Lecture 20: Hypoxia & Dead Zones

Lecture 120: Hypoxia & Dead Zones

In the first five modules we have explored different disciplines and concepts in oceanography. Now it's time to put some of the disciplinary pieces of the puzzle together and see how they combine--or integrate--together to create important phenomena in the ocean. This lecture will explore a specific case where the physics, chemistry, biology and geology all play a part with wide-ranging consequences for climate, fisheries, agriculture, recreation etc. We will specifically focus on '***Hypoxia and Dead Zones***'.

Hypoxia and anoxia refer to very low levels of dissolved oxygen (hypoxia) or a lack of dissolved oxygen all together. Given that animals need oxygen for respiration, these conditions can lead to massive die offs of marine animals and disruptions of ecosystems. Hypoxic/anoxic events are caused by a variety of factors, but most common is by an input of excess nutrients in the water column (especially in coastal regions). High nutrient input, called eutrophication, leads to massive phytoplankton blooms that, once they die and decompose by microbial activity, lead to the depletion of oxygen. There are also areas of the oceans whereby low oxygen water from 'oxygen minimum zones' (OMZs) is brought to the surface and threatens fisheries. The photo below is a large sardine kill in Chile that resulted from anoxia – imagine how that smells!

Low or depleted oxygen in a water body leads to 'dead zones '— regions where life cannot be sustained. In some cases, vast stretches of open water become hypoxic. Hypoxic waters are those in which the dissolved oxygen levels drop below 2 mg/L, a level below which most animals can survive. Unable to sustain life, these areas, called dead zones, may cause die-offs of fish, shellfish, corals, and aquatic plants. Some of the more highly mobile species of fish may move out of hypoxic waters, however, the bottom dwelling benthos often cannot excape and die. Or if the dead zones are large enough, even the mobile nektonic species cannot escape. Since 1985, NOAA-sponsored research has monitored the largest dead zone in the United States, which forms every spring in the northern Gulf of Mexico. In 2019, it grew to cover more than 6,900 square miles of the sea floor.

[Watch this video now](https://youtu.be/ovl_XbgmCbw) (https://youtu.be/ovl_XbgmCbw)

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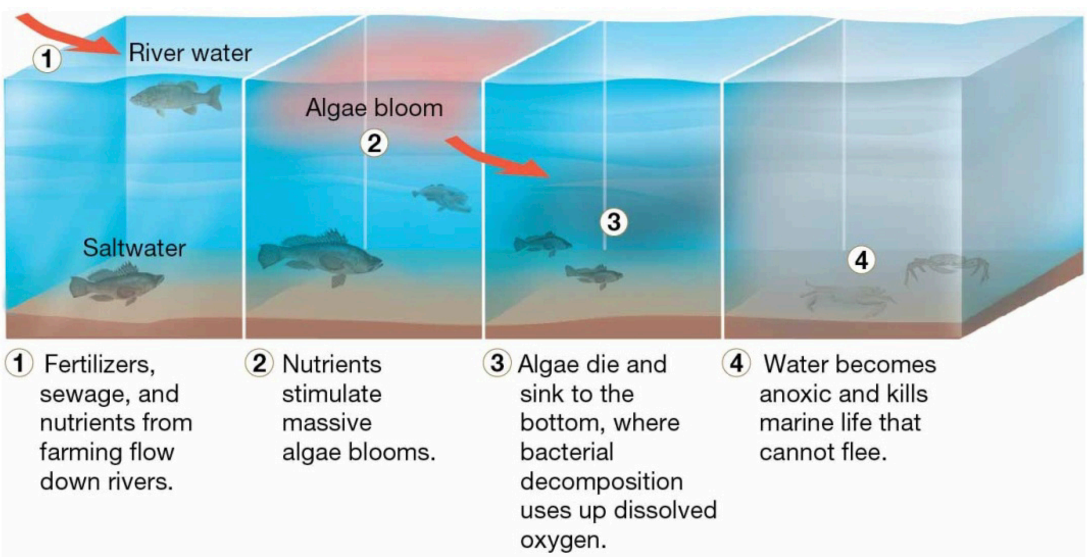
to review dead zones and learn about the hypoxic waters of the Gulf.

