PISCO
Partnership for Interdisciplinary
Studies of Coastal Oceans

Science of Hypoxia

How is the Pacific Northwest dead zone formed?

Every summer off Oregon and Washington, northerly winds and the earth's rotation combine to drive surface waters offshore and bring naturally nutrient-rich but oxygen-poor waters to the coast (see Figure A). When this water upwells to the ocean surface, microscopic plants called 'phytoplankton' bloom and contribute to Oregon's and Washington's productive ocean ecosystem. Those phytoplankton can also sink toward the sea floor where microbes decompose them, further consuming oxygen from the water column. The upwelling process can thus lead to lower levels of oxygen near the sea floor and extend up to 2/3rds of the water column; hypoxia does not usually affect the sea surface. Oxygen can also stay high right near the shore and at the ocean surface, where breaking waves efficiently mix oxygen into the water.

If coastal winds become southerly (downwelling-favorable), the earth's rotation causes surface waters to move back toward the shore, driving bottom waters away from the coast – a process called downwelling (Figure B). If upwelling periods alternate with periods of sufficiently strong downwelling, low-oxygen waters do not accumulate at the bottom along the coast.

If, however, downwelling-favorable winds do not blow, then low-oxygen waters can accumulate. When that happens, each successive strong upwelling brings the low-oxygen waters closer to shore. Upwelling also brings nutrients to the lighted zone. This causes phytoplankton blooms that eventually sink and decay, resulting in even lower levels of oxygen. Repetitions of these events cause the mass of low-oxygen water near the sea floor to become thicker as well as lower in oxygen. Changes in the strength and pattern of upwelling winds and the oxygen and nutrient content of the offshore waters that feed the coastal ecosystem can thus impact the likelihood and severity of hypoxia events.

The normal upwelling period runs from about April to September. October to March is generally dominated by downwelling-favorable coastal winds. Even during years in which hypoxia develops in the summertime, high-oxygen conditions have reappeared in October, with the beginning of downwelling that pushes low-oxygen waters away from the coast.

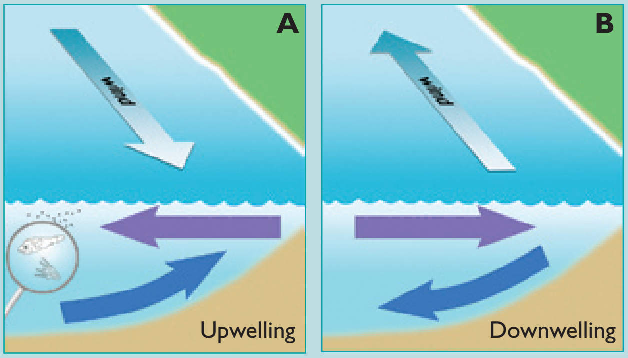


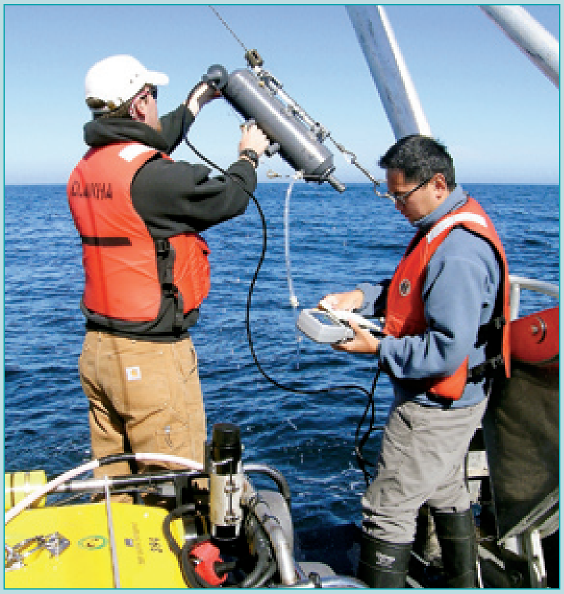
Figure A. Along the Oregon coast, northerly winds often cause the surface water to flow offshore. This water is replaced with deep, cold, nutrient rich, but oxygen-poor water in a process termed "upwelling".

Figure B. When coastal winds become southerly, surface waters move back toward the shore.

