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Triple Trouble – Ocean under Stress

Scientists concerned how three environmental problems could combine to threaten the ocean, take warnings to the climate change discussion at the United Nations Framework Convention on Climate Change Seventeenth session of the Conference of the Parties (COP17) in Durban, South Africa.

Over the coming decades and centuries, the ocean will become increasingly stressed by at least three interacting factors. Rising seawater temperatures, ocean acidification and ocean deoxygenation will cause substantial changes in marine physics, chemistry and biology. These changes will affect the ocean in ways that we are only beginning to understand; these changes are likely to affect every one of us.

The global ocean covers nearly three quarters of Earth's surface, contains 96% of its living space, provides around half of the oxygen we breathe and is an increasing source of protein for a rapidly growing world population. However, human activity over the last 200 years is having an impact on this precious resource on local, regional and global scales. It is imperative that international decision-makers understand the enormous role the ocean plays in sustaining life on Earth and the consequences of a high CO_2 world for the ocean and society.

An international partnership of Plymouth Marine Laboratory, Scripps Institution of Oceanography at UC San Diego; OCEANA; the UK Ocean Acidification Research Programme (27 partner institutes from the UK); the European Project on Ocean Acidification (32 partner institutes from 10 countries); and the Mediterranean Sea Acidification in a Changing Climate programme (16 partner institutes from 10 countries mainly bordering the Mediterranean Sea), is now highlighting its concern about the impacts of the multiple and interacting stressors of warming, acidification and deoxygenation on ocean systems, which will occur in the coming decades as the result of a high CO_2 world.

Plymouth Marine Laboratory's Dr Carol Turley OBE, will be taking these messages to the Conference of the Parties 17 at the UNFCCC meeting in South Africa. *"I'm here to take the message to stakeholders and policymakers from a diverse group of organisations including, international science partnerships, oceanographic institutions and an NGO. Often forgotten in such discussions are the ocean and the enormous and diverse resources it provides, including food and other resources even half the oxygen we breathe. The health of the ocean is therefore relevant to everyone one of us on Planet Earth and we are concerned about how these three stressors - ocean warming, acidification and deoxygenation - produce a very worrying combination which threatens the ocean and everything it provides us. We have produced a short* ***'Ocean Stress Guide'*** *that sums this up in clear language; we would urge everyone to read it."*

While ocean acidification has recently been recognized as a topic of high research priority leading to a growth of studies, deoxygenation has not reached that level of recognition. The study of warming is more mature but research at the level of ocean ecosystems and biogeochemistry requires more attention.

But what is really missing is the joint perspective, where the full and combined effect of two or all three stressors acting at the same time is investigated. Already detailed laboratory studies and field experiments from regional to global scale monitoring and modelling are beginning, through cross-disciplinary and international cooperative partnerships. In order to better understand the impacts on ecosystems and the consequences for every one of us, research will increasingly have to follow a multi-disciplinary approach across the physical, chemical, life, Earth, social and economic sciences.

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These studies need to be policy relevant and ensure a rapid transfer of knowledge to and from researchers and decision makers. Importantly, research capacity needs to be grown globally, particularly in developing countries where their dependence on the goods and services provided by the ocean makes them particularly vulnerable and where capacity is notably low. To achieve all this there would be a need for greater coordination of monitoring, research and training at the international level.

Professor Bob Watson, Chief Scientist for the UK's Department of Environment, Food and Rural Affairs (Defra), echoed the need for acceptance of these issues and the potential impacts of them working together: *"The ocean is an incredible source of food and an amazing source of biodiversity. Now we see these irreplaceable resources facing not one but three stressors potentially acting together in ways that we are only just beginning to investigate and understand. Highlighting this unholy alliance is essential if stakeholders and governments are to make decisions that will affect everyone on this planet. Carbon dioxide, the common factor, is related to energy, energy is related to economic growth and therefore, as we argue that we need to reduce the threat of climate change, ocean acidification or oxygen depletion, we will have to change the way we produce and use energy, the way we manage our land as well."*

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796 words

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Note to Editors

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The *Ocean Stress Guide* can be downloaded at www.oceanunderstress.com

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Dr Carol Turley: representing the partner organisations and programmes and will be available for interviews at COP17 in Durban, South Africa from 28th November – 8th December. Prior to the meeting, Dr Turley will be available until 4pm on Saturday 26th November for questions or comments.

