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Oxygen Minimum Zones near the BC Coast

Christina Schallenberg, MSc Oceanography, Dalhousie University. Current PhD student at the University of Victoria, School of Earth and Ocean Sciences. Commissioned by the Institute for Climate Solutions (PICS).

Issue

The supply of oxygen to the ocean and its distribution comprise a finely tuned system that is threatened by climate change. Warming of the surface layer of the ocean may place a “cap” on deeper waters that prevents exchange with atmospheric gases, leaving the deeper ocean deficient in oxygen.

Most marine animals need oxygen to live, so a decrease in the oxygen concentrations of seawater endangers species and their habitats. While fish may be able to move into areas of higher oxygen, they may find these to be too crowded, filled with predators, at the wrong temperature, or short in food supply. Bottom dwellers and sessile animals have an even harder lot as they cannot get away and simply suffocate when oxygen levels fall below a certain threshold.

Like acidification of the sea, the loss of oxygen from subsurface waters represents an underappreciated impact of anthropogenic global warming.

Background

The ocean is a strongly stratified system in which multiple layers of water lie on top of each other. There is only limited mixing between these layers while lateral transport through them is much more prevalent. The surface ocean is the only layer that receives oxygen from the atmosphere, and it is also the only place where tiny plants, called phytoplankton, can grow and produce oxygen. So mixing, sinking of water away from the surface, and transport along layers that reach the surface at some point are the only means by which oxygen is supplied to the deeper layers of the sea.

Meanwhile, fish and other animals use the oxygen in the ocean interior. But the biggest oxygen consumers are bacteria that devour dead organic material. They are especially active underneath the sunlit surface layer of the ocean, where the phytoplankton grow. When the plankton die, they sink, and most of them are decomposed by bacteria long before they reach the ocean floor. Also, organisms that eat phytoplankton produce fecal pellets that sink and fuel bacterial growth on their journey downwards. As a result, oxygen concentrations are usually lowest below the surface layer of the ocean, where lots of organic material is produced. In fact, the more organic material “rains down”, the lower the oxygen level.

In extreme cases, this can lead to dead zones such as the one in the Gulf of Mexico, which results from nutrients delivered to the Gulf by the Mississippi River. The nutrients fuel phytoplankton growth, which in turn enhances the export of organic material into deeper waters, where bacteria use up oxygen as they decompose the detritus. Scientists speak of “oxygen minimum zones” or “hypoxia” when oxygen levels fall below a certain threshold, but marine organisms may be adversely affected even when oxygen is still above that threshold.[i] Mapping out areas of hypoxia may underestimate the true impact of low oxygen levels.

North Pacific

Even without any discernable human impact, the North Pacific has been known to host the world’s largest oxygen minimum zone. Simply put, the deeper waters of this ocean are cut off from the atmosphere more efficiently than is the case for most other oceans. A “lid” of relatively fresh – i.e. less salty – water rests on top of the cold and saltier—thus, denser—deep water, preventing it from renewing its oxygen supply from the atmosphere. But there is still some exchange going on, otherwise the deep ocean would be devoid of oxygen. With warming temperatures due to climate change, though, the density of the surface layer further decreases. This intensifies the lid effect, making it even more difficult for the deeper layers to renew their oxygen.

Indeed, researchers have been observing declining oxygen levels in the interior of the eastern North Pacific while surface temperature has been rising.[ii] It now appears evident that this trend is at least in part a result of the warming climate, though some long-term natural influences may also play a role. Over the 50 years of observation, the average boundary where hypoxia begins has shoaled from 400 to 300 metres. This corresponds to a loss of 22% of the oxygen from waters between 100 and 400 metres depth.[ii]

Impacts

Such a decrease not only affects open ocean species, but it may also have an impact on organisms living on the shelf. Along-shore wind can cause ocean currents to bring water from depth closer to the surface in a process called “upwelling”. Along the BC coast, such upwelling onto the shelf occurs frequently and draws up water from as deep as 250 metres and more, i.e. from a depth where oxygen levels have been declining. In addition, climate change is likely to favour the winds that cause upwelling. As a result, researchers expect that ecosystems on the shelf will lose oxygenated habitat.[ii]

Indeed, disturbing changes have already been observed. In 2002, researchers detected severe hypoxia on the Oregon shelf, which caused unprecedented fish and crab die-offs.[iii] The low oxygen levels were the result of strong upwelling and a southward relocation of the North Pacific oxygen minimum zone.[iii]

In British Columbia, the groundfish fishery alone is worth around 300 million dollars per year.[iv] Landings of wild salmon weigh in at 150 million, and the crab and prawn fishery are worth more than 40 million dollars each.[iv] There’s only limited information on the low oxygen tolerance of individual species, but shellfish in particular have been found to be vulnerable even at oxygen levels well above hypoxia.[i] Groundfish are at risk because the deepest water layers on the shelf will likely be the first to experience hypoxia.

Conclusions

- Declining oxygen levels in the ocean interior are yet another grim consequence of global climate change.
- As temperatures continue to rise, further oxygen declines seem inevitable.[v]
- The factors causing near-shore hypoxia now, such as increased upwelling on the Oregon shelf in 2002, may be amplified in the future by continued global warming.[v]
- Nutrient input from land further exacerbates the situation in coastal waters, as it fuels phytoplankton growth and decay, the latter of which consumes oxygen.
- Valuable BC fisheries may be at risk.
- More research is needed to better predict the impact that declining oxygen levels will have on marine species and ecosystems, both near-shore and in the open ocean.

References

[i] Raquel Vaquer-Sunyer and Carlos M. Duarte (2008). Thresholds of hypoxia for marine biodiversity. PNAS 105(40): 15452-7. Online at:

http://www.pnas.org/content/105/40/15452.full

[ii] Frank A. Whitney, Howard J. Freeland and Marie Robert (2007). Persistently declining oxygen levels in the interior waters of the eastern subarctic Pacific. Progress in Oceanography 75: 179-99.

[iii] Brian A. Grantham, Francis Chan et al. (2004). Upwelling-driven nearshore hypoxia signals ecosystem and oceanographic changes in the northeast Pacific. Nature 429: 749-54.

[iv] http://www.env.gov.bc.ca/omfd/fishstats/graphs-tables/index.html

[v] Ralph F. Keeling, Arne Körtzinger and Nicolas Gruber (2010). Ocean Deoxygenation in a Warming World. Annual Review of Marine Science 2 (2010): 199-229.