The geographic extent of hypoxia in 2006 and 2007. Light blue shows the extent of hypoxia (<1.4 ml/l) and purple shows the region of severe hypoxia (<0.5 ml/l). Waters closest to the shore remain high in oxygen due to breaking waves. Dots represent sampling sites. *Data made available by PISCO and NOAA-Fisheries, NWFSC.*

What are the long-term consequences of a dead zone and is the ecosystem recovering from dead zones?

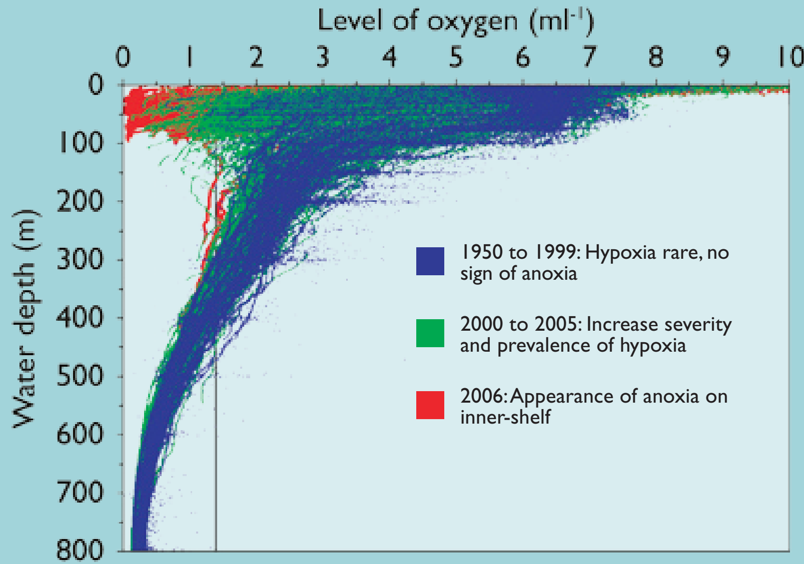
Observations from a remotely operated vehicle (ROV) by PISCO and ODFW researchers have revealed the immediate loss of many species of bottom dwelling marine organisms when oxygen declines to hypoxic and anoxic levels. Marine animals are either suffocated by the lack of oxygen or are forced to move up into the water column or very close to the shore to find higher oxygen environments. When dead zones have been short-lived or moderate in their severity, the risk of marine life mortality events has been low. In 2006, the dead zone lasted 4 months and large areas of the coastal ocean were affected by oxygen levels that dropped as low as zero. ROV surveys revealed mass die-offs of many marine invertebrates that inhabit near-shore reefs in the core anoxia region. Because dead zones are a new disturbance, the long term consequences are difficult to predict. PISCO and ODFW scientists are actively tracking the potential for recovery among animal communities hardest hit by the severe 2006 dead zone. Initial observations indicate that some mobile species such as rockfishes have returned to rocky reef habits. In contrast, a number of bottom dwelling animals such as sea cucumbers and some seastar species continue to be missing from the system altogether.



PISCO scientists measuring oxygen content in seawater from a sampling bottle that has been lowered to a precise depth. The ROV operated by ODFW appears in the lower left corner.
Photo: Jane Lubchenco

Have there been dead zones off the Pacific Northwest coast before?

Prior to 2002, dead zone events had not been reported in the near-shore waters off the Oregon and Washington coasts. It is important to note that low-oxygen water is a normal feature in deep, offshore waters. Fishermen and scientists both know that this low-oxygen water can be present in the summertime on the outer portions of the continental shelf and slope. What is different in the last several years is the presence of low-oxygen water in the inner shelf (less than 50 m (165') of water). An analysis of historical oxygen data from 1950 to 2006 shows that conditions off the Oregon coast have changed significantly since 2000.



The figure shows oxygen levels as they change with the depth of water, from the ocean's surface (top of graph) down to depth (where low-oxygen is normal). Oxygen levels below 1.4 ml/l are hypoxic, too low to support most life.
Data: Chan, et al, 2008. Emergence of Anoxia in the CA current large marine ecosystem. Science, vol 319.

This summary was prepared by PISCO at Oregon State University. PISCO (Partnership for Interdisplinary Studies of Coastal Oceans) is a research & outreach collaboration of universities along the west coast.
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or visit http://www.piscoweb.org/outreach/topics/hypoxia.

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