Sea change

In efforts to improve understanding of the rapidly changing marine environment, marine scientist **Dr Patrizia Ziveri** is coordinating a comprehensive research programme investigating the anthropogenic acidification impacts in the Mediterranean Sea and the necessary sustainability policy responses

To begin, could you explain why the Mediterranean Sea was chosen as the focus for your investigations?

The Mediterranean Sea is considered a small-scale ocean with high environmental variability and steep physicochemical gradients within a relatively restricted region. It is too small and complex to be adequately resolved in global-scale biogeochemical climate models. To properly project how key biogeochemical and ecosystem processes will change, it is fundamental to adequately represent the general circulation of the Mediterranean basin, such as the fine-scale processes that control it and the highly variable atmospheric forcing. Although the general impact of acidification on water chemistry is globally well understood, fine-scale regional models are needed to resolve the complexity of the physical and ecological interactions of small and complex basins, such as the Mediterranean Sea.

How much is presently understood about the effects of ocean acidification in this region?

The impacts of acidification and climate change on Mediterranean marine organisms and processes are poorly understood. Both acidification and warming are expected to alter marine ecosystems of the Mediterranean Sea. The warming of recent decades has already impacted species distribution patterns reflected by documented biogeographic shifts. Direct consequences on the Mediterranean Sea are already apparent, including meridionalisation, rapid northward shifts of species and an increasing mortality rate of some marine species during unusually warm summers. Indirect ecosystem impacts are very poorly documented but their significance may be profound.

Acidification and warming could have significant impacts on coral in the Mediterranean Sea. Can you explain the ramifications of coral extinction and the aims of the European Mediterranean Sea Acidification in a changing climate (MedSeA) project?

Mediterranean red coral are among the longest-living inhabitants of the Mediterranean Sea and are emblematic of pristine waters prized by tourists. So far, no studies have evaluated effects of acidification and warming on these important ecosystem engineering species. Understanding the impact of acidification on corals is essential for management of Mediterranean biodiversity. So far we discovered that Mediterranean red corals are strongly affected by the change in seawater carbonate chemistry (pH) and water temperature. By the end of MedSeA we hope to have a large scale evaluation of the ecological and economic impacts of ocean acidification upon corals.

Are you studying the effects of these changes on any other key organisms in the Mediterranean?

The project is structured to investigate endemic Mediterranean species and key groups and processes that appear most likely to be susceptible to acidification. The project studies pelagic species, including coccolithophores, dinoflagellates, copepods and jellyfish, as well as benthic organisms, such as mussels, seagrass, corals and encrusting red algae. When selecting the organisms, we took into consideration whether they were unique or endemic to the Mediterranean Sea, contributors to habitat building, major contributors to ecological function and the species of economic value in the Mediterranean region. MedSeA is not limited to the study of organisms, but also covers the past and present conditions of carbonate chemistry. This will ultimately contribute in providing maps for identifying the sectors of the Mediterranean Sea that are most affected by pH changes.

The project involves chemists, biologists, Earth scientists, modellers and economists. How has this interdisciplinary approach aided the project?

A complete study of the acidification effects on the Mediterranean – covering chemical, climatic, ecological, biological and economical changes – requires an interdisciplinary approach and a multidisciplinary team. The MedSeA consortium is comprised of leading European research institutions mainly from Mediterranean countries, including three top Mediterranean institutions of International Cooperation Partner Countries (Morocco, Tunisia and Egypt).

How are you collaborating with other institutions and policy makers in order to ensure the success of the project?

The MedSeA project spawned the Mediterranean Reference User Group (MRUG) whose objective is to enable a two-way information exchange between MedSeA scientists and the target audiences. MRUG is composed of key stakeholders, policy makers, environmental agencies, industry and NGOs from countries with Mediterranean coastlines. MedSeA also has an International Scientific Advisory Panel comprised of four scientists from the US and Europe who provide an external evaluation of the project and help link MedSeA to other programmes and activities mainly outside of Europe. MedSeA is also searching complementarities with other European projects from the marine environmental research area. In this regard, we will be contributing to the gathering of the Mediterranean and Black Sea region projects happening in Athens in June this year.

