EU-project HYPOX: oxygen monitoring in aquatic ecosystems

A short introduction to project tasks and partners

Seventh Framework program
Contract number 226213

GROUP ON EARTH OBSERVATIONS

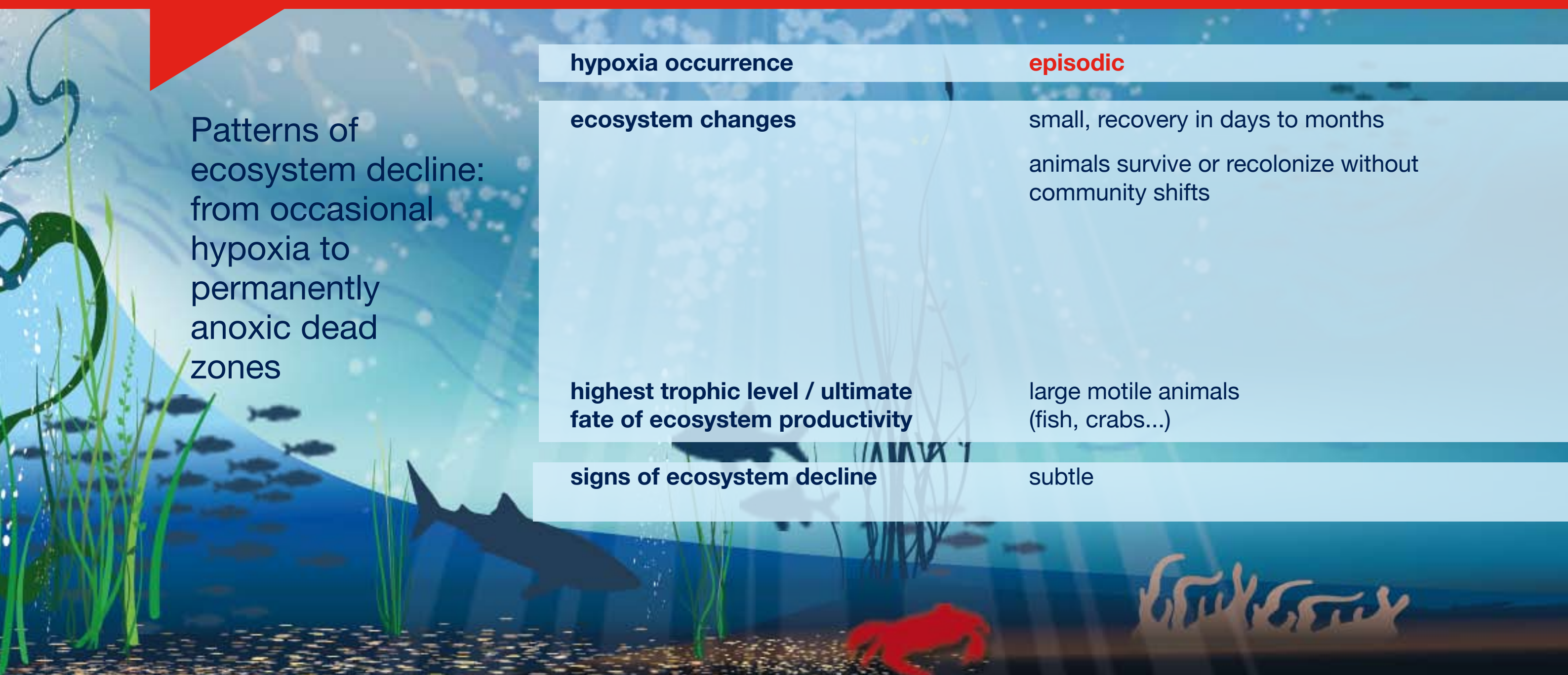
SEVENTH FRAMEWORK PROGRAMME

EUROPEAN COMMISSION
European Research Area

Aquatic systems short of breath: how come and why should we care?

