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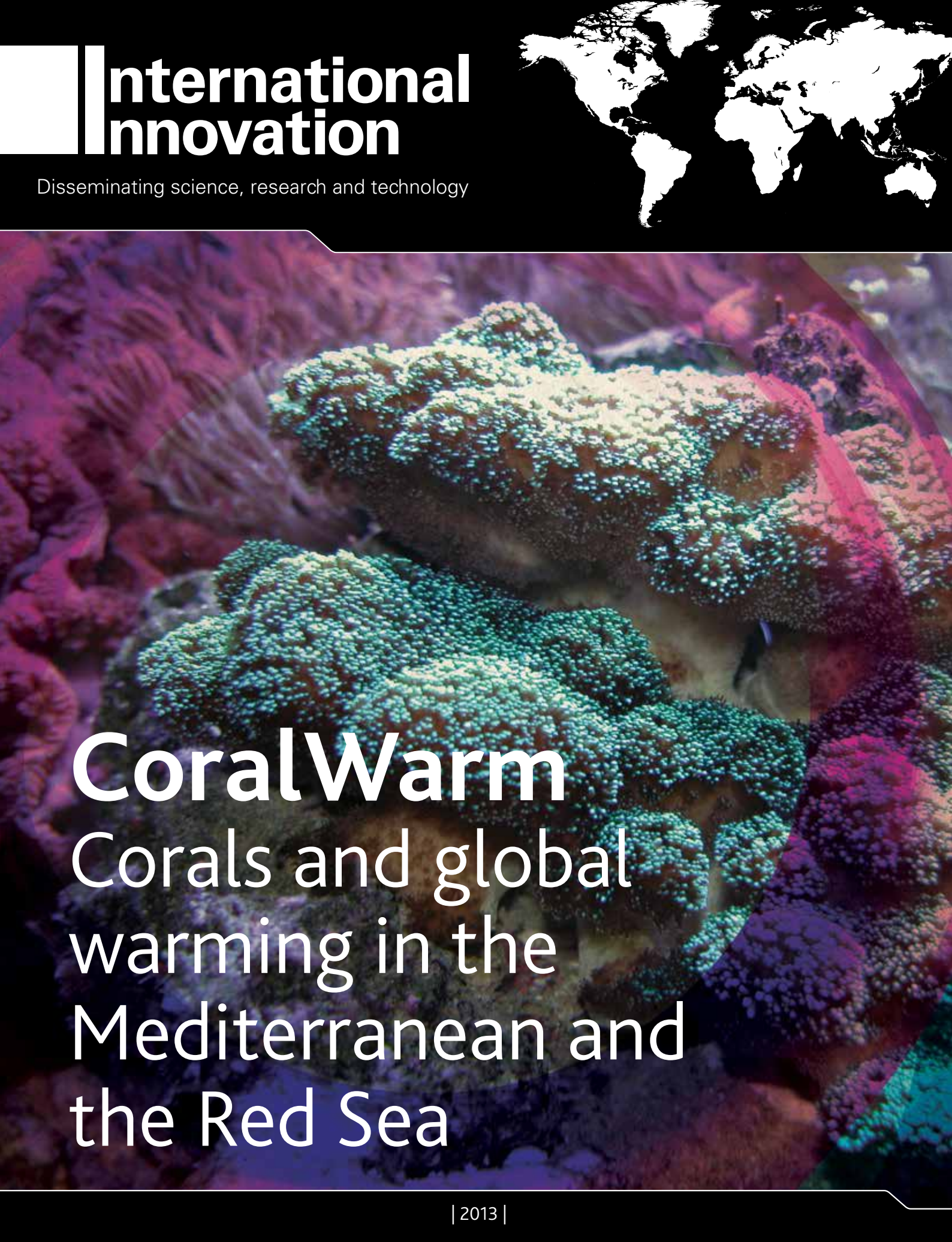

CoralWarm

Corals and global warming in the Mediterranean and the Red Sea

| 2013 |

Coral conundrum

Professor Zvy Dubinsky from Bar-Ilan University, Israel, and **Professors Stefano Goffredo** and **Giuseppe Falini** from the University of Bologna, Italy, are performing groundbreaking research into coral and climate change. Here, they detail the key aspects of the work

Top left:
Professor
Stefano Goffredo

Top right:
Professor
Giuseppe Falini

Bottom right:
Professor
Zvy Dubinsky

To begin, could you highlight the key aims of the CoralWarm project?

