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UTILIZZO DI EMISSIONI VULCANICHE MARINE DI CO_2 PER LO STUDIO DEGLI EFFETTI DELL'ACIDIFICAZIONE SUL BENTHOS: ESPERIENZE AL CASTELLO ARAGONESE D'ISCHIA (MAR TIRRENO)

Abstract – *Current research into ocean acidification is mainly being carried out using short-term experiments whereby CO_2 levels are manipulated in aquaria and enclosures. We have adopted a new approach in our studies of the effects of ocean acidification on Mediterranean marine biodiversity by using volcanic carbon dioxide vent systems as 'natural laboratories' as they cause long-term changes in seawater carbonate chemistry. A range of organisms, including macroalgae, seagrasses, invertebrates, and selected scleractinians and bryozoans have now been investigated in a shallow area located off the island of Ischia (Castello Aragonese, Tyrrhenian Sea, Italy). Our in situ observations give support to concerns, based on model predictions and short-term laboratory experiments, that ocean acidification will likely combine with other stressors (e.g., temperature rise) to cause a decrease in Mediterranean marine biodiversity and lead to shifts in ecosystem structure.*

Key-words**:** *CO_2 vents, ocean acidification, pH, benthic organisms, biodiversity.*

Our seas currently absorb over 25 million tons of CO_2 every day. This has caused surface waters to become 30% more acidic since wide-spread burning of fossil fuels began (Doney *et al*., 2009). As well as lowering pH, increased pCO_2 levels are altering surface water chemistry with falling carbonate levels a major concern since these are the building-blocks of tests and skeletons for many marine organisms from tiny coccolithophores to giant coral reefs (Kleypas *et al.,* 2006). Current research into ocean acidification is mainly being carried out using short-term experiments whereby CO_2 levels are manipulated in aquaria and enclosure mesocoms (CIESM, 2008). We have adopted a new approach in our studies of the effects of ocean acidification on Mediterranean marine biodiversity by using volcanic carbon dioxide vent systems as 'natural laboratories' as they cause long-term changes in seawater carbonate chemistry (Hall-Spencer *et al*., 2008).

In this study system, volcanic vents occurred in shallow waters on the north and south sides of Castello Aragonese, island of Ischia (Tyrrhenian Sea, Italy), adjacent to a steeply sloping rocky shore emitting 1.4×10^6 $l d^{-1}$ of gas comprising 90-95% CO_2. At the south vent site, gas was emitted at mainly >5 vents m^{-2} whereas at the north vent site, gas was emitted at mainly <5 vents m^{-2} acidifying seawater along a pH gradient from 8.17 down to 6.57 for 300 m running parallel to the rocky shore on both sides of the Castello Aragonese (Hall-Spencer *et al*., 2008). Monitoring stations have been established along the pH gradient, where experimental transplants have been performed. Here we synthesise projects to date. Specific methods for each study can be found in the published papers (see references).

Macroalgae, seagrasses, invertebrates, scleractinians and bryozoans have been investigated in collaboration between the Stazione Zoologica Anton Dohrn, the Plymouth University (UK), the IAEA-Monaco (MC) and the ENEA-CRAM (La Spezia, Italy).

The most obvious effects on benthic plants and animals was that all calcifiers (coralline algae epiphytes on Posidonia oceanica leaves, molluscs, polychaete spirorbids, foraminifera) show an important reduction in abundance or are absent from the low pH areas (pH down to 6.6) reducing benthic biodiversity in the acidified zone (Hall-Spencer *et al*., 2008; Hall-Spencer & Rodolfo-Metalpa, 2008; Porzio *et al*., 2008; Martin *et al*., 2008; Cigliano *et al*., 2009 and unpublished data). A few species, including some macroalgae, crustacean peracarids and polychaetes were resilient to the low pH values predicted for the end of this century (Caldeira & Wickett, 2003), as well as lower values. While *P. oceanica* meadows survived in the vents areas, and shoot density remained high at low pH, the daily leaf growth rate was lower compared to plants growing at normal local pH and no difference in the photosynthetic performances was detected in comparison to normal pH exposed plants (Buia *et al*., 2009).

Some experiments were conducted on selected scleractinians and on the calcitic bryozoan *Myriapora truncata* (Pallas) transplanted to normal, low, and extremely low pH conditions (Rodolfo-Metalpa *et al.,* 2010). In extremely low pH (mean pH 7.43) dead skeletons of both scleractinians and the bryozoan dissolved rapidly and, although the live bryozoans gained weight in these conditions, the net calcification rates of live specimens were significantly lower than at normal pH. Moreover, in the live specimens the organic tissue covering the skeleton was still present when exposed to the acidic conditions reflecting a possible role of organic tissues in protecting the skeleton (Rodolfo-Metalpa *et al.,* 2010). Therefore, while the bryozoan seemed to be quite resilient to low pH, they died at the end of an unusually warm summer during the experiment in 2008, by the combination of both stressors.

Overall, our *in situ* observations give support to concerns, based on model predictions and short-term laboratory experiments, that ocean acidification, especially when combined with other stressors (e.g., temperature rise), will cause a decrease in Mediterranean marine biodiversity and lead to shifts in ecosystem structure. Further studies are in progress on plant and animal species to test eco-physiological responses to increased pCO_2. Although the CO_2 venting sites, such as the Castello d'Ischia example, are not precise analogues of global-scale ocean acidification, due to their localised nature and relatively high temporal variability in pH, nonetheless they can provide information about the ecological effects of long-term exposures to high CO_2 levels that encompass the life cycles of interacting macrobenthic organisms as they include the feedbacks and indirect effects that occur within natural marine systems (Hall-Spencer *et al*., 2008).

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