

# Enhanced ecotoxicity of Gadolinium in a warmer and acidified changing ocean using a multibiomarker approach: the case of the surf clam *Spisula solida*

Cátia Figueiredo <sup>a,b</sup>, Tiago F. Grilo <sup>c</sup>, Rui Oliveira <sup>b</sup>, Inês João Ferreira <sup>d</sup>, Fátima Gil <sup>e</sup>, Clara Lopes <sup>a,b</sup>, Pedro Brito <sup>a,b</sup>, Pedro Ré <sup>c</sup>, Miguel Caetano <sup>a,b</sup>, Mário Diniz <sup>d,f</sup>, Joana Raimundo <sup>a,b</sup>

<sup>a</sup> CIIMAR – Interdisciplinary Centre of Marine and Environmental Research, Avenida General Norton de Matos S/N, 4450-208 Matosinhos, Portugal  
<sup>b</sup> Division of Oceanography and Marine Environment, IPMA – Portuguese Institute for Sea and Atmosphere, Av. Alfredo Magalhães Ramalho, 6, Algés 1495-165, Portugal  
<sup>c</sup> MARE - Marine and Environmental Sciences Centre, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Lisboa 1749-016, Portugal  
<sup>d</sup> Associate Laboratory I4HB - Institute for Health and Bioeconomy, School of Science and Technology, NOVA University Lisbon, Caparica 2819-516, Portugal  
<sup>e</sup> Aquário Vasco da Gama, Rua Direita do Dafundo, Cruz Quebrada 1495-718, Portugal  
<sup>f</sup> LAQV-REQUIMTE, Chemistry Department, NOVA School of Science and Technology, Caparica 2829-516, Portugal  
<sup>g</sup> UCIBIO – Applied Molecular Biosciences Unit, Department of Chemistry / Department of Life Sciences, School of Science and Technology, NOVA University Lisbon, Caparica 2819-516, Portugal  
 \*catia.figueiredo@ipma.pt

## Introduction

Humans have exhaustively combusted fossil fuels, and released pollutants into the environment, at continuously faster rates resulting in global average temperature increase and seawater pH decrease.

In a worst-case scenario (i.e., SSP5-8.5), by the end of the 21st century, an increase of up to 3.3–3.9 °C and a decrease of 0.3–0.4 pH units is likely to take place in the Mediterranean Sea and North Atlantic Ocean



Sc	Y	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	U
17 Rare Earth																	

The escalating applications of REE and lack of regulation on usage and discharge has categorized these elements as contaminants of emergent concern

Several advanced and modern-day technologies are increasingly reliant on these elements for the manufacture of batteries, lasers, magnets, superconductors, and various others.

Gadolinium is extensively used as in magnetic resonance imaging (MRI) as an injected contrast with paramagnetic features. Here, this element is required to be applied complexed to safeguard the recognized toxic effects of Gd<sup>3+</sup>

The limited literature on Gd-induced environmental hazards shows how Gd toxicity has been understudied by the scientific community

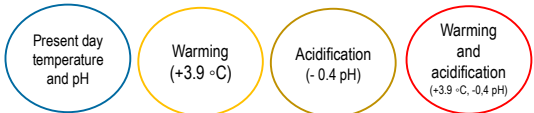
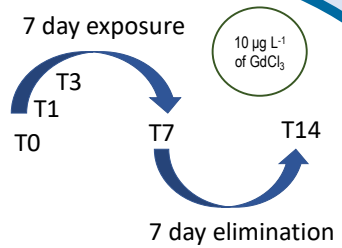


## Objective

Explore the effects, combined and as single stressors, of ocean warming, acidification, and Gd (10 µg L<sup>-1</sup>) on the accumulation, elimination and biochemical performance of the bivalve *Spisula solida*



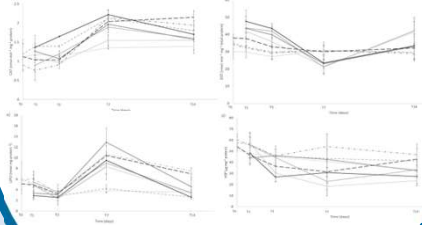
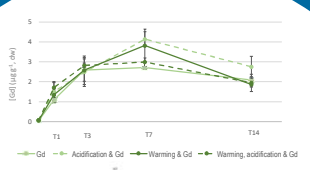
## Materials and Methods



We exposed surf clams to 10 µg L<sup>-1</sup> of GdCl<sub>3</sub> for seven days, under warming, acidification, and their combination, followed by a depuration phase lasting for another 7 days and investigated the Gd bioaccumulation and oxidative stress-related responses after 1, 3 and 7 days of exposure and the elimination phase.



## Results and Discussion



Warming and acidification, and their interaction, did not significantly impact Gd concentration. However, there was a significant interaction on clam's biochemical response.

*Spisula solida* accumulated Gd after just one day. Gadolinium was not eliminated after 7 days, and elimination is further hampered under climate change scenarios.

The augmented total antioxidant capacity and lipid peroxidation values show that the significant impacts of Gd on the oxidative stress response are enhanced under warming.

The increased superoxide dismutase and catalase values demonstrate the combined impact of Gd, warming & acidification.

Ultimately, lipid damage was greater in clams exposed to warming & Gd. The biochemical response was triggered, however damage occurred.

## Conclusion

The results highlight the enhanced toxic effects of Gd in a changing world