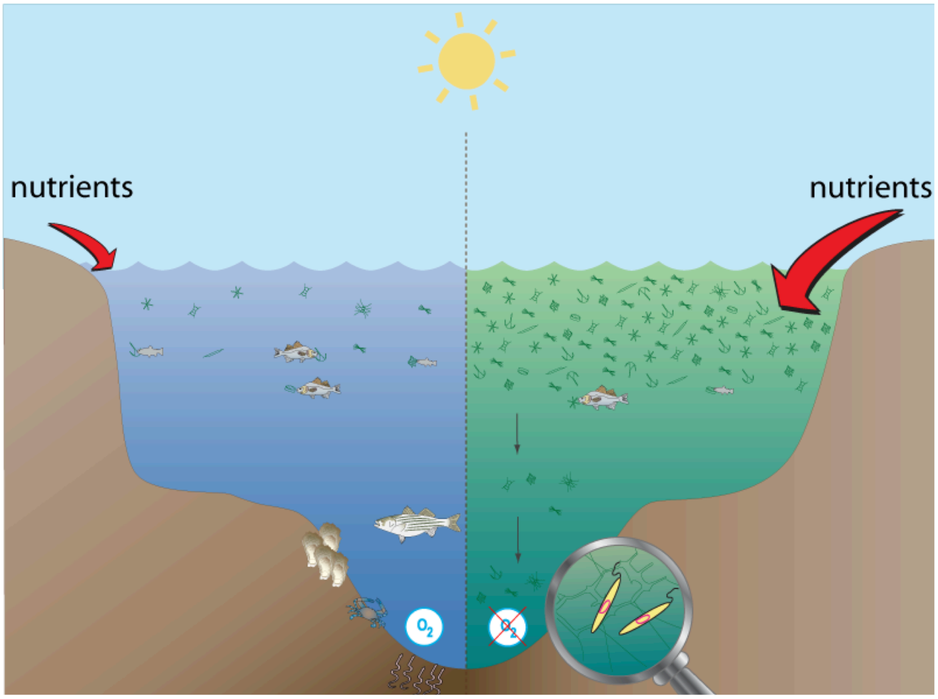
To recap – this concept of hypoxia and dead zones integrates a number of concepts that we have already learned about. Increases in runoff carrying high nutrient loads can cause massive blooms of algae, that then die and drop to the bottom of the ocean where the dead material is respired as bacteria and other things break it down. That respiration process uses oxygen, which creates zones of depleted oxygen (hypoxia). These zones of low oxygen can remain relatively stable in one place until surface currents and mixing occur that brings refreshed oxygen to the area.



Globally, the number of marine dead zones have doubled every decade from the 1960s to the 21st century. There are somewhere around 500 dead zones globally. **[Here is a link](https://www.wri.org/data/interactive-map-eutrophication-hypoxia) (https://www.wri.org/data/interactive-map-eutrophication-hypoxia)** to an awesome data visualization tool that let's you see where these areas are around the world. As you explore the data shown on that map, you should note a few things. First, these dead zones tend to be located in areas close to the coast. That makes sense because the source of nutrients that cause them are from terrestrial sources. Second, they are also centered around major urban centers where people live or grow food – again makes sense because that is the source of the nutrient pollution. If you were to zoom in around the world, you might note that the biggest dead zone is in the Baltic Sea. The second largest marine dead zone in the world forms annually off the mouth of the Mississippi River in the Gulf of Mexico. When looking at that global map, you might also note some of the areas noted in blue in this map. Those are areas that remain low in dissolved oxygen, but are improving due to efforts to control or reduce industrial or wastewater nutrient inputs.