Most aquatic life depends on oxygen. It is, thus, an alarming finding that the occurrence of hypoxic (low oxygen) conditions is increasing world-wide. This is mainly a consequence of anthropogenic eutrophication (nutrient input) and climate change. In eutrophied waters the excess algal biomass produced is typically not passed on along the food chain. Instead it sinks to the seafloor where it is utilized by micro-organisms consuming oxygen. If bottom water oxygen drops significantly, faunal communities and chemical conditions start to change. Ecosystems undergo successive deterioration, eventually turning into permanently anoxic environments where micro-organisms replace all higher life (see figure below). This collapse of animal communities leads to a dramatic decline in ecosystem functions and services such as biodiversity, fisheries, aquaculture and tourism. Since the 1960ies, the records of such "dead zones" doubled every ten years.

Hypoxic (low oxygen) conditions are increasing due to eutrophication and climate change. To better understand dynamics and drivers of oxygen depletion, the EU-funded project HYPOX is starting to build a global observation system for continuous oxygen monitoring. HYPOX further includes experimental and modeling studies on hypoxia drivers and consequences for ecosystems, to gain predictive and decision-making capabilities from the obtained monitoring data. All activities will be embedded into the framework of the Global Earth Observation System of Systems (GEOSS) which aims at integrating all earth related observations into a single source of data.



Patterns of ecosystem decline: from occasional hypoxia to permanently anoxic dead zones

hypoxia occurrence	episodic
ecosystem changes	small, recovery in days to months animals survive or recolonize without community shifts
highest trophic level / ultimate fate of ecosystem productivity	large motile animals (fish, crabs...)
signs of ecosystem decline	subtle

Climate change will add to oxygen depletion in several ways: warming of water will lead to degassing of oxygen, and an enhanced microbial oxygen demand. Together with changes in wind and precipitation patterns, higher temperatures will potentially increase stratification and reduce vertical oxygen transport to deeper waters and to the seafloor. Early stages of hypoxia are typically missed until obvious signs (e.g., fish mass mortality) show that dramatic changes did already occur.

To be alarmed before ecosystems lose functions that may take several decades to restore, oxygen monitoring capacities have to be improved.

Within the project HYPOX monitoring of oxygen and related parameters is carried out at several different sites to improve our understanding of hypoxia formation and potential effects of anthropogenic activities and climate change on future oxygen levels.

As ecosystem responses depend on frequency, duration, spatial extent and severity of hypoxia events, continuous monitoring of oxygen concentrations is needed. In order to understand the reasons of hypoxia formation and to be able to predict potential effects of anthropogenic activities and global warming on future oxygen levels, monitoring of oxygen and related parameters have to be carried out in a variety of aquatic systems that differ in oxygen status and sensitivity towards change. Experimental and modeling studies of hypoxia drivers as well as consequences of oxygen depletion for ecosystems are needed to gain predictive and decision-making capabilities from the monitoring data obtained.

Successive stages of ecosystem decline upon exposure to increasing levels of hypoxia. Note that strong shifts may go unnoticed if oxygen is not properly monitored and early hypoxia events are missed.

periodic	seasonal	persistent
moderate, recovery in months to years	severe, recovery takes years	severe, recovery needs decades
shift towards smaller animals, reduction in biodiversity	partial recolonization between hypoxic periods, severe biodiversity loss	no higher life left, endemic species extinct
restricted sediment reworking reduces denitrification and adds to eutrophication	additional eutrophication by phosphate released from reduced sediments	accumulation of reduced compounds in sediments impedes recovery. methane release adds to global warming and formation of new hypoxia events
large and small sessile animals (e.g., worms)	small animals and microbes	microbes and organic matter burial
nothing obvious („black spots“)	fish catches may start to decline	collapsing fish catches and mass mortality

Exceptions are the standard: selecting appropriate monitoring sites

Location and characteristics of observatories and target sites

Observatories in land-locked water bodies

Koljoe Fjord | Sweden

Rationale > effect of exchange and benthic activity on oxygen dynamics in a non-eutrophied fjord system | Task > deployment of benthic observatories in the fjord & adjacent waters | Leading institution > University of Gothenburg, SE (UGOT)

