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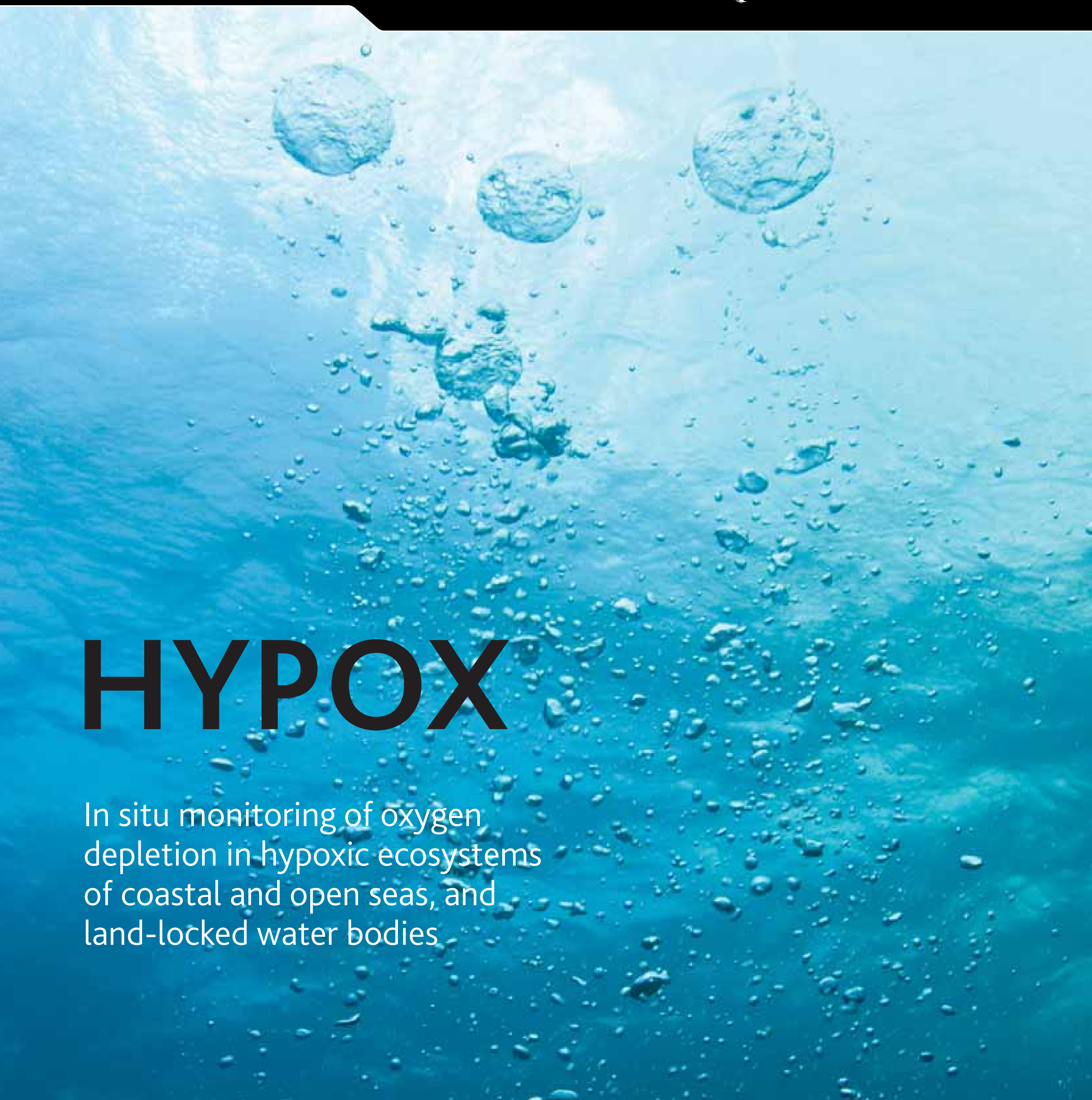

HYPOX

In situ monitoring of oxygen depletion in hypoxic ecosystems of coastal and open seas, and land-locked water bodies