Further information about the organizations and projects involved:

Plymouth Marine Laboratory – www.pml.ac.uk

Scripps Institution of Oceanography at UC San Diego - www.sio.ucsd.edu

OCEANA - www.oceana.org

UK Ocean Acidification Research Programme - www.oceanacidification.org.uk

European Project on Ocean Acidification - http://epoca-project.eu

Mediterranean Sea Acidification in a Changing Climate Programme - http://medsea-project.eu

Ocean acidification

Ocean acidification is directly caused by the increase of carbon dioxide (CO_2) levels in the atmosphere. When CO_2 enters the ocean it rapidly goes through a series of chemical reactions which increase the acidity of the surface seawater (lowering its pH). The ocean has already removed about 30% of anthropogenic CO_2 over the last 250 years, increasing acidity at a rate not seen for around 60 million years.

This effect can be considered beneficial since it has slowed the accumulation of CO_2 in the atmosphere and the rate of global warming; without this ocean sink, atmospheric CO_2 levels would already be greater than 450ppm. However, the continuation of such a fundamental and rapid change to ocean chemistry is likely to be bad news for life in the sea; it will not only cause problems for organisms with calcium carbonate skeletons or shells (such as oysters, mussels, corals and some planktonic species) but will also impact many other organisms, ecosystems and processes with potentially serious implications for society.

The average acidity of the upper ocean has already declined by around 0.1 pH unit (30% increase in acidity) since the industrial revolution; it is expected to further decline by about 0.3 pH units (100% increase in acidity) by the end of this century if CO_2 emissions continue at the current rate.

Ocean warming

Over the last decades ocean warming has been a direct consequence of increasing atmospheric temperature due to the 'greenhouse effect'. This warming affects the exchange of gases between the ocean surface and the atmosphere, and their transport and storage in deeper waters. In a warmer ocean, there will also be less mixing between the nutrient-rich deep waters and the nutrient-poor surface ocean, particularly in tropical areas with detrimental consequences for ocean productivity, hence significantly diminishing food security from fisheries.

Ocean warming is also likely to have direct effects on the physiology of marine organisms and thereby alter the geographical distribution of species, including those of commercial importance, currently well-adapted to existing conditions; for example temperature increase is almost certainly contributing to the decline of cod in the North Atlantic.

The heat content of the ocean is immense with ~90% of the energy from warming of the Earth system stored in the ocean over recent decades. There has already been a mean sea surface warming of about 0.7^{o}C over the last 100 years, likely to increase by over 3^{o}C in some ocean regions by the end of this century.

Ocean deoxygenation

Ocean deoxygenation is the reduction of dissolved oxygen (O_2) in seawater. Climate change can influence oxygen levels in the ocean in several ways. This is certain to occur in a warmer ocean since higher temperatures reduce oxygen solubility. Warming is also likely to create a more stratified ocean, decreasing the downward oxygen supply from the surface. Ocean acidification and nutrient run-off from streams and rivers can also contribute to deoxygenation.

Fish, sea-mammals and many other marine organisms depend on sufficient levels of oxygen to function, and may therefore be stressed by declining oxygen concentrations. Extended zones of low oxygen may result in the exclusion of such organisms. However, other organisms tolerant of low oxygen, particularly microbes are likely to flourish, altering the balance of communities. Low oxygen levels in the ocean may also increase the amount of greenhouse gases in the atmosphere by changing feedback mechanisms involving methane and nitrous oxide.

Current ocean models project declines of 1 to 7% in the global ocean oxygen inventory over the next century. However, there are considerable uncertainties regarding the scale and location of oxygen changes, and their ecological impacts.

Triple trouble - multiple stressors

In the future many parts of the ocean are likely to experience more than one of these environmental stressors at the same time, since they are driven by the same underlying process – increases in atmospheric CO_2 and other greenhouse gases. These "hot spots" will not only be warmer, but are also likely to be more stratified, have increased acidity and contain less oxygen, increasing the stress on marine life in ways that may be more than the simple addition of each.

For example, ocean acidification can make species more susceptible to the impacts of warming waters, and higher CO_2 alongside lower oxygen levels can create respiratory difficulties. Acting together these stressors could more rapidly threaten biogeochemical cycles, ecosystems and the goods and services the ocean provides to society, thereby increasing the risk to human food security and industries depending on productive marine ecosystems. Furthermore, changes in the exchange of gases between the atmosphere and ocean will impact on climate change.

Importantly and worryingly, these "hot spots" of multiple stressors are likely to coincide with areas high in ocean productivity - and currently supporting significant fisheries.

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