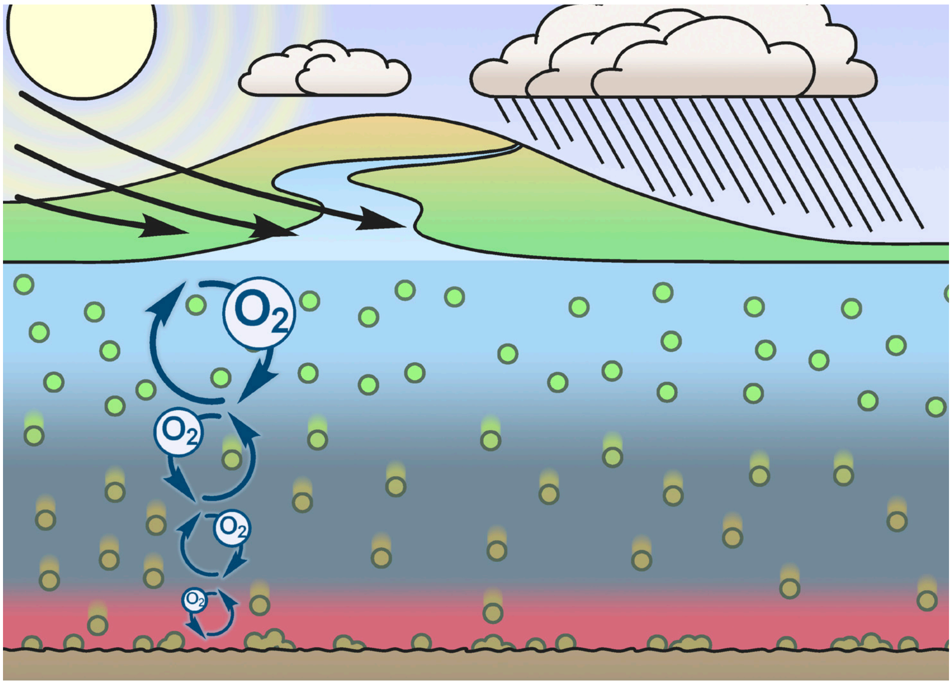
Plentiful in air but scarce in waters: oxygen depletion in aquatic systems

Oxygen is generated as a byproduct of photosynthesis and therefore directly connected to the productivity of photosynthesizing organisms. The cycle is closed if all photosynthesized matter is consumed and respired by animals and microorganisms. However, if nutrients or organic material are supplied in excess, oxygen demand can increase locally. Aquatic ecosystems can turn hypoxic (low in oxygen) as oxygen transport in waters is much slower as compared to the atmosphere. In order to understand causes and consequences of oxygen depletion the EU project HYPOX specifically focuses on areas that are prone to hypoxia.

Oxygen deserves attention: too little oxygen even more

Oxygen is on the decline in aquatic ecosystems worldwide and is expected to decrease further, mainly due to anthropogenic pressures. Oxygen depletion ('hypoxia') has substantial consequences for life, its biodiversity and hence ecosystem goods and services. The EU project 'HYPOX' (www.hypox.net) developed novel oxygen monitoring strategies to identify ecosystems at risk and to support decisions on effective countermeasures. This series of 'Hypoxia Briefs' provide information on hypoxia causes and consequences and findings from three years of intense hypoxia research in European waters.