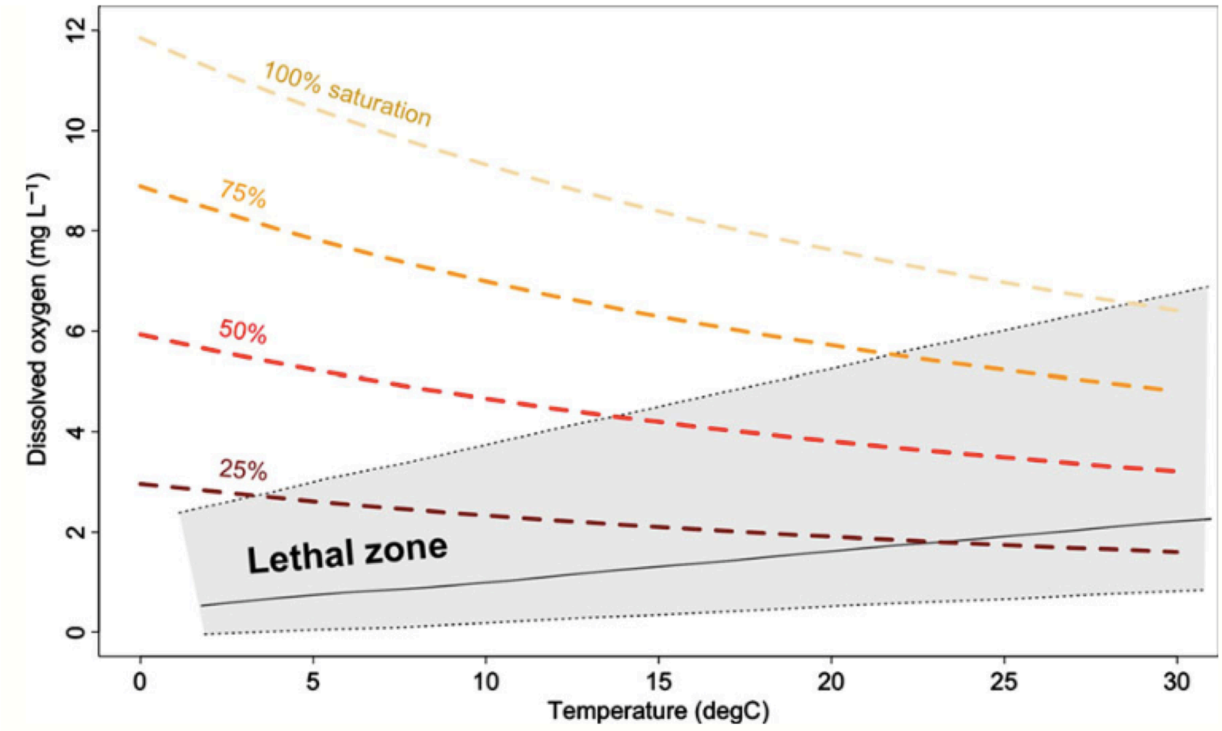
While the number of dead zones have increased since the 1960's, the severity and extent (size) have also increased. Some marine dead zones are only persistent for a short period of time, whereas others last a long

long time. As an example, the Black Sea in Europe is a relatively permanent dead zone. By contrast, areas of the Chesapeake Bay experience seasonal hypoxic conditions, but they don't last permanently. The nutrient inputs to the system are what drives the hypoxic conditions. In a normal coastal marine system that is balanced, there will be just enough nutrients to support an algae population that can be the base of the food chain (recall food chains and food webs from previous lectures). When there is a very large excess of nutrients, the system is sent out of balance and too much algae is produced and the consumers in the food chain/web are overwhelmed. This condition of excess nutrients is called eutrophication (note the right side of the image below).

