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Low Oxygen Levels Could Temporarily Blind Marine Invertebrates

First study to demonstrate vision in marine invertebrates is highly sensitive to the amount of oxygen in water

Scientists at Scripps Institution of Oceanography at the University of California San Diego have found that low oxygen levels in seawater could blind some marine invertebrates.

These results, published recently in the Journal of Experimental Biology, are the first demonstration that vision in marine invertebrates is highly sensitive to the amount of available oxygen in the water.

Oxygen levels in the ocean are changing globally from natural and human-induced processes. Many marine invertebrates depend on vision to find food, shelter, and avoid predators, particularly in their early life stages when many are planktonic. This is especially true for crustaceans and cephalopods, which are common prey items for other animals and whose larvae are highly migratory in the water column.

Research on terrestrial animals has shown that low oxygen levels can affect vision. In fact, humans can lose visual function in low oxygen conditions. Pilots flying at high altitude, for instance, have been shown to experience vision impairment if aircraft fail to supplement cockpits with additional oxygen. Additionally, health problems such as high blood pressure and strokes, both associated with oxygen loss, can damage vision.

“With all of this knowledge about oxygen affecting vision in land animals, I wondered if marine animals would react in a similar manner,” said Lillian McCormick, lead author of the National Science Foundation-funded study and PhD student at Scripps Oceanography.

Her results shocked her. Studying four local California marine invertebrates – market squid, two-spot octopus, tuna crab, and a brachyuran crab – she found that vision was reduced by 60-100 percent under low-oxygen conditions.

Using larvae collected in the waters off Scripps, McCormick tested the acute response – the short-term reaction to exposure to reduced oxygen – in the vision of the larvae. She worked with Nicholas Oesch, a researcher at the UC San Diego Department of Psychology, to develop a setup for such small specimens.

“Most of the work in the lab is geared towards addressing biomedical questions in mammalian vision,” said Oesch. “So it has been fun to step out to less traditional model systems and apply our techniques to a completely different field.”

Placed on a microscope stage with flowing seawater of gradually reduced oxygen levels, the larvae were exposed to light conditions that McCormick could use to elicit visual responses. She measured these responses using electrodes connected to the retina of the larvae. This technique is called an electroretinogram.

“Imagine the device as an EKG machine for the eye,” said McCormick. “Instead of measuring electrical activity in the heart, we’re looking at the part of the eye called the retina.”

As soon as the oxygen availability began decreasing from well-oxygenated levels, such as are found at the surface of the ocean, McCormick saw an immediate response from the larvae. This was especially true in the brachyuran crab and squid, which lost almost all of their vision at the lowest oxygen conditions tested, about 20 percent of surface oxygen levels. Octopuses held out longer, with retinal responses only declining after oxygen was reduced to a certain level, while the tuna crabs were quite resilient. Adult tuna crabs are known to tolerate low-oxygen waters.

“I was surprised to see that even within a few minutes of being exposed to low oxygen, some of these species became practically blind,” said McCormick.

Fortunately, when oxygen levels were restored, most of the specimens recovered some visual function, indicating that the damage may not be permanent for short-term periods of low oxygen.

McCormick is interested in how this reduced vision could affect animal behavior, especially in those that experience the most dramatic vision loss. These animals rely on cues from light, and an inability to detect these cues could affect their survival. One example is migration. Larvae of these species migrate vertically, sinking to deeper depths during the day and ascending to the surface at night, and use changes in light intensity as their migration cue.

Additionally, the larvae rely on vision for finding prey and avoiding predators. Squid larvae hunt fast-swimming prey, like copepods, and their vision is crucial for this. The response speed of the retina in squid larvae was slowed during exposure to low oxygen, indicating that this visual impairment may inhibit the larvae's ability to detect copepods and feed. Losing the ability to react to changes in light intensity – such as a shadow of a predator – or visually see prey might decrease survival in these highly-visual larvae. Market squid in San Diego may be particularly susceptible because they lay their eggs in areas prone to low oxygen, like the seafloor near the canyon off La Jolla.

In the marine environment, oxygen levels change over daily, seasonal, and inter-annual time scales. There are also large fluctuations of oxygen with depth. However, these conditions are changing due to human-influenced climate change and even pollution. Atmospheric warming is changing temperatures in the ocean as well, which decreases the mixing of well-oxygenated surface waters to deeper waters. Additionally, nearshore environments are increasingly losing oxygen in a process called eutrophication, in which excessive nutrients in the water fuel a bloom of plankton that then deplete available oxygen dissolved in the water. This can lead to die offs of fish and other marine animals. Eutrophication is often the result of coastal pollution, like runoff from agriculture or sewage. Oxygen losses are especially pronounced in areas of naturally occurring low oxygen and upwelling, such as off the coast of California.

These results are based on acute responses, and McCormick is curious how long-term exposure to low oxygen could affect these animals in the wild. Her future work will test visual behaviors under different oxygen conditions, as well as compare the results from physiology and behavior studies to oxygen and light conditions in the ocean over time.

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