Loch Etive | Scotland, GB

Rationale > effect of bottom water renewal frequency and duration on climate-driven hypoxia in a Sea Loch with limited exchange | Task > deployment of two cabled benthic observatories with real time data transfer in the sea loch & adjacent waters | Leading institution > Scottish Association for Marine Science, GB (SAMS)

Lake Zurich, Lake Lugano & Lake Rotsee | Switzerland

Rationale > lake oxygenation affected by climate-driven changes of thermal stratification and wind forcing | Task > frequently monitor lake chemocline with improved probes that resolve oxygen at trace levels | Leading institution > Swiss Federal Institute of Aquatic Science and Technology, CH (Eawag)

Ionian Sea Lagoons & Embayments | Greece

Rationale > effect of gas seepage and hydrography on oxygen dynamics in Mediterranean fjord-like & coastal systems | Task > Areal surveys and long-term monitoring by towed and moored multiparametric modules | Leading institutions > University of Patras, GR (UPAT) and National Institute of Geophysics and Volcanology, IT (INGV)

Observatories in coastal and open seas

HAUSGARTEN deep sea observatory | Fram Strait

Rationale > potential decrease in bottom water oxygen as climate change affects deep water formation | Task > adding oxygen sensors to long-term moorings and benthic observatories | Leading institution > Alfred Wegener Institute for Polar and Marine Research, DE (AWI)

Gotland Basin | Baltic Sea

Rationale > dynamics and consequences of oscillations in mid water oxygen concentration, redoxcline position and benthic activity | Task > deployment of a stationary profiling observatory | Leading institutions > Institute for Baltic Sea Research, DE (IOW), Leibniz Institute of Marine Sciences at the University of Kiel, DE (IFM-GEOMAR), Gothenburg University, SE (UGOT)

Crimean shelf | Black Sea

Rationale > benthic processes under changing oxygen concentrations due to chemocline oscillations | Task > deployment of a benthic observatory | Leading institutions > Institute of Biology of the Southern Seas, UA (IBSS), Max Planck Institute for Marine Microbiology, DE (MPI)

North-western shelf off Romania | Black Sea

Rationale > shelf ecosystem recovery under decreasing anthropogenic nutrient supply and the effect of climate patterns on shelf hypoxia dynamics | Task > deployment of a benthic observatory | Leading institutions > National Institute of Marine Geology and Geo-ecology of Romania, RO (GeoEcoMar), Alfred Wegener Institute for Polar and Marine Research, DE (AWI)

Bosporus / Istanbul Strait area | Black Sea

Rationale > effect of lateral intrusions of oxic Mediterranean waters on anoxic Black Sea waters | Task > deployment of drifting profiling observatories | Leading institutions > Istanbul Technical University, Eastern Mediterranean Centre for Oceanography and Limnology, TR (ITU-EMCOL), French Research Institute for Exploitation of the Sea, FR (Ifremer), Max Planck Institute for Marine Microbiology, DE (MPI)

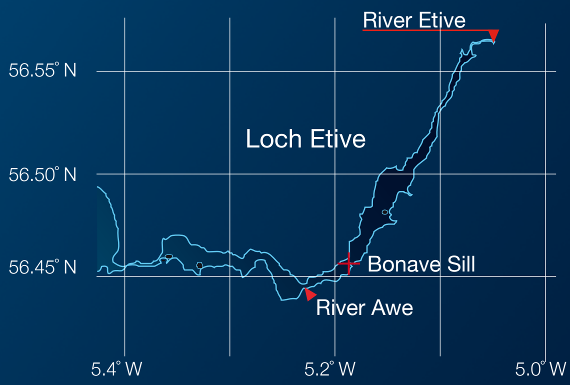
Oxygen availability at a given site depends on the balance between oxygen supply (mainly physical transport and mixing) and removal (mainly biological oxidation of organic matter) which both vary on different time scales. The response of an ecosystem to hypoxia is determined by even more factors (e.g., adaptation of organisms to hypoxia, availability of nearby fauna for re-colonization, sediment inventory of oxidized and reduced components). To cope with this complexity, monitoring efforts in HYPOX encompass sites that differ both in oxygen availability and sensitivity towards change: Open ocean, oxic areas with high sensitivity to global warming (Arctic Ocean) are included as well as semi-enclosed basins where oxygen is naturally depleted (Black Sea, Baltic Sea), and partly eutrophied landlocked systems that experience hypoxia seasonally or locally (fjords, lagoons, lakes).

