Marine Ecological Modelling Global Climate Change

Potential applications of Ecological Niche Modelling

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Ecological Niche Modelling

Widely used in conservation biology, ecology and evolution:

1. Understand the environmental drivers of species distributions.

2. Identify areas that should be prioritised for conservation (e.g., where endangered or ecosystem structuring species occur).

3. Predict how biodiversity will be affected by climate change.

4. Evaluate the potential of invasive species to settle in new areas.

Relationship between occurrence and the environment

Contents lists available at ScienceDirect

Marine Environmental Research

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Environmental drivers of rhodolith beds and epiphytes community along the South Western Atlantic coast

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ABSTRACT

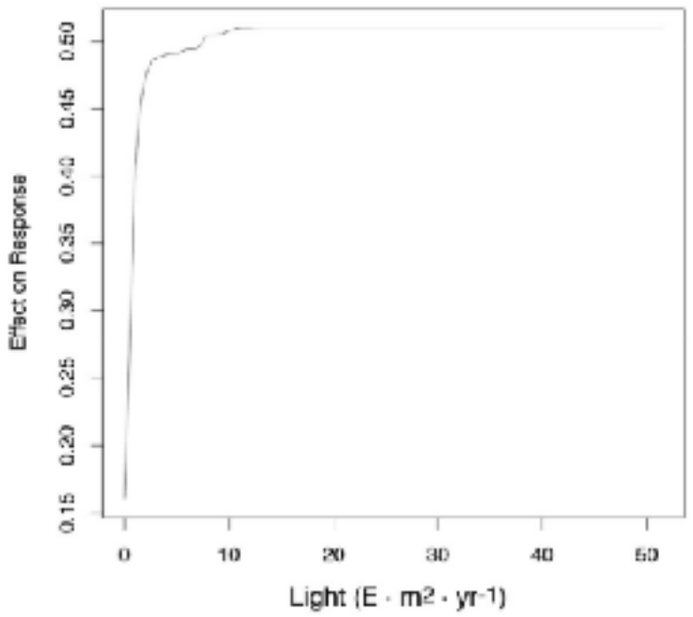
Environmental conditions shape the occurrence and abundance of habitat-building organisms at global scales. Rhodolith beds structure important hard substrate habitats for a large number of marine benthic organisms. These organisms can benefit local biodiversity levels, but also compete with rhodoliths for essential resources. Therefore, understanding the factors shaping the distribution of rhodoliths and their associated communities along entire distributional ranges is of much relevance for conservational biology, particularly in the scope of future environmental changes. Here we predict suitable habitat areas and identify the main environmental drivers of rhodoliths' variability and of associated epiphytes along a large-scale latitudinal gradient. Occurrence and abundance data were collected throughout the South-western Atlantic coast (SWA) and modelled against high resolution environmental predictors extracted from Bio-Oracle. The main drivers for rhodolith occurrence were light availability and temperature at the bottom of the ocean, while abundance was explained by nitrate,

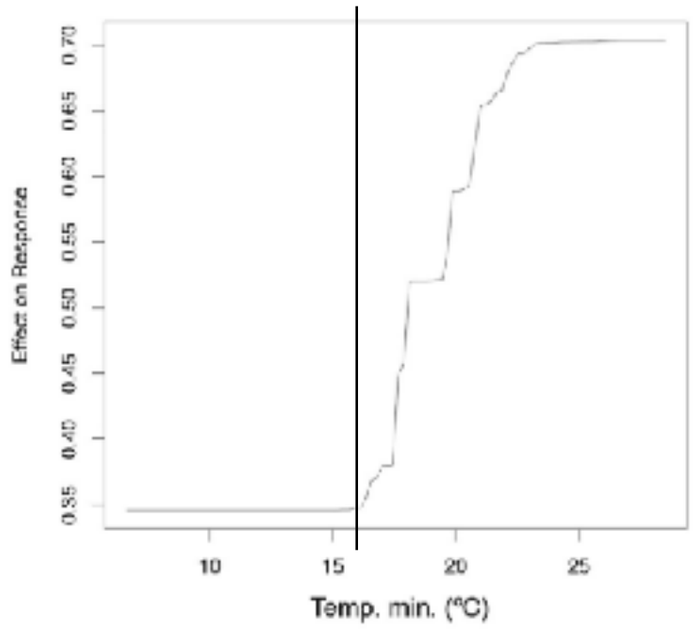
Rationale: Rhodolith beds structure important hard substrate habitats for a large number of organisms. But their **deep and cryptic occurrence hinders knowledge about where they are, and about the factors shaping their distribution**.