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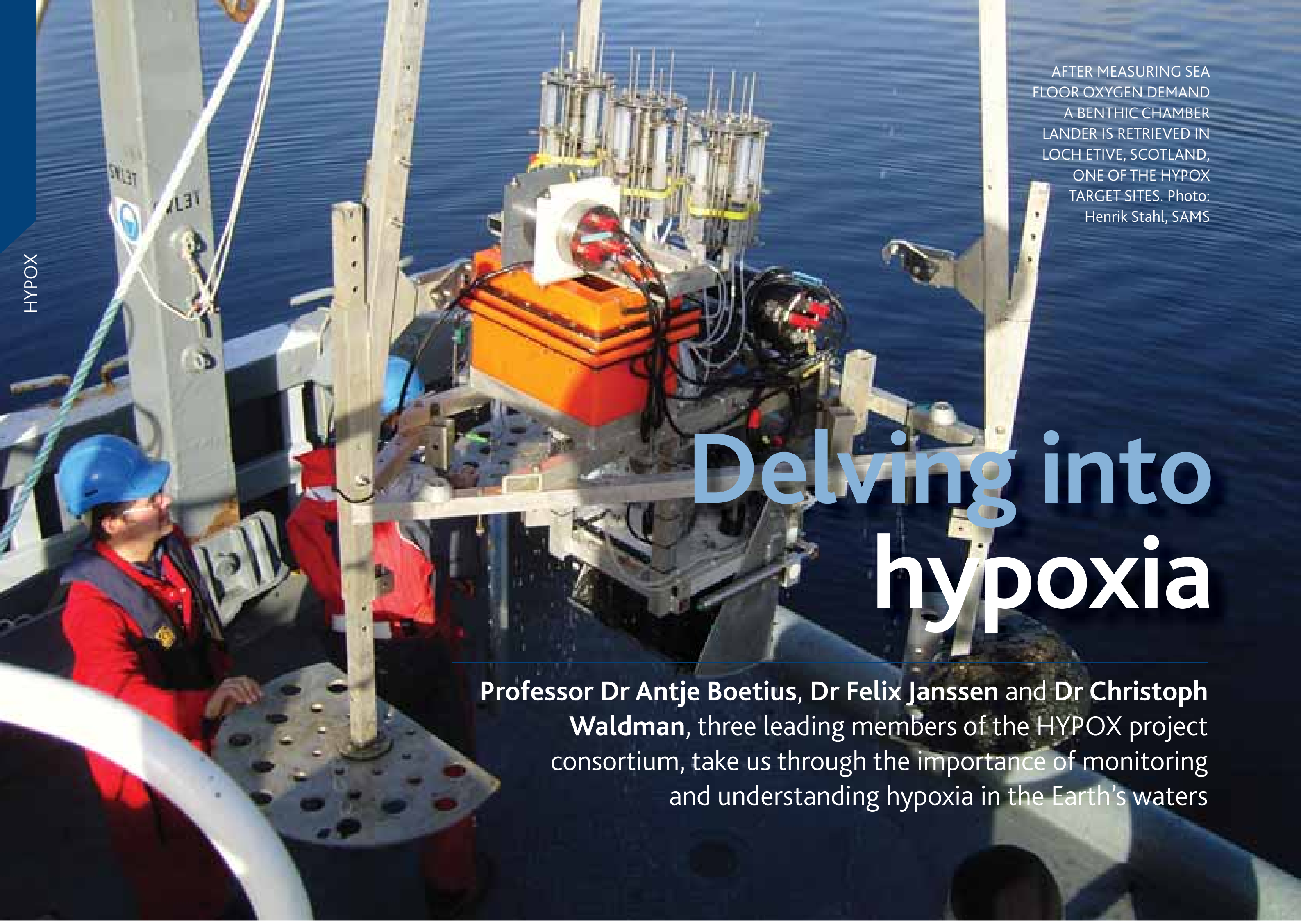
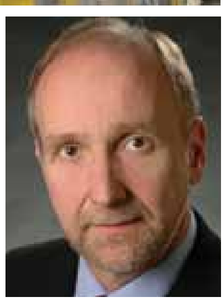


AFTER MEASURING SEA FLOOR OXYGEN DEMAND A BENTHIC CHAMBER LANDER IS RETRIEVED IN LOCH ETIVE, SCOTLAND, ONE OF THE HYPOX TARGET SITES. Photo: Henrik Stahl, SAMS

Delving into hypoxia

Professor Dr Antje Boetius, **Dr Felix Janssen** and **Dr Christoph Waldman**, three leading members of the HYPOX project consortium, take us through the importance of monitoring and understanding hypoxia in the Earth's waters



Top; *(AB)* Prof Dr Antje Boetius, *PI and project coordinator of HYPOX – Max-Planck Institute for Marine Microbiology, Bremen, Germany*
Left; *(FJ)* Dr Felix Janssen, *project vice-coordinator of HYPOX – Max-Planck Institute for Marine Microbiology, Bremen, Germany*
RIght; *(CW)* Christoph Waldman, *PI, Marum Center for Marine Environmental Sciences at Bremen University, Germany*

Could you offer an insight into the background and the overall aims and objectives of the HYPOX programme?