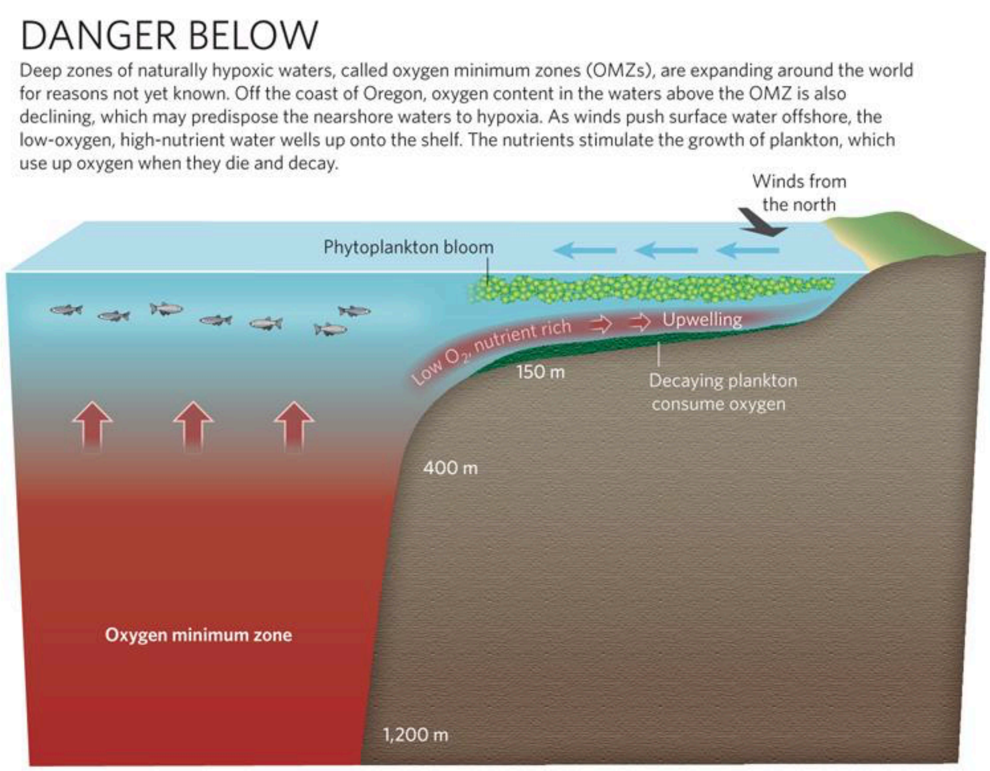


As noted above, there are many sources of these excess nutrients into marine systems and agriculture (farming) is the biggest among them. Agricultural fertilizers are high in nitrogen and phosphorous which are the major contributors to the nutrients causing hypoxia. Other sources of nutrients into coastal marine systems that cause hypoxia include sewage treatment plants, septic tanks, road runoff, golf course and lawn fertilizer runoff, and atmospheric nitrogen compounds from cars and factories.

When conditions of hypoxia are found, they are commonly associated with other environmental stressors. When more than one environmental stressor occur together, we call them multiple stressors. Temperature and low dissolved oxygen are one such example. In general, the impacts of hypoxia are made worse by the increase in global temperatures in the ocean (multiple stressors). However, as you already know from learning about the unique chemical and physical properties of water, warmer water is able to carry less oxygen (follow along the dotted lines in the figure below as an example of this). High temperature stress also makes organisms less able to handle the additional stress of low oxygen - you can see this by tracking the grey zone in the figure below. At low temperatures, dissolved oxygen below 2mg/L are bad, but as temperature increases, the levels of dissolved oxygen that are lethal are higher meaning the animals are less able to tolerate even less hypoxic conditions as temperature increases. This all means that high temperature and low dissolved oxygen tends to coincide and interact which makes this situation even worse for marine life.



Another physical ocean condition that causes low oxygen to occur in coastal areas can sometimes be upwelling. The deepest parts of the ocean are naturally low in dissolved oxygen (you have already learned why – there is more respiration and no light therefore no photosynthesis there nor contact with the atmosphere to replenish oxygen). We call these areas of the deep ocean, the oxygen minimum zones (OMZ). We are not sure exactly why, but those OMZs are expanding in the world's ocean. Now, the marine life that lives in the deep ocean are already adapted to the many challenges – including low dissolved oxygen – so you might ask why that is a problem. Well, what if these OMZ deep waters manage to make their way up to the coastal shallow zones? How might that happen? You know the answer to this one – upwelling! If you can't recall how upwelling occurs, look back at previous lectures to refresh your memory.



All is not lost – flip back to that cool data visualization of global dead zones. Focusing on the blue circles, there are ways that we can combat this issue. They include alternating timing of fertilizing on farms in watersheds, reducing overall fertilizer use, agricultural crop rotation, reducing impervious surfaces (these are things like roads and concrete that help water to go straight from land to ocean), improving the health and extent of marshes that help to strip those nutrients out of the runoff before it gets to the ocean, and enforcing clean-water regulations. There are others as well, and clever scientists of the futue like you will find even more. But one thing is abundantly clear – we must act to reduce ocean dead zones.