The HYPOX approach: from local observations to general predictions

Continuous measurements of oxygen and associated parameters are an important first step to examine the status of the system that is monitored. In order to extend the gained knowledge, however, modeling efforts need to be made. Modeling is the key tool to turn observations into generalizations that can be applied also to other ecosystems and predictions that extend the current observations into the future. These generalizations and forecasting capabilities are essential to examine the effects of future climate and eutrophication scenarios for oxygen availability and ecosystem functioning. If ecosystems are deteriorating, modeling capabilities will also provide means to decide on adequate countermeasures to be taken. Being aware of these issues, the HYPOX strategy complements oxygen monitoring with modeling efforts. To fully comprehend oxygen dynamics, HYPOX modeling aims to combine physical transport and biogeochemical processes in both the sediment and the water column. The measurements produced by the observatories and during targeted field campaigns will be used to verify the models and, via data assimilation, to improve their predictive capabilities. Model exploration will be used to extract early warning indicators and tipping points in system behavior. Combining observations and predictions of oxygen availability with existing knowledge about the effects of hypoxia on animal communities and ecosystems will improve our understanding of the potential loss of ecosystem functions and services as a consequence of climate change and eutrophication.

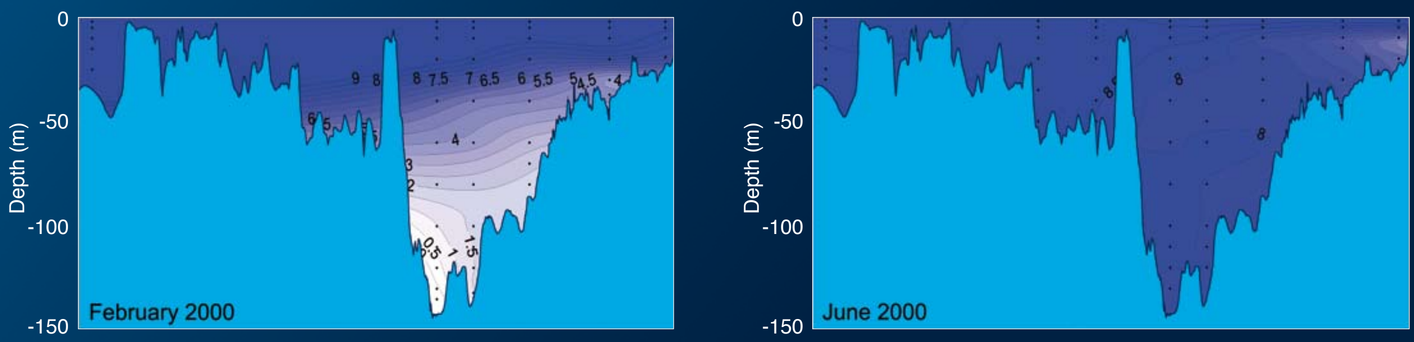
Simulations of hypoxia dynamics and consequences are an intrinsic part of the HYPOX work plan. Combining physical and biogeochemical modeling of both the water column and the sediments will provide means to extrapolate findings to similar ecosystems and to predict future hypoxia. These capabilities are needed to understand the effect of climate change and eutrophication on ecosystem functions and services and to decide on countermeasures that may be taken.