AB: Aquatic systems without oxygen are devoid of higher organisms like worms, mussels, crustaceans or fishes. Examples of such environments are the deep Black Sea and the deep basins of the Baltic where oxygen is naturally lacking. However, it is alarming finding that oxygen is also decreasing in historically oxic aquatic systems. HYPOX has been designed to monitor the oxygenation status of selected habitats and to investigate physical and biological processes that control oxygen availability. This will improve our understanding of hypoxia formation and help to predict the impact of future anthropogenic activities and climate change.

Has the introduction of the GEOSS (Global Earth Observation System of Systems) working principles and standardised guidelines proved to be a useful addition to the HYPOX project?

CW: We are convinced of the need to standardise datasets, and to make them available to the scientific community. To begin with, there are obvious points such as ensuring all datasets use the same units. Furthermore, there are questions such as: where and when was the measurement carried out? Which method or sensor was used? And what was the accuracy of that sensor and when was it last calibrated?

AB: Although providing such metadata takes an extra effort initially, the reward is significant. Well-documented, standardised and accessible data will convince colleagues of the value of data sharing and the need to follow such recommendations themselves.

The number of 'dead zones' has doubled every decade since the 1960s. What are the main causes of hypoxia, and what can be done to reduce the rate at which affected areas appear?

AB: The main reason for hypoxia is the so-called eutrophication – the fertilisation of water bodies with wastewater and runoff from farmlands. Fed with this anthropogenic nutrient supply, microalgae grow in vast amounts. After dying off, the algae sink to seafloor where they are utilised by micro-organisms that consume oxygen. Climate change is expected to worsen the situation, since warming of the ocean will reduce oxygen solubility and oxygen transport to deeper waters.

FJ: Engineering solutions, like aeration of the water or widening of the connection to adjacent waters, if useful at all, are restricted to small and confined water bodies. In open marine

environments the only option is to reduce the man-made pollution before the ecosystems collapse.

Are anthropogenic activities the only cause of hypoxia or are there natural events that increase the number of deoxygenated areas?

AB: Hypoxia is not always connected to human activities and is much older than mankind. In fact for most of its history Earth was an anoxic planet. Naturally hypoxia occurs where water ventilation is low and biological productivity and oxygen consumption is high. For example, semi-enclosed basins and waters where strong density gradients impair a downward transport of oxygen are naturally prone to hypoxia. The observed global increase of hypoxia in recent times, however, is clearly directly or indirectly related to human activities, e.g. increased nitrogen fertilisation and warming.

What are the long-term consequences on a local and a global scale?

FJ: The global area of oxygen deficient shelf zones will grow as well as the oxygen minimum zones in low latitudes. This will result in biodiversity loss and decreasing stocks of economically important organisms like fishes and crustaceans. What is also worrying is that hypoxia formation may be self-enhancing. Both the important nutrient phosphate and the powerful greenhouse gas methane are typically released from anoxic sediments and will add to eutrophication and global warming.

What are your plans for the future of the HYPOX initiative?

CW: A main objective of HYPOX is to prove that technologies, data pipelines and environmental expertise including ecosystem modelling is available in Europe to build a larger observatory infrastructure for issues like oxygen depletion. In addition, we use the GEOSS principles of connecting and sharing Earth observation data openly.

FJ: We really hope that our work will contribute to a much larger European effort in ocean observation and field monitoring, and we believe that our multidisciplinary approach allows us to go beyond physical measurements to study the effects on biodiversity and ecosystem services in connection to the monitoring.

Breathing life in to hypoxia monitoring

HYPOX is an EU-funded collaborative project aiming to bring better understanding to the underexplored global changes in oxygen depletion in water bodies