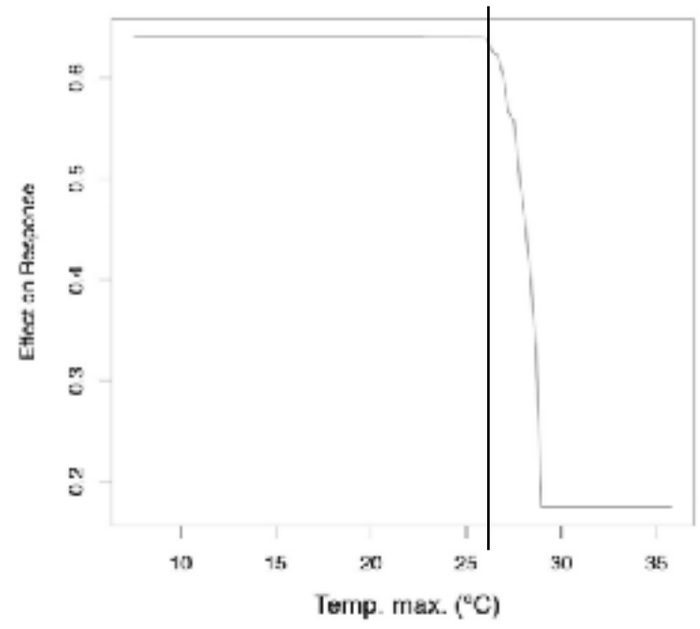
Goal: **Predict suitable habitat areas and identify the main environmental drivers of rhodoliths**.

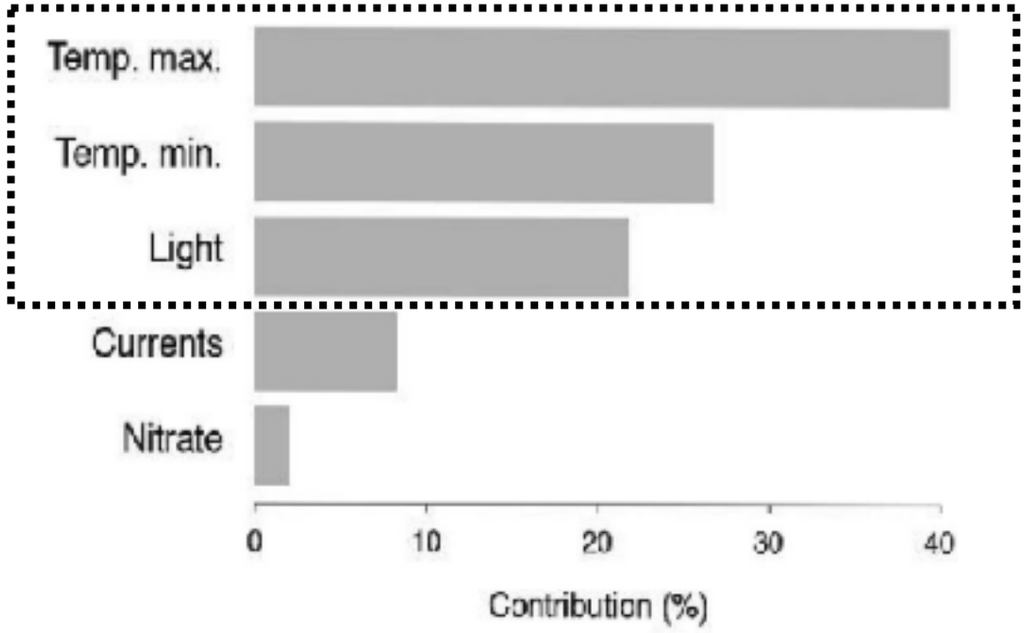
Methods

Occurrence records collected throughout the coast of Brazil and **modelled them against high resolution** environmental **predictors extracted from Bio-Oracle**.