Our aim is to gain an understanding of the responses of representative temperate and tropical corals to the ongoing warming and acidification of world oceans from the molecular level to whole ecosystems.

How do you intend to add to the existing body of knowledge surrounding the survival and growth of coral in the context of ocean temperature and acidity variations?

We already know that warming of surrounding waters depletes the energy provided to symbiotic algae living in the coral's animal host – the zooxanthellae – resulting in coral 'bleaching' episodes of death and reef collapse. We likewise have evidence that acidification shifts the balance from skeletal carbonate deposition towards its dissolution, severely affecting coral growth. Moreover, we observed that some aspects of the mineralogy of the skeleton are affected and that these are controlled by specific intraskeletal molecules, generally referred to as organic matrix.

We are adding molecular aspects of specific genes being up- or downregulated upon experimental exposure of corals to warming and/or acidification. We are also studying how gametogenesis and reproduction is affected by warming and acidification. These effects are linked to provide deeper understanding of the physiological and demographic responses of corals to global climate change, elevated temperature and lowered pH.

Could you expand on the Panarea experiment performed at underwater CO_2 vents in the Tyrrhenian Sea?

That experiment has provided us with an ideal, unique testing ground. The crater has a steep acidity gradient from pH 6.5-8.2 across 50 m, which allowed us to expose corals to this naturally varying stressor and study their response for almost two years. The respiration, calcification, mortality and photosynthesis rates of the three coral species in that extensive field experiment were measured during an intense field campaign on Panarea, where novel, specially designed equipment was used for the measurements. The tissues and skeletons of these corals are being sampled for subsequent biochemical, molecular, compositional, crystallographic and histological analyses. Growth rates and reproduction of the corals are being followed in order to quantify their response to pH levels.

Have you made any significant discoveries to date?

Yes, quite a few. Specific genes that respond to warming and acidification were identified for the first time, and their function, as witnessed in metabolic changes, has been established. We also observed for the first time, through *in*

vitro calcification experiments, that the skeletal calcium carbonate polymorphism is controlled by organic matrix macromolecules.

The direct negative impact of warming on photosynthetic energy storage efficiency of the algal symbionts has been measured by a novel application of photoacoustics. That method and the instrumentation developed for it has been patented and will be developed as a diver-operated device to monitor the health of corals, seaweeds and seagrasses affected by climate change and pollution. Different sensitivities among coral species to acidification and warming are emerging.

Have you conducted other tests into the impact of temperature that do not involve field trials?

We have designed and constructed a unique computerised aquaria facility that allows us to simulate different International Panel on Climate Change scenarios for 2100. These consist of various precise combinations of temperature and pH, on which seasonal light regimes are superimposed. In these aquaria, the responses of Mediterranean and Red Sea corals to subtle climate change are studied.

Are you collaborating with any other research groups or policy makers in order to collate and communicate the results of your efforts so far?

We are collaborating with socioeconomists to evaluate the effect of coral reef decline on dependent communities, and with groups studying related problems from different angles. Our colleagues include geochemists documenting the Panarea vents, and teams studying organisms such as calcifying algae and molluscs. We collaborate with marine botanists and experts in algal biotechnology studying the beneficial effects of ocean acidification on photosynthesis and the potential for algal-based biofuel ventures. We are also working to communicate the research-based knowledge, expertise and skills within our group to potential users of this knowledge including the scientific community, energy and environmental policy makers, industry, NGOs and the general public.

How do you expect these findings on the impact of acidification on coral to be used for the protection of coral reefs in the future?

We hope to identify sensitive and tolerant coral species, create refuges and gene banks of the endangered species, and use resilient ones for damaged reef remediation.