One example of a HYPOX observatory site: combining continuous monitoring and advanced modeling at Loch Etive (Scotland)



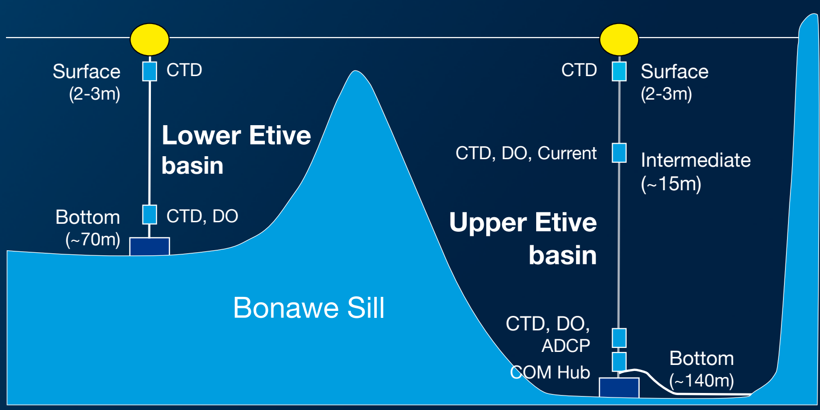
Location

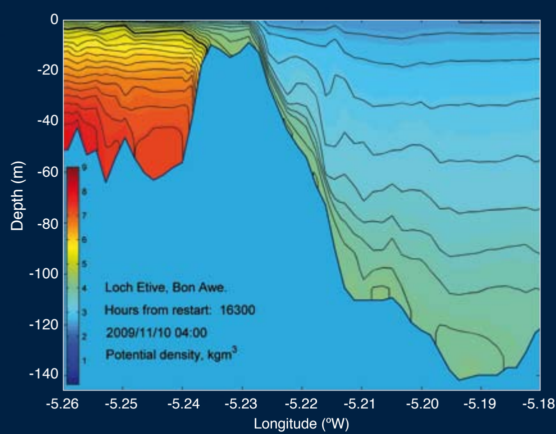
Loch Etive, Scotland, GB.
The extended fjord-like sea loch consists of two basins that are connected through the shallow "Bonawe Sill".



Existing observations

Data from monthly monitoring indicate pronounced oxygen dynamics that are closely linked to bottom topography, stratification and deep water exchange events. The contour plots show oxygen distributions along a cross section of Loch Etive. Figures: Scottish Association for Marine Sciences, REES programme





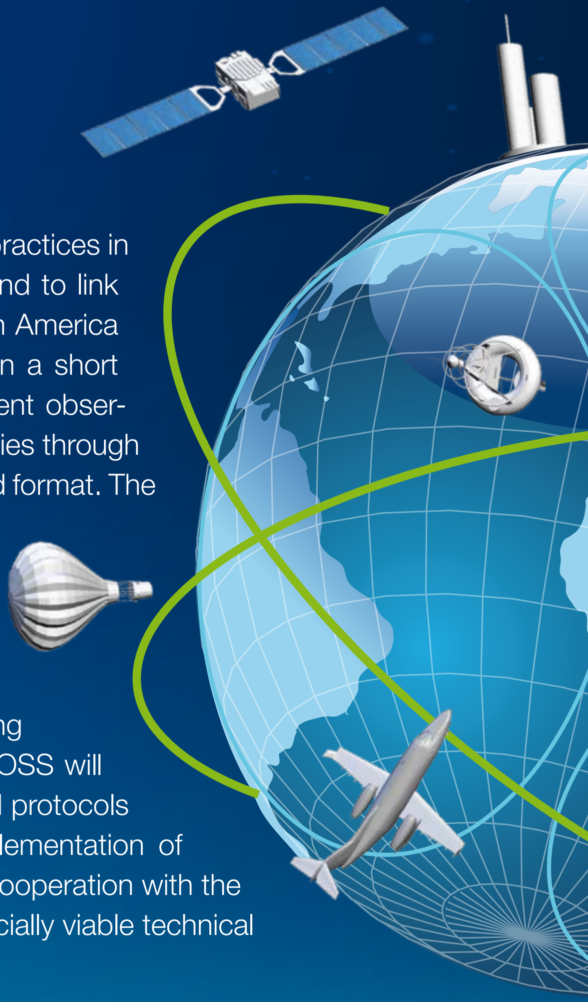
Observatory installation

In HYPOX, a cabled observatory is deployed that resolves oxygen dynamics by continuous measurements of oxygen and related parameters.
Figure: Scottish Association for Marine Sciences, Henrik Stahl

