoplankton as a whole. This is, perhaps, intuitive as photosynthesis uses carbon dioxide and *produces* oxygen. Therefore, it is typical to find elevated levels of oxygen in depths where larger concentrations of phytoplankton are found. However, this does not necessarily mean that phytoplankton are absent in areas of low dissolved

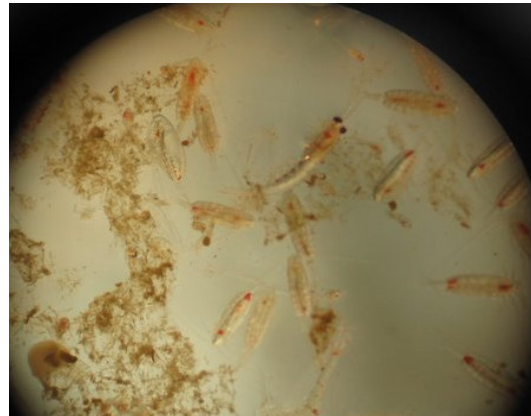
oxygen. When small phytoplankton populations are encountered within regions of low dissolved oxygen, it may be attributed to elevated water turbidity restricting light penetration or limitations on available nutrients. The dissolved oxygen content of an area of water, then, is the net result of the production of oxygen by photosynthesizers (phytoplankton and some bacteria), minus the oxygen used by other organisms during respiration.

The fall phytoplankton bloom in Hood Canal is a regular event that occurs sometime between September and November. The weak intensity of tidal mixing and estuarine circulation contribute to strong stratification in the upper layer of the water column. A local wind event or energetic tide exchange can disrupt the stratification of the water and bring up nutrients from lower in the water column. With the onset of winter the phytoplankton growth rate should decrease due to lower solar radiation and losses due to estuarine outflow, mixing and grazing.

Zooplankton

Although the fish kills took place in Hood Canal, there remains an abundance of zooplankton. As smaller organisms, with lower oxygen needs and higher surface area-to-volume ratios, they are less sensitive to the low-oxygen waters.

Copepods are the biggest source of protein in all the Earth's oceans even though they rarely grow bigger than about 2 mm. They live in nearly every body of water, including small freshwater ponds and streams. They belong to the subphylum Crustacea

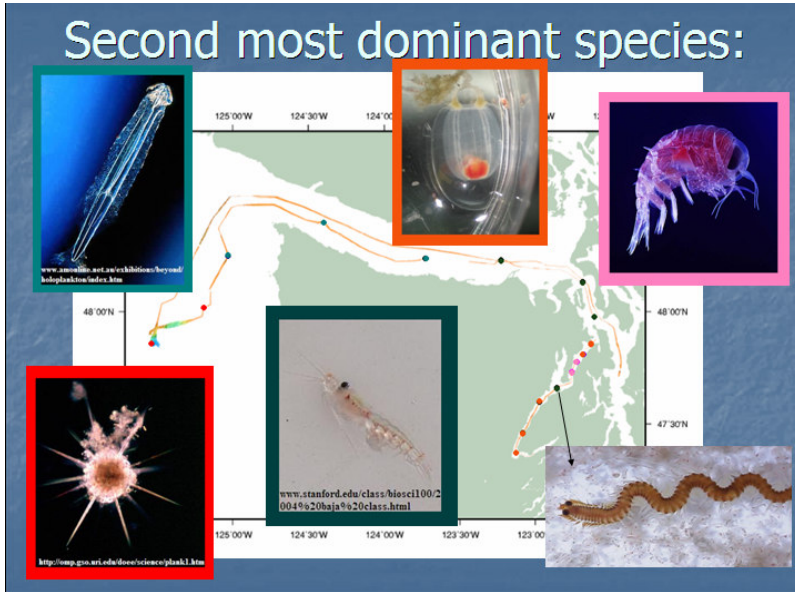


*Above, copepods and a euphausiid
Below, a copepod, which is the most common type of zooplankton in Puget Sound.*



making them cousins to crabs and lobsters. Copepods feast on a diet mainly consisting of diatoms and are in turn eaten by larger drifters, larval fish, and filter feeders, such as barnacles. This cycle makes them one of the most important species in the food chain.

We found the most abundant number of copepods in the open ocean. In general, areas further into Puget Sound had fewer copepods. We do not know the role of dissolved oxygen in this



phenomenon, but it is not surprising that more copepods were found in the areas (open ocean) where their main food source, phytoplankton, was also abundant.

As shown below, the first two stations had an abundance of radiolarians, which are tiny protozoans. Radiolarian abundance is

related to variables such as temperature, salinity, water quality, and available nutrients. Perhaps the differences between the Strait, Hood Canal, and the open ocean are keeping them fairly concentrated in the open ocean.

Chaetognatha, also known as arrow worms, are in a class of their own. They are able to ambush large numbers of copepods and swallow them whole. Arrow worms are most common in the Strait of Juan de Fuca, though there are fewer copepods there.

The northern part of Hood Canal, showed an large number of Euphausiids, commonly known as krill. Krill is a preferable food to baleen whales and salmon. They are crustaceans and related to shrimp and copepods.

Conclusion

So is Hood Canal recovering? The simple answer is no. Though there was little data from before or during the fish kill, making any correlation difficult, the most telling sign now of the canal's health is the level of dissolved oxygen, which has remained treacherously low.

There seems to be no clear link between the abundance of phytoplankton and zooplankton and the fish kills. This may be because phytoplankton and zooplankton are the organisms least affected by the low concentrations of dissolved oxygen.

Most of the dissolved oxygen comes from the atmosphere and once it is dissolved, it is moved throughout the water column by currents and water mixing. Since the waters are so sluggish at Hood Canal and the main area of mixing is at the sill, the dispersal of dissolved oxygen is very constrained. Due to all of these factors, it may take a long time for the canal to show higher dissolved oxygen concentrations.