Studying coral **at depth**

Funding from the European Research Council has brought world-class scientists together to work on the innovative **CoralWarm** research programme. This cutting-edge study aims to understand how climate change is shaping the future of our coral reefs at a molecular level and beyond

CORAL REEFS ARE some of our most valuable marine ecosystems. They provide food and shelter to thousands of different plants and fish making them a top destination for scuba divers, fishing industries and scientists. Many coral thrive as a result of their symbiotic relationships with microalgae. These tiny plants provide energy to the coral through photosynthesis in return for a safe home within its structure. Their relationship is crucial to the corals' survival and in turn supports the wider ecosystems of which they are a vital part. However, thanks to the increasing acidification of our oceans due to global warming, this relationship is under threat.

As our oceans absorb more CO_2 their pH levels drop and the algae struggle to survive, leading to bleaching of the corals as they are gradually starved of energy. The destruction of coral reefs is devastating to the life forms and industries they support. The WWF predict that if current rates of destruction continue, 60 per cent of the world's coral reefs will be laid to waste in the next 30 years.

Against this context, scientists from Bar-Ilan University in Israel and the University of Bologna in Italy are working hard to understand the effects of ocean acidification on coral in more detail and to predict what the future holds for this vulnerable invertebrate. With funding from the European Research Council, they have established the CoralWarm project, which uses innovative tools and methods to explore these issues in impressive depth.

INTERDISCIPLINARY INNOVATIONS

Professor Zvy Dubinsky of the Mina and Everard Goodmand Faculty of Life Sciences at Bar-Ilan University and Professors Giuseppe Falini and Stefano Goffredo from the University of Bologna's Giacomo Ciamician Department of Chemistry and Department of Biological, Geological and Environmental Sciences, respectively, are leading the project. Their ambitious work involves collaboration with partners from a diverse range of disciplines including molecular biology, crystallography, biomineralisation, physiology, systems ecology and statistics. This unique combination allows them to integrate numerous factors and concepts to obtain the best possible prediction of the future of coral reefs.

Coral transplants at the natural CO_2 vents area in Panarea Island. The volcanic crater is a perfect underwater laboratory for experiments on ocean acidification effects on marine biodiversity.

CoralWarm stands out from previous studies thanks to an innovative approach which examines the links between changes to the corals at a molecular level and the wider environmental process of ocean acidification. The team's work focuses on key Mediterranean and Red Sea species and will result in the first projections of coral survival generated by investigating how the metabolic and skeletal processes are affected by their changing environment, not only in laboratory conditions but also in the field.

THE PANAREA EXPERIMENT

The perfect *in situ* test site was found in a recently formed volcanic crater in the Mediterranean Sea. The Panarea experiment began almost three years ago in this crater in the Tyrrhenian Sea near Sicily. Here, naturally occurring CO_2 vents provide a range of underwater pH levels so that the investigators can test the ecological reactions of different species of coral to changing levels of acidity. After two years of monitoring, the experiment has already yielded fruitful results.

To begin, samples of the selected species were transplanted to different sites with varying pH levels along the crater. Temperature and salt levels were carefully measured using state-of-the-art probes at regular intervals between July 2010 and June 2012. The area of the transects covered by the different species was measured three times, in July 2011, December 2011 and April-May 2012. This allowed the team to monitor how the coverage of the experimental

CoralWarm

CORALS AND GLOBAL WARMING: THE MEDITERRANEAN VERSUS THE RED SEA

OBJECTIVES

To generate for the first time projections of temperate and subtropical coral survival by integrating sub-lethal temperature increase effects on metabolic and skeletal processes in Mediterranean and Red Sea key species.

PARTNERS

Oren Levy; **David Iluz**; **Yulia Pinchasov**; **Yuri Kamenir**; **Keren Maor Landaw**; **Sarit Karako-Lampert**; **Michal Ramot**, Mina and Everard Goodmand Faculty of Life Sciences, Bar-Ilan University, Israel • **Estelle Waise**, EU Research Authority, Bar-Ilan University, Israel • **Simona Fermani**; **Michela Reggi**, Department of Chemistry, University of Bologna, Italy • **Francesco Zaccanti**; **Bruno Capaccioni**; **Erik Caroselli**; **Fiorella Prada**; **Valentina Airi**; **Francesca Gizzi**; **Chiara Marchini**, Department of Biological, Geological, and Environmental Sciences, University of Bologna, Italy • **Paola Fantazzini**; **Luca Pasquini**, Department of Physics and Astronomy, University of Bologna, Italy • **Francesca Sparla**, Department of Pharmacology and Biotechnology, University of Bologna, Italy • **Villiam Bortolotti**, Department of Civil, Environmental, and Materials Engineering, University of Bologna, Italy • **Verdiana Bandini**; **Paola Motetti**, EU Research Authority, University of Bologna, Italy