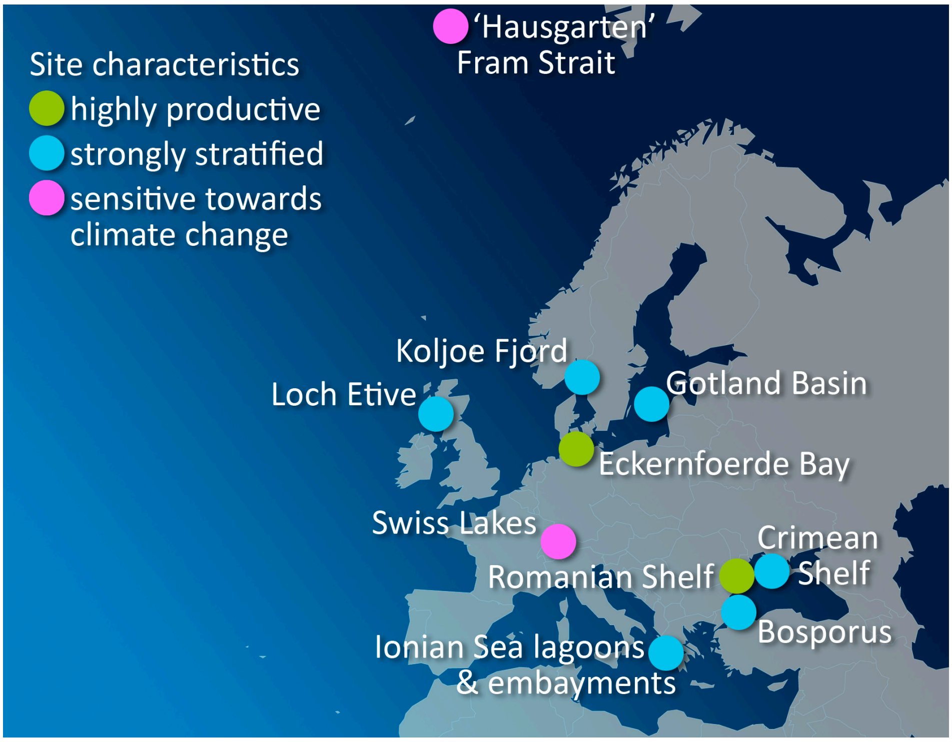
Oxygen needed for the decay of algae biomass at depth is mixed down by water movements created by winds and tides. Mixing intensity and oxygen availability diminish with depth, especially when solar radiation and freshwater input creates stratification. If high oxygen demand coincides with low supply by mixing, hypoxic conditions (pinkish zone) may occur (figure: Felix Janssen).

Oxygen always suffices – it's just not equally distributed

On Earth, the oxygen production by photosynthesizing organisms is almost equivalent to the oxygen respired by animals (including humans), microorganisms, and fungi. In aquatic systems, however, areas depleted in oxygen are rather common. This is because water bodies are characterized by low oxygen solubility, slow transport, and the restriction of oxygen production to the sunlit surface waters.

Grazing thousands of meters below the meadow

New production of oxygen in aquatic systems is restricted to the surface layer where sunlight allows for photosynthesis. In addition oxygen in surface waters is replenished from the atmosphere. Algal biomass produced by photosynthesis eventually sinks out of this layer and feeds organisms living in deeper waters or at the seafloor. But the maximum oxygen content of water is 20 to 40 times smaller as compared to air. In addition, transport of oxygen to depth is slow as mixing rates are several orders of magnitude lower than in the atmosphere. Oxygen availability in the interior of aquatic systems is hence a fragile balance between production, transport, and consumption of oxygen and organic matter.



Overview of the HYPOX target sites categorized according to main oxygen depletion characteristics. 'Sensitive towards climate change' signifies sites where oxygen availability at depth may reduce due to climate change impacts on deep circulation. (Figure: Sabine Luedeling, www.medieningenieure.de)

Triggers for hypoxic conditions

The project HYPOX focused on coastal systems and lakes where hypoxia is particularly common. Here, nutrient input from land can support high growth rates of microalgae. If this matter sinks to the seafloor a high oxygen demand is created. Bottom water hypoxia often occurs in summer, when high water temperatures and weak winds decrease oxygen solubility and mixing. In many cases density gradients additionally promote hypoxia development by reducing the downward mixing of oxygen. Warming of surface layers and freshwater input results in stratification and largely impedes oxygen transport to more dense waters below. In the deep Baltic as well as in fjords studied in HYPOX, oxygen at depth is replenished only during rare deep-water renewal events. Thorough investigations are needed to understand the complex processes that drive oxygen dynamics at the different sites. This knowledge is needed to predict future oxygen conditions and the impact of anthropogenic pressures and to decide on appropriate mitigation measures to prevent hypoxia.

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Further reading

Rabalais, N. N. et al. (2010) Dynamics and distribution of natural and human-caused hypoxia. Biogeosciences 7: 585-619 (www.biogeosciences.net/7/585)

Information on lake and river oxygenation by NSF project 'Water on the Web': www.waterontheweb.org/under/waterquality/oxygen.html

Information on hypoxia in the Gulf of Mexico: www.gulfhypoxia.net; http://serc.carleton.edu/microbelife/topics/deadzone/index.html; http://water.epa.gov/type/watersheds/named/msbasin/hypoxia101.cfm

Hypoxia science and status in the northwest Pacific by the PISCO program (including links to videos & images): www.piscoweb.org/research/science-by-discipline/coastal-oceanography/hypoxia

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