An ocean of possibilities: how to select the right oxygen monitoring strategy

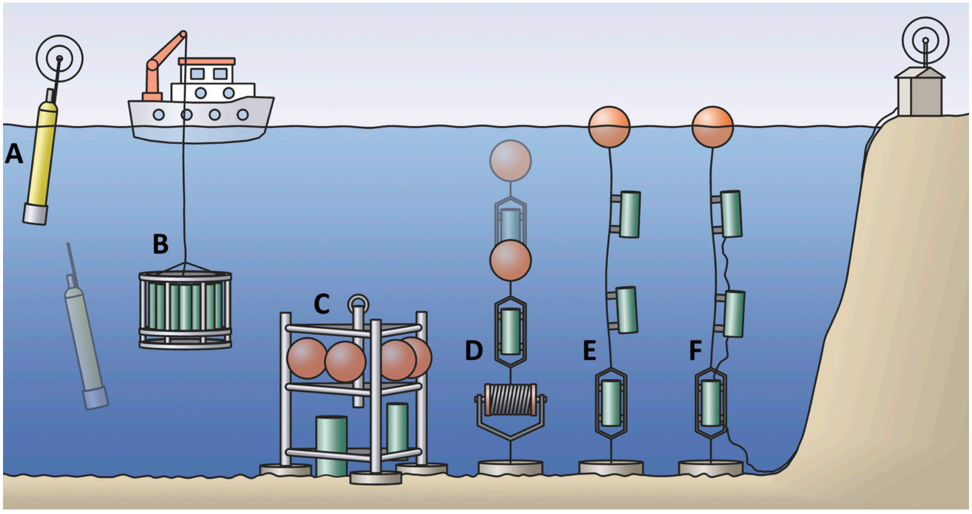
The classical oxygen monitoring approach with monthly to quarterly site visits is inappropriate to capture ecosystem status and trends. Instead, duration, frequency and spatial extent of hypoxia (low oxygen conditions) as well as hypoxia thresholds of key organisms and processes need to be considered. The project HYPOX addressed the relevant temporal and spatial scales by evaluating a variety of monitoring approaches targeted to contrasting ecosystems. In order to strengthen the contribution of oxygen monitoring to earth observation, HYPOX engaged in the Global Earth Observation System of Systems (GEOSS).

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.

EUROPEAN COMMISSION
European Research Area

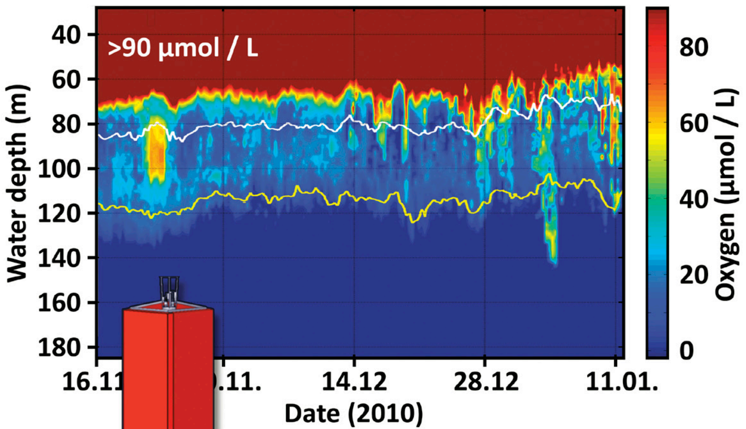
SEVENTH FRAMEWORK PROGRAMME

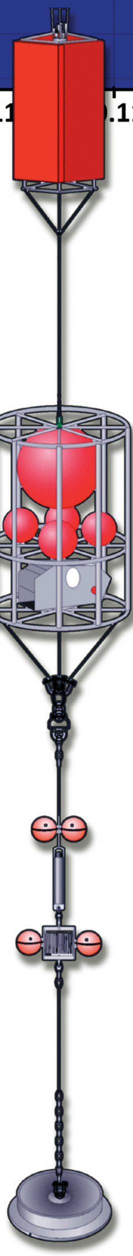


Schematics of the different oxygen observatory types used in HYPOX. (A) Argo float type drifting observatory, (B) ship-based towed or profiling instruments, (C) benthic observatories, (D) profiling moorings, (E) and (F) Stand-alone and cabled moorings (figure: Felix Janssen).

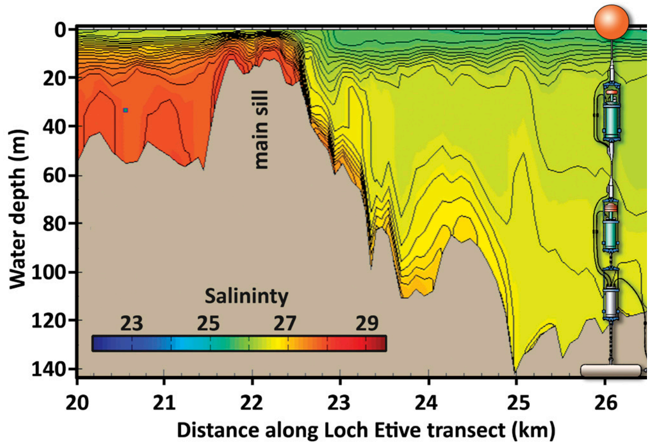
What to consider in hypoxia monitoring or: how low is 'low in oxygen'?

