

A TRIPLE THREAT: OCEAN WARMING, ACIDIFICATION, AND RARE EARTH ELEMENTS EXPOSURE TRIGGERS A SUPERIOR ANTIOXIDANT RESPONSE AND PIGMENT PRODUCTION IN THE ADAPTABLE *ULVA RIGIDA*

Cátia Figueiredo ^{a,b*}, Tiago F. Grilo ^c, Rui Oliveira ^b, Inês João Ferreira ^d, Fátima Gil ^e, Clara Lopes ^{a,b}, Pedro Brito ^{a,b}, Pedro Ré ^c, Miguel Caetano ^{a,b}, Mário Diniz ^{d,f}, Joana Raimundo ^{a,b}

^a CIIMAR – Interdisciplinary Centre of Marine and Environmental Research, Avenida General Norton de Matos S/N, 4450-208 Matosinhos, Portugal
^b Division of Oceanography and Marine Environment, IPMA – Portuguese Institute for Sea and Atmosphere, Av. Alfredo Magalhães Ramalho, 6, Algés 1495-165, Portugal
^c MARE - Marine and Environmental Sciences Centre, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, Lisboa 1749-016, Portugal
^d Associate Laboratory i4HB - Institute for Health and Bioeconomy, School of Science and Technology, NOVA University Lisbon, Caparica 2819-516, Portugal
^e Aquário Vasco da Gama, Rua Direita do Dafundo, Cruz Quebrada 1495-718, Portugal
^f LAQV-REQUIMTE, Chemistry Department, NOVA School of Science and Technology, Caparica 2829-516, Portugal
^g 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

Elements from Lanthanum to Lutetium are usually referred to as **Rare Earth Elements (REE)**



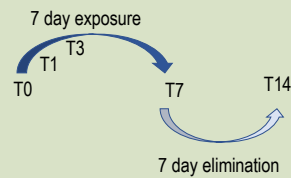
Poorly known combined effects of climate change and increasing REE availability

REE are essential for:

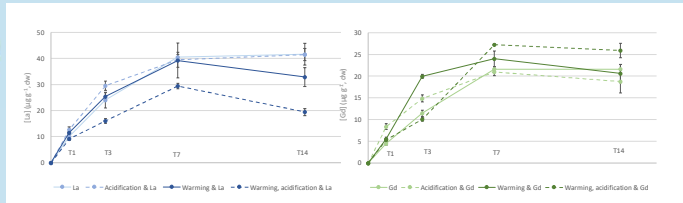
- modern electronic technology
- medical and industry products
- agriculture
- aquaculture

METHODS

[Lanthanum] = 15 µg L⁻¹ or [Gadolinium] = 10 µg L⁻¹
 + Ocean warming (+4°C)
 + Ocean acidification (~900 µatm)
 + Ocean warming and acidification (+4°C, ~900 µatm)



RESULTS



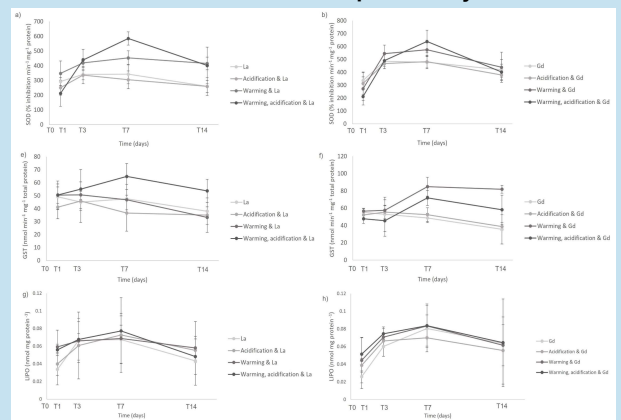
The exposure to La and Gd triggered the activation of the antioxidant defence system, and this response seems to be quicker in the case of Gd exposure.

Lanthanum and Gd triggered an **adequate activation of the antioxidant defence system**, by avoiding lipid damage.

After one day of experiment La and Gd clearly showed accumulation/adsorption in different patterns, at future conditions.

Unlikely for Gd, **Warming and Acidification contributed to the lowest La accumulation, and increased elimination.**

La and Gd are not proficiently eliminated.



CONCLUSION

REE exposure, in a near-future scenario, triggered an overproduction of ROS that requested an enhanced antioxidant response. Additionally, an increase in total chlorophyll and carotenoids could indicate an unforeseen energy expense in response to a multi-stressor environment. **These enhanced energy requirements may impose downstream impacts on species fitness.**