Modeling hydrodynamics: The first step

Predicted density distribution upon application of tidal and wind forcing. The resulting stratification is one of the main parameters that govern oxygen supply to the deep water of the loch. Currently developed models will include biogeochemical processes and will be verified by monitoring data obtained in Loch Etive. Figure: Scottish Association for Marine Sciences, Dmitry Aleynik.

Standardization, integration, dissemination: compliance with the Global Earth Observation initiative



HYPOX is aiming at forming a community of practices in the field of oxygen observations in Europe and to link these activities with similar programs in North America and other countries engaged in this field. On a short time scale it is planned to establish permanent observatory stations and to link different observatories through free exchange of data in an accepted standard format. The dissemination of the collected information and description of available services and products will be made available through the GEOSS common infrastructure – basically a set of archives that helps to search for data and results of past and ongoing measuring campaigns. An important contribution to GEOSS will be to test and define common standards and protocols for oxygen observations. The technical implementation of the infrastructure will be carried out in close cooperation with the industry to identify cost efficient and commercially viable technical solutions.

From the perspective of a scientific user GEOSS will offer new opportunities to evaluate and interpret measurement results. For example, meteorological forcing will have an immediate impact on oxygen depleted waters in particular for shallow depths. The reliable availability of meteorological and standard ocean data is important for improved forecasts of oxygen conditions. Within HYPOX different modeling approaches will be used to demonstrate the forecasting capabilities.
The HYPOX project will help to develop a vision on how GEOSS helps scientists to improve their knowledge on processes having a direct impact on the society and economy, in particular in regions close to the sea.

The GEOSS concept:
linking earth observation through a common infrastructure
to the benefit of various societal areas

The Global Earth Observation System of Systems (GEOSS) will provide a comprehensive framework to disseminate and retrieve information about earth related processes. HYPOX will particularly contribute by providing recommendations on measurement procedures and best practices with regard to data collection and processing of *in situ* oxygen measurements.

Photos courtesy of
(upper left to lower right)

1. Giuditta Marinaro, INGV
2. Olaf Pfannkuche, IFM-GEOMAR
3. Henrik Stahl, SAMS
4. Jana Friedrich, AWI
5. Marian-Trajan Gomoiu, GeoEcoMar
6. Thomas Soltwedel, AWI
7. Olaf Pfannkuche, IFM-GEOMAR
8. George Papatheodorou, UPAT
9. George Papatheodorou, UPAT
10. Per Hall, UGOT
11. Guiseppe Etiope, INGV
12. Gilles Lericolais, Ifremer
13. Onay Yilmaz, milliyet, turkey
14. Carsten Schubert, Eawag
15. Christoph Waldmann, Marum
16. Onay Yilmaz, milliyet, turkey
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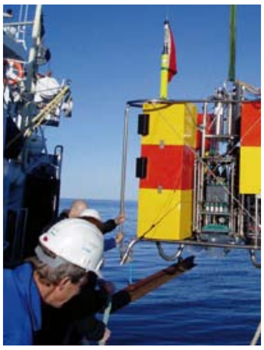

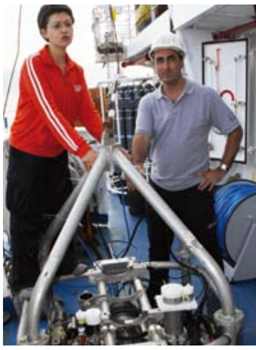

In order to cover all aspects of hypoxia's causes and consequences a multidisciplinary approach is essential. The HYPOX project is built on a consortium of experts from 16 partner institutions located in 11 countries in and around Europe. Fields of expertise include disciplines as diverse as physical and biological oceanography, geology, anorganic and organic geochemistry, biogeochemistry, biodiversity, microbial and general ecology, taxonomy, instrumentation development, and numerical modeling.


Prof. Antje Boetius


Dr. Jana Friedrich


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Dr. Carsten Schubert


Prof. Marian-Trajan Gomoiu


Prof. Emil Stanev


Prof. Nelli Sergeeva


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Getting to know the crowd

MPI, Bremen, Germany
Max Planck Institute for Marine Microbiology
Prof. Antje Boetius, aboetius@mpi-bremen.de
„The immense spreading of hypoxia in the last decades is one of the most alarming findings for environmental scientists."
Expertise: Microbial communities & habitats
Leader of workpackage "Coordination, dissemination and outreach"

AWI, Bremerhaven, Germany
Alfred Wegener Institute for Polar and Marine Research
Dr. Jana Friedrich, jana.friedrich@awi.de
„HYPOX is a great opportunity for me to continue my long term research on the human impact on the Black Sea ecosystem."
Expertise: Aquatic biogeochemistry & natural radionuclides.
Leader of workpackage "Impacts of hypoxia on ecosystems"

Eawag, Dübendorf, Switzerland
Swiss Federal Institute of Aquatic Science and Technology
Dr. Carsten Schubert, carsten.schubert@eawag.ch
„After realizing that oxygen concentrations in the atmosphere are declining, the participation in HYPOX is a must for our institute."
Expertise: Biomarker studies

GeoEcoMar, Constanţa, Romania
The National Institute of Marine Geology and Geo-ecology of Romania
Prof. Marian-Trajan Gomoiu, mtg@cier.ro
„We need to understand the recovery of the northwestern Black Sea ecosystem upon the decrease in environmental stress over the past 15 years."
Expertise: Aquatic ecology & environment protection

GKSS, Geesthacht, Germany - Institute for Coastal Research
Prof. Emil Stanev, emil.stanev@gkss.de
„HYPOX brings together expertise in measuring and modeling."
Expertise: Modeling of oceanography, biogeochemistry & sediment dynamics
Co-leader of workpackage "Modeling and prediction of short and long term factors affecting oxygen depletion"

IBSS, Sevastopol, Ukraine
A.O.Kovalevsky Institute of Biology of the Southern Seas
Prof. Nelli Sergeeva, nserg05@mail.ru
„How can higher life occur when oxygen concentrations are very low?"
Expertise: Meiobenthos diversity and ecology
Co-leader of workpackage "Indicators of past hypoxia dynamics "

IFM-GEOMAR, Kiel, Germany
Leibniz Institute of Marine Sciences at the University of Kiel
Dr. Olaf Pfannkuche, opfannkuche@ifm-geomar.de
„Environmental change and its consequences should be a prime target of European Research."
Expertise: *In situ* experiments & marine N-cycle

Ifremer, Plouzane, France
French Research Institute for Exploitation of the Sea
Dr. Gilles Lericolais, Gilles.lericolais@ifremer.fr
„We are eager to launch monitoring equipment at the Bosporus outlet - one of the areas in focus of the ESONET Network of Excellence."
Expertise: Marine geology & geophysics
Leader of workpackage "Assessing *in situ* oxygen depletion in shelf and open seas"

Dr. Gilles Lericolais | Dr. Giuditta Marinaro | Prof. Gregor Rehder | Dr. Christoph Waldmann | Prof. Jack Middelburg | Henrik Stahl | Prof. Per Hall | Prof. George Papatheodorou

INGV, Rome, Italy - National Institute of Geophysics and Volcanology
Dr. Giuditta Marinaro, giuditta.marinaro@ingv.it
„HYPOX will improve our understanding of variations in oxygen depletion: a great opportunity to improve environmental health!"
Expertise: Scientific payload of seafloor observatories & data management
Leader of workpackage "Improving and integrating *in situ* observation capacities of oxygen depletion"

IOW, Rostock, Germany - Institute for Baltic Sea Research
Prof. Gregor Rehder, gregor.rehder@io-warnemuende.de
"HYPOX provides us with a platform to exchange and develop ideas amongst the leading scientists working in this field in Europe."
Expertise: Marine chemistry & geochemistry