Projecting the future from the past

Whilst the impacts of ocean acidification are generally well acknowledged, local-level changes remain a mystery.The **MedSeA** project is building a clearer picture of the Mediterranean Sea's response to elevated atmospheric CO_2 conditions focusing on ocean acidification and warming

OCEANS ARE HOME to around 80 per cent of the world's biodiversity and they produce over 50 per cent of the atmospheric oxygen. Yet, whilst they underpin life on Earth, much of the marine environment remains a mystery. Against this context, developing appropriate policy responses to anthropogenic influences can be challenging. The International Union for Conservation of Nature (IUCN) observes that the threats facing the marine environment are numerous and complex. One way to ensure that the oceans are more effectively protected is to assemble a robust body of scientific information.

A region currently receiving particular attention is the Mediterranean Sea. With a resident population of 150 million, in 22 countries on the Mediterranean coast, it is an economically and socially vital marine ecosystem. Of particular concern is the impact from ocean acidification and warming, which can affect marine biodiversity, and the goods and services they provide.

UNDERSTANDING THE LEGACY OF OCEAN ACIDIFICATION

The European Mediterranean Sea Acidification in a changing climate (MedSeA) project is a collaborative initiative aiming to provide robust science-based modern conditions and projections of ocean acidification within the Mediterranean Sea. Funded by the EU Seventh Framework Programme (FP7), it comprises 22 institutions from 12 countries. The overriding objective is to deliver important and relevant information to stakeholders and policy makers on the basin-scale for smarter regional adaptation and mitigation strategies.

Project Coordinator Patrizia Ziveri explains that future projections are the central focus in MedSeA, emphasises identifying best estimates and related uncertainties of future changes in the Mediterranean Sea, including pH, calcium carbonate saturation states and other biogeochemical-ecosystem variables. In addition, they are assessing the changes in habitat suitability of relevant ecologically- and economically-important species: "Projections will be based on new observations of chemical conditions as well as experimental data on the responses of key organisms and ecosystems to acidification and warming," Ziveri outlines.

The Intergovernmental Panel on Climate Change clearly acknowledges that global climate changes and CO_2 emission rates are now occurring much faster than at any time in the last 300 million years. At present, we know that the ocean is responsible for the uptake of around 25 per cent of the CO_2 produced through the burning of fossil fuels, cement production and deforestation that is emitted to the atmosphere. This means the ocean has been absorbing CO_2 and reducing global warming rates. However, it is now believed that the tipping point has been reached and the ocean has absorbed so much CO_2 that its own chemistry is altering, as Ziveri elaborates: "Ocean pH is declining, with model projections indicating that the rate of decline will only increase with time". This has the potential to significantly alter oceanic processes and systems, which in turn will severely impact on marine ecosystems and socioeconomic activities.

As a part of assembling data on these changes, MedSeA is in its second year of conducting fine-scale regional studies into oceanic acidification through a trans-Mediterranean oceanographic cruise on the Spanish R/V Angeles Alvariño covering 27 sample stations from Cadiz, Spain to Heraklion, Crete, Greece, and then to Barcelona, Spain. Ocean acidification is occuring with other major environmental changes either directly linked to the rapid increase of atmospheric CO_2 or other direct anthropogenic pressures such as overfishing, pollution, and invasion of new species by very intense marine shipping.

The major objective of the 2013 MedSeA research cruise is to complete a comprehensive water column sampling in both the eastern and western Mediterranean. "The cruise provide diverse water sampling for several chemical and biological parameters and processes as well as undisturbed recent sediment to study anthropogenic effects occurring in the past two centuries," she notes. The GEOTRACES programme is also contributing to this work.

Thousands of samples are taken for seawater chemistry, sediments, plankton and bioaerosols.

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The risk posed by warming and acidification continues to become more acute and integrated management supported by robust data is critical

MEDITERRANEAN *CORALLIUM RUBRUM* © LORENZO BRAMANTI

"This great achievement has been possible thanks to the fantastic crew and a highly multidisciplinary research team".