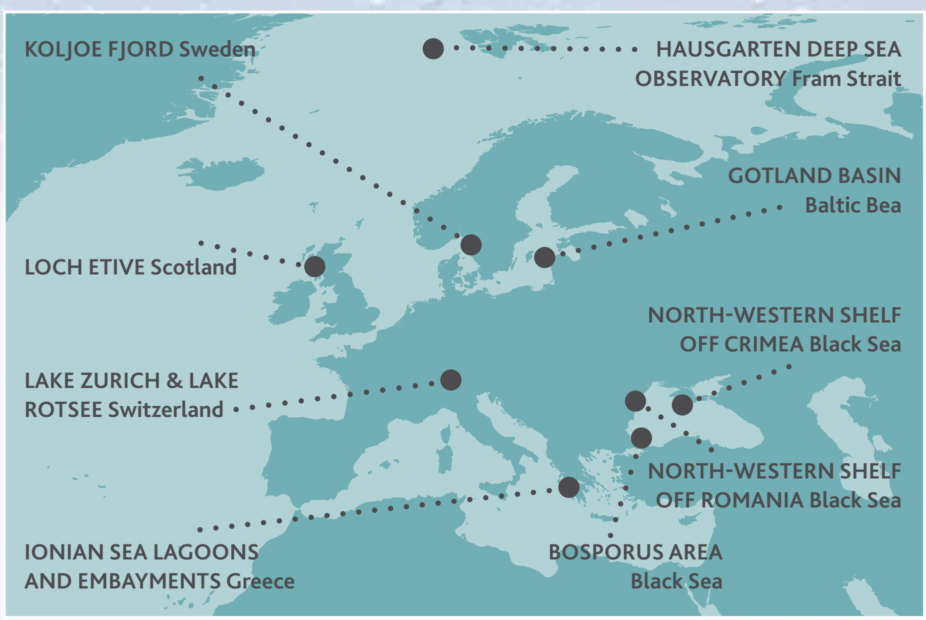
All higher aquatic life depends on oxygen. It is alarming then that hypoxic (low oxygen) conditions are on the increase in our waters worldwide. Since the 1960s, the records of so-called 'dead zones' have doubled every decade. The cause is largely manmade - wastewater and runoff from farmland leads to eutrophication of the waters allowing for microalgae to grow in vast amounts. Eventually some of this production sinks to the bottom where it gets utilised by micro-organisms that drain the oxygen from the bottom waters. Recent predictions suggest that climate change will cause the problem to worsen further for several reasons including a reduced oxygen solubility and a decrease in vertical transport of oxygen from the atmosphere to the bottom. As hypoxia occurs, more phosphate and methane are released from anoxic sediments, again adding to eutrophication and increasing global warming. Once duration and intensity of hypoxia surpasses a certain threshold it results in a permanent loss in biodiversity and, consequently, a dramatic fall in stocks of economically important fish and crustaceans. Despite the obvious importance in monitoring and preventing hypoxia, early symptoms are often missed until it is too late. With this background in mind, the HYPOX project was founded 12 months ago - to monitor oxygen levels in water systems and extend understanding of the causes and consequences of hypoxia.

GLOBAL ACTION

A better understanding of global changes in oxygen depletion requires a global monitoring strategy and continuous observations. By providing reliable and quality approved sensors in a variety of locations for in situ monitoring, HYPOX is contributing to this endeavour. The actual task of recognising hypoxia is a simple one. Many aquatic animals will change their behaviour when oxygen concentrations are low. It is also relatively easy to measure oxygen levels. Observing the early changes is vital, as there are physiological tipping points beyond which further decreases in oxygen cause major shifts in the function and composition of ecosystems. A vice-coordinator on the HYPOX project, and a specialist in the biogeochemistry of coastal sediments – Dr Felix Janssen – suggests that often, these changes may not be caught in time because it is impossible to view them via satellite, let alone with the naked eye: 'Since neither humans nor satellites can look into aquatic systems," he explains, "we have too few observations of the temporal and spatial variation of oxygen depletion." Consequently, as explained by Janssen's colleague and project coordinator at the Max Planck Institute for Marine Biology, Professor Dr Antje Boetius, amongst the central aims of HYPOX is the need to put in place the means to measure oxygen over the time

OBSERVATORIES IN LAND-LOCKED WATER BODIES

OBSERVATORIES IN COASTAL AND OPEN SEA



HYPOX

OBJECTIVES

In situ monitoring of oxygen depletion in hypoxic ecosystems of coastal and open seas, and land-locked water bodies

FUNDING

€4,665,281 of which EC Seventh Framework Programme contributes €3,499,711

DURATION

36 months, since 1 April 2009

CONSORTIUM

16 partners from 11 countries

CONTACT

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ANTJE BOETIUS is Professor for Geomicrobiology at the University Bremen and group leader of the joint Helmholtz – Max Planck Group on Deep Sea Ecology and Technology. She is an expert on the biogeochemistry and microbiology of ocean margins and has participated in many EU Projects of the 5th, 6th and 7th FP. Since her first studies on the Black Sea ecosystem, Antje Boetius is intrigued by the role of oxygen in shaping benthic communities

FELIX JANSSEN graduated in 1999 on studies of the relevance of large organic food falls to the deep sea. He joined the MPI for Marine Microbiology in Bremen, Germany for his PhD on the biogeochemistry of sands. From 2004 on, he continued as a PostDoc with a focus on the biogeochemistry of shallow water sediments.