To understand life in low oxygen environments it helps to climb up high. On Mount Everest we only get 30% of the oxygen we're used to and conditions become detrimental for most of us. This threshold we share with many fish and crustaceans that start to die off at oxygen levels below 30% air saturation. Many bivalves or bottom dwelling worms, however, live happily at much lower concentrations. At oxygen levels as low as a few percent all higher aquatic life ceases. Remaining traces of oxygen still matter for microbial processes – with huge implications for large scale element cycling. Also temporal and spatial scales of oxygen depletion need to be considered as the ability to tolerate enduring and recurrent hypoxia or to escape into neighboring areas differs a lot between species. Long term monitoring is needed to assess ecosystem trends and to separate natural variability from effects of anthropogenic pressures and climate change. Hypoxia monitoring hence needs specific observatory instrumentation, and strategies have to be tailored to the ecosystems and processes in question.





Time series of oxygen profiles in the Gotland Basin chemocline and a sketch of the profiling mooring used for data acquisition (not to scale). The yellow and white line indicate typical chemocline densities (sigma 8.5 and 9.5). Data and sketch courtesy of Ralf Prien.



Modeled salinity distribution in the Scottish fjord Loch Etive during saltwater inflow events (graph courtesy of Dmitry Aleynik). The sketch shows the cabled observatory that monitors oxygen and inflow events (not to scale). The data are used to validate the model (mooring sketch courtesy of Henrik Stahl and AADI, Bergen, NO).

Advanced hypoxia monitoring in HYPOX

Oxygen monitoring in HYPOX mostly focused on continuous measurements with stand-alone or cabled observatories. The observed temporal variability was unexpected and is intriguing for ecosystem modeling. Strong oxygen dynamics were found in the Baltic Sea water column, one of earth's most stratified systems. In bottom waters of the Black Sea hypoxic conditions sometimes developed in a matter of hours exposing seafloor communities to severe oxygen stress. Continuous monitoring also captured rare episodic events. Cabled observatories in Swedish and Scottish fjords recorded occasions of inflow and mixing that replenished oxygen at depth. Measurements were fed into simulations to better understand fjord exchange processes. The spatial scales addressed in HYPOX ranged from meter size fine structures of hypoxic lake waters to the basin scale oxygen distribution in the Black Sea. Two profiling floats recorded as many as 260 oxygen profiles - equivalent to 8% of all deep Black Sea oxygen profiles collected since measurements started in 1923.

Turning monitoring data into information

Once data are collected they need to be made available and discoverable. To this end it is essential to comply with common standards and practices with respect to the measured parameters and to the data flow from the observatories to the data archives and, finally, to the users. In combination with modeling activities a substantial contribution can be made to the definition of the 'Good Environmental Status' within the Marine Strategic Framework Directive. In order to merge oxygen observations with other complementary earth observation data, links to large scale initiatives as OceanSites, GOOS, and GEOSS need to be established. In support of GEOSS, HYPOX provided hypoxia-related data, linked HYPOX observatories to GEOSS, and pioneered in the testing and definition of common standards and protocols for oxygen observation.

Further reading

Boetius, A. et al. (2010) Oxygen Monitoring In Aquatic Ecosystems – EU-Project HYPOX. Earthzine online publication (http://www.earthzine.org/?s=hypox)

Gruber, N. et al. (2007) The ARGO-Oxygen Program - A white paper to promote the addition of oxygen sensors to the international Argo float program. Argo Steering Committee, 60pp. (www.ioccp.org/Docs/o2_argo_whitepaper_15feb07_r.pdf)

Peña, M. A. et al. (2010) Modeling dissolved oxygen dynamics and hypoxia. Biogeosciences 7: 933-957 (www.biogeosciences.net/7/933)

Data portal EU-FP7 Project HYPOX: http://dataportals.pangaea.de/hypox/

International and European Argo float initiatives and data: http://www.argo.net, http://www.euro-argo.eu, http://www.coriolis.eu.org

Chesapeake Bay Environmental Observatory: http://cbeo.communitymodeling.org/index.php

Global Earth Observation System of Systems (GEOSS): http://www.earthobservations.org/geoss.shtml

Joint deepwater observatory initiative: http://www.oceansites.org

UNESCO / IOC Global Ocean Observing System http://www.ioc-goos.org

Contact

Antje Boetius (HYPOX coordinator), HGF-MPG Group for Deep Sea Ecology and Technology, Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany, Antje.Boetius@awi.de

Project: HYPOX, EU-FP7 #226213, www.hypox.net

Authors: Felix Janssen, Christoph Waldmann, Per Hall, Robert Huber, Antje Boetius

Layout: Sabine Lüdeling, www.medieningenieure.de