USING MESOSCALE EXPERIMENTAL TOOLS

The MedSeA researchers are focusing a key part of their efforts on mesocosm experiments, a tool which enables scientists to focus on a portion of the marine environment under controlled conditions (eg. sea water carbonate chemistry). So far they have completed two pelagic mesocosm acidification experiments off the coasts of Corsica (in 2012) and Villefranche, France (in 2013), with the final pelagic mesocosm experiments to be undertaken in September 2013 in Crete. In this last experiment the combined effects of the next decade's acidification and sea surface temperature on microplankton. This is the first time such experiments have been conducted, and are coordinated by the Hellenic Center of Marine Research. The first mesocosm study in Corsica involved 37 researchers and students from eight countries. "They deployed nine mesocosms (52m3) over a 20 days period and six different levels of CO_2 partial pressure (pCO_2) and three control mesocosms (~400 µatm), were used, in order to cover the range of pCO_2 anticipated for the present century," Ziveri details. For the second experiment in France, 25 scientists from eight institutes and six countries participated. These experiments were led by the MedSeA group based at the Observatoire Océanologique Villefranche.

The collection and analysis of the diverse datasets is offering fascinating new insights into the dynamics and timing of the Mediterranean carbonate system and calcifying organisms during the late Quaternary and Anthropocene time frames. The work studying the sediments demonstrates that during times of change in atmospheric CO_2, the carbonate mass of planktonic calcifying organisms found in the Mediterranean Sea was seen to be negatively responding to elevated atmospheric CO_2 and the main circulation forcing. "Our study of the pelagic and benthic organisms show that even the so-called 'winners' of ocean acidification, such as sea grass, are exposed to a multitude of additional environmental stressors," observes Ziveri. Particularly striking findings that relate to ocean management and policy making are that most of the vermetid reefs along the South Eastern Mediterranean are facing extinction, and that biodiversity is decreasing in elevated CO_2 conditions nearby natural CO_2 vents. The information we now have reveals the Mediterranean is already a fragile ecosystem.

INFLUENCING POLICY MEASURES

One of the main goals of MedSeA is to create new data that can be fed into existing finescale models of the Mediterranean Sea, enabling improvements in representation of key processes; the researchers can then use these to help project future changes. Geographical variations in oceanic processes such as these are critical for shedding light on the impact of environmental stresses, such as pollution, over fishing and habitat destruction, in order to build the resilience of the marine environment. In addition, the data is critical for informing those creating effective marine protected areas, and used in marine spatial planning tools to promote the conservation and sustainable management of coastal ecosystems.

The work is essential to help understand the rapid changes in chemical and environmental conditions of the Mediterranean Sea, and to inform global policy and financing processes, but in particular to help the adoption of stringent reductions in greenhouse gas emissions, including those from marine industries. The risk posed by warming and acidification continues to become more acute and integrated management supported by robust data is critical. "The implementation of ecosystem-based adaptation strategies through integrated coastal and ocean management institutions at national, regional and local levels throughout the Mediterranean Sea are absolutely fundamental, all of which is validated through the work of MedSeA," Ziveri expounds. This includes the establishment and effective management of networks of marine protected areas as healthy and intact marine systems that can ultimately reduce the effects of multiple environmental stressors.

INTELLIGENCE

MEDSEA

EUROPEAN MEDITERRANEAN SEA ACIDIFICATION IN A CHANGING CLIMATE

OBJECTIVES

To forecast chemical, ecological, biological, and socioeconomical changes of the Mediterranean driven by increases in CO_2 and other greenhouse gases, while focusing on the combined impacts of acidification and warming on marine organisms, ecosystems and biogeochemical processes.

PARTNERS

Universitat Autònoma de Barcelona, Spain (coordinator) • **Université de Perpignan**, France • **Bar Ilan University**, Israel • **Hellenic Centre for Marine Research**, Greece • **Centro Euro-Mediterraneo sui Cambiamenti Climatici**, Italy • **Laboratoire d'Océanographie Villefranche**, France • **Plymouth Marine Laboratory**, UK • **Instituto Mediterráneo de Estudios Avanzados**, Spain • **University of Plymouth**,UK • **Alfred Wegener Institute**, Bremerhaven, Germany • **Consorzio Nazionale Interuniversitario per le Scienze del Mare**, Italy • **Institut National de Recherche Halieutique**, Morocco • **National Institute of Oceanography and Fisheries**, Egypt • **University of Sfax**, Tunisia • **Istituto Nazionale di Oceanografia e di Geofisica Sperimentale**, Italy • **Laboratoire des Sciences du Climat et de l`Environnement**, France

Associated Partners: **University of Gothenburg**, Sweden • **Uludag University**, Turkey • **University of Pisa**, Italy • **University of Modena**, Italy • **University of Athens**, Greece • **ENEA**, Italy

FUNDING

EU Seventh Framework Programme (FP7) – contract no. 265103

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