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ZVY DUBINSKY has an impressive CV, with around 200 published papers in peer-reviewed journals, among which top journals like *Nature* and *Proceedings of the National Academy of Sciences*. During his career, he has made significant contributions to fields such as the understanding of light energy utilisation of phytoplankton and zooxanthellae.

STEFANO GOFFREDO has developed original aspects in the interpretation of growth and population data, advancing population dynamics, reproductive biology and conservation monitoring, creating a novel school in Italy: the Marine Science Group, at the University of Bologna.

GIUSEPPE FALINI is Professor of Chemistry at the University of Bologna. He studied chemistry at the same university where he obtained his PhD in Chemical Sciences. Falini's research focuses on biomineralisation processes in molluscs and corals, the effects of global warming on calcifying organisms, and bio-inspired materials synthesis.

quadrants by the individual coral species varied according to acidity levels. Using a waterproof camera, photographs were taken of each test site for analysis by specialist digital software.

To complement these *in situ* experiments, other corals were monitored in aquariums designed to mimic conditions predicted by different International Panel on Climate Change scenarios. This allowed the team to control and measure the effect of increasing temperatures on the same coral species. The combination of laboratory and field tests confirmed their predictions that increasing acidity is dangerous to coral. Every aspect of their growth; mortality, reproduction, respiration, photosynthesis and biomass, was adversely affected by higher pH levels.

FASCINATING FINDINGS

All species, including a stony coral, a mollusc, two calcifying and one non-calcifying macro algae, were unable to survive in the most acidic zones. From this, it became clear that increasing levels of CO_2 irrevocably reshapes life at the bottom of the sea. There was, however, a ray of hope among the findings: "Interestingly, we have established that the presence of the algal symbionts endows corals with increased tolerance to acidification, in comparison with symbiont-lacking species," the researchers reveal. The results from the crater thus showed that certain species, such as *Lumbriculus Variegata*, can survive at higher levels of CO_2 than previously thought thanks to their algae partners, potentially crucial information when it comes to understanding the future for coral in our warming seas.

The Panarea experiment is thus likely to prove vital to monitoring the long-term effects of ocean acidification on sea-floor plants, animals and ecosystems. It allows scientists to integrate molecular knowledge of each coral species with their biochemical reactions to changes in their environment, be they rising temperatures or acidity levels. Coral growth is severely affected by changing conditions; increased acidity can erode the very structure and architecture of a coral colony. The team is working on new, more reliable, models to predict the impact of climate change on coral species and their prospects of surviving in our rapidly changing seas.

CoralWarm research team members in the field, at Panarea Island. **Front left**: Dr Oren Levy; **front right**: student Michal Grossowicz; **back left**: Stefano Goffredo; **back right**: Zvy Dubinsky.

ADAPTING TO AN UNCERTAIN FUTURE

The researchers remain realistic about the chances of reducing the impact of climate change: "Only political determination leading to replacement of fossil fuels and massive reforestation can stabilise atmospheric CO_2 levels in the long term (albeit at considerably higher than current concentrations), which leads us to predict higher seawater temperatures and further ocean acidification, causing a massive decrease in coral reefs in all oceanic domains," they state. However, their work will reveal which species of coral are the hardiest and therefore best suited for transplantation into areas where bleaching is threatening some of the ocean's most diverse ecosystems.

The interdisciplinary nature of the project has certainly provided great promise for future research; strong Italian-Israeli research links have been forged and already students are benefiting from the opportunities this relationship provides to train in exciting new approaches to marine research. Further experimentation will allow the collaborators to develop novel techniques so that coral can be cultivated in challengingly acidic conditions. Hopefully, thanks to CoralWarm, future generations will not miss out on the benefits and beauty of these complex organisms.

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