ITU-EMCOL, Istanbul, Turkey - Istanbul Technical University
Eastern Mediterranean Centre for Oceanography and Limnology
Prof. Namik Çagatay, cagatay@itu.edu.tr
„Understanding major oxygen level changes in the Black Sea history will help to predict future hypoxia in the Black Sea and elsewhere."
Expertise: Geochemistry
Co-leader of workpackage "Indicators of past hypoxia dynamics"

Marum, Bremen, Germany
Center for Marine Environmental Sciences at Bremen University
Dr. Christoph Waldmann, waldmann@marum.de
"HYPOX will foster standardization and the use of common infrastructures in ocean monitoring."
Expertise: Oceanographic technology & GEOSS
Co-leader of workpackage "Data sharing, standardization and interoperability according to GEOSS"

NIOO-KNAW, Yerseke, The Netherlands
Centre for Estuarine and Marine Ecology
Prof. Jack Middelburg, j.middelburg@geo.uu.nl
„Dissolved oxygen levels are declining in many aquatic ecosystems and we have to understand the ecological, biogeochemical and Earth System consequences."
Expertise: Benthic ecology and biogeochemistry
Co-leader of workpackage "Modeling and prediction of short and long term factors affecting oxygen depletion"

SAMS, Oban, Great Britain - Scottish Association for Marine Science
Henrik Stahl, henrik.stahl@sams.ac.uk
"We need to monitor hypoxia. It is a global problem already – and might become even worse due to climate change."
Expertise: *In situ* measurements
Leader of workpackage "Assessing *in situ* oxygen depletion in land-locked water bodies"

UGOT, Gothenburg, Sweden - University of Gothenburg
Prof. Per Hall, perhall@chem.gu.se
"We need to get a better balanced view of oxygen depletion in coastal and fjord systems - a view that considers natural causes and does not overemphasize anthropogenic impacts."
Expertise: Benthic biogeochemistry & sediment-water interactions

UPAT, Patras, Greece - University of Patras
Prof. George Papatheodorou, gpapathe@upatras.gr
"HYPOX will improve our understanding of hypoxia in Amvrakikos Gulf and other unique Ionian Sea ecosystems that are of fundamental economic importance for the local societies."
Expertise: Submarine mass transport & gas charged sediments

www.hypox.net

data portal

The HYPOX consortium consists of 16 partners form 11 nations in and around Europe. The project will run for three years (2009-2012).

HYPOX partner institutions are:

- Max Planck Institute for Marine Microbiology, Bremen, Germany (MPI)
- Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany (AWI)
- Swiss Federal Institute of Aquatic Science and Technology, Dübendorf, Switzerland (Eawag)
- The National Institute of Marine Geology and Geo-ecology of Romania, Constanta, Romania (GeoEcoMar)
- Institute for Coastal Research, Geesthacht, Germany (GKSS)
- A.O.Kovalevsky Institute of Biology of the Southern Seas, Sevastopol, Ukraine (IBSS)
- Leibniz Institute of Marine Sciences at the University of Kiel, Kiel, Germany (IFM-GEOMAR)
- French Research Institute for Exploitation of the Sea, Plouzane, France (Ifremer)
- National Institute of Geophysics and Volcanology, Rome, Italy (INGV)
- Institute for Baltic Sea Research, Rostock, Germany (IOW)
- Istanbul Technical University, Eastern Mediterr. Centre f. Oceanogr. & Limnology, Istanbul, Turkey (ITU-EMCOL)
- Center for Marine Environmental Sciences at Bremen University, Bremen, Germany (Marum)
- Centre for Estuarine and Marine Ecology, Yerseke, The Netherlands (NIOO-KNAW)
- Scottish Association for Marine Science, Oban, Great Britain (SAMS)
- University of Gothenburg, Gothenburg, Sweden (UGOT)
- University of Patras, Patras, Greece (UPAT)

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