CHRISTOPH WALDMANN completed his PhD in 1985 in Applied Physics at the University of Kiel and since then has been involved in the development of technologies and methods in ocean sciences. His current interest lies in the assessment of the performance of sensor systems to allow for a better judgment on the quality of collected data.

periods necessary: "We deploy observatories that measure oxygen continuously," Boetius points out, "in order to be able to see early signs and take countermeasures before fish mass mortalities prove that it is already too late".

To provide global relevance to the study, HYPOX is exploring a variety of aquatic systems. The sites fall under three categories: open ocean (oxic); semi-enclosed (periodically or permanently anoxic); and seasonally or locally anoxic and sometimes eutrophied land-locked systems. Boetius explains that by researching diverse environments, the team is anticipating a variety of results: "HYPOX is targeting contrasting sites where we can expect to see large differences in causes and dynamics in oxygen concentration and of the formation and consequences of hypoxia," she notes. Specifically, the Black and Baltic Seas are selected to provide data on areas naturally depleted of oxygen, while lagoons, lakes and fjords in Scotland, Sweden, Switzerland and Greece are the focus for sites with restricted exchange that are vulnerable to eutrophication. A site in the Arctic, though far from depleted of oxygen, provides insightful information on the open ocean, which Boetius expects will give the team an opportunity to examine what part global warming may play in such an environment: "We are observing the effect of ocean warming on oxygen dynamics with a high sensitivity." The response of each environment to oxygen depletion is different and subject to a number of factors, such as the adaption of organisms to low oxygen concentrations, the availability of nearby fauna for re-colonisation, and the sediment inventory of oxidised and reduced components. With several cruises and the first observatories now completed,

FIGURE 1. An oxygen sensor equipped recording current meter is attached to a moored observatory upon deployment at the Crimean Shelf, Ukraine. Photo: Daphne Donis, MPI

Boetius outlines HYPOX's intention to draw on this local information through a process of models and simulations to provide general predictions for the future of hypoxia: "We are aiming to identify the driving forces that lead to hypoxia," she observes, "in order to be able to predict future hypoxia formation and ecosystem responses".

IN THE WATER

The HYPOX team's observatories consist of packages of sensors for oxygen and other relevant parameters that are attached to moorings or frames. Where possible, these are permanently deployed and can be equipped with online data communication. However, for some sites, the logistics and shipping traffic calls for periodic deployments or for drifting platforms. Alongside the observatories are targeted field campaigns that investigate the causes and consequences of hypoxia formation in each region, enabling searches for particular compounds and species that can be used as indicators for other cases of hypoxia. This contributes to the development of an adequate monitoring strategy. There may be technical difficulties to solve in order to extend global monitoring capacities but the overwhelming challenge is that of funding. That being said, Boetius is confident that these difficulties can be overcome: "In situ observation in aquatic systems is expensive, but we are making excellent progress with the technologies."

COLLABORATION IS KEY

Collaboration is an integral part of the HYPOX project. Partners provide diverse expertise from a total of 16 research institutions based in 11 European countries. This interdisciplinary approach allows the provision of a wide array of necessary skills for the construction and installation of observatories, the study of animal communities and investigation of traces that hypoxia leaves behind in the sedimentary record. Modelling is also conducted by partners, who use measurements for generalisations and predictions. Such datasets also provide invaluable feedback in terms of delineating the most valuable measurements for those working on the campaigns and observatories. Collaboration within HYPOX has increased significantly by sharing information based on GEOSS principles. Although the amount of work invested to achieve interoperability between different observatory sites is initially higher compared to the traditional individualised approach, encouraging signs for the project suggest that the benefits far outweigh the extra effort – not least because HYPOX aims to link its activities to those in other areas of the world engaged in the same field. The GEOSS common infrastructure makes this a real possibility.

LEADING BY EXAMPLE

The HYPOX project's achievements are being put forward as an example of what can be done in the field. Their success so far is hoped to act as a catalyst in Europe. Now that the project has proven itself, co PI Christoph Waldmann, based at MARUM, the Center for Marine Environmental Sciences at Bremen University, believes that the developed monitoring strategies including the technological implementation will be of interest for other research groups worldwide. GEOSS is providing an ideal platform for disseminating the gained knowledge, and furthermore opens up new opportunities for forecasting capabilities. Combined meteorological, standard ocean data and forecasts of oxygen conditions could benefit coastal societies and economies enormously, helping safeguard the future of these areas.