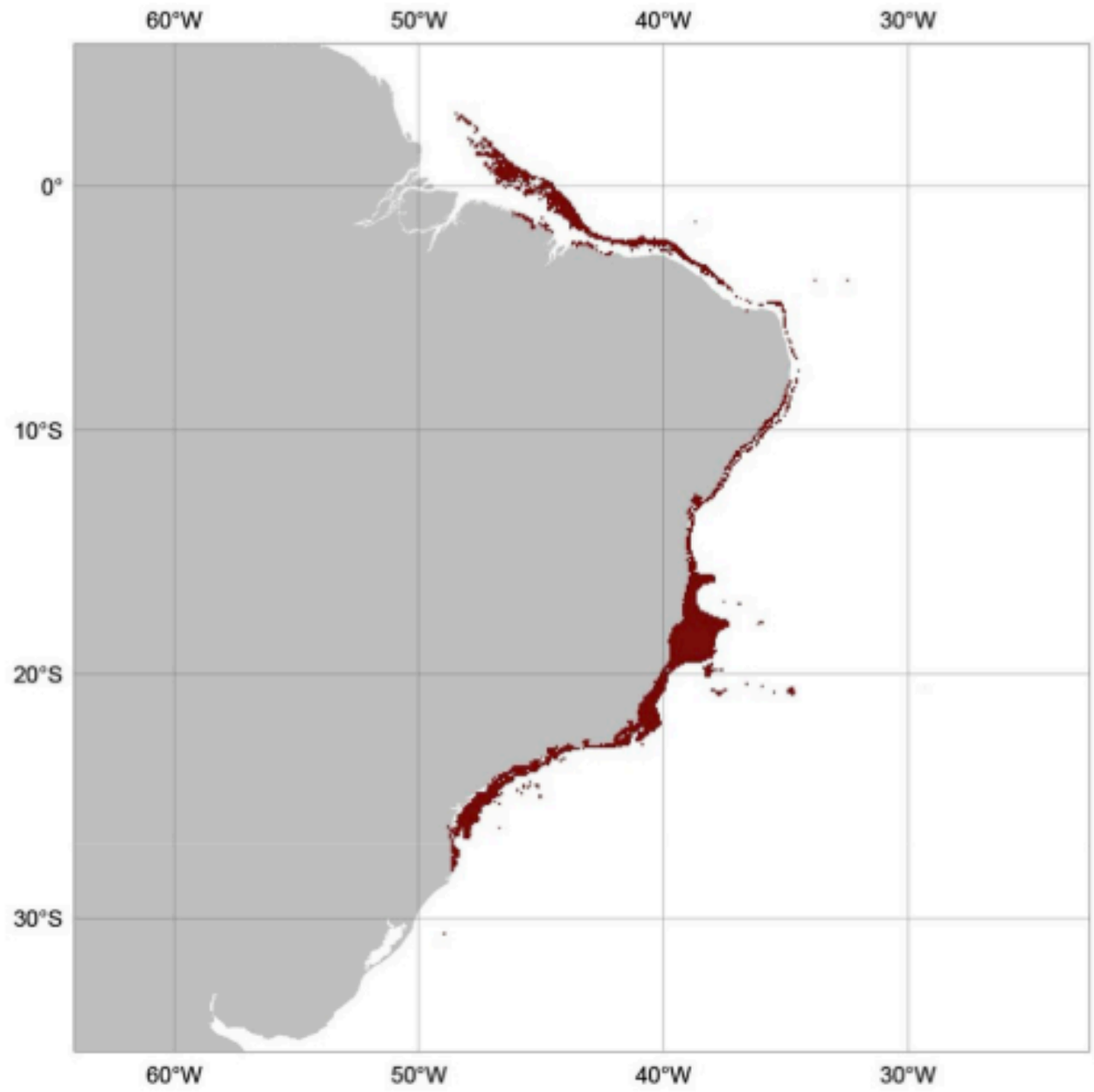






Results

Main drivers for rhodolith occurrence were **light availability and temperature**, with **clear ecological responses explained by additional empirical studies.**



Results

The Brazilian tropical-temperate region provides broad suitable areas for rhodoliths, decreasing toward extreme warm and cold regions.

Brazil oil spill response: Protect rhodolith beds

In his News In Depth story "Mystery oil spill threatens marine sanctuary in Brazil" (8 November 2019, p. 672), H. Escobar highlights important ecosystems that have been affected by the spill. However, he did not mention the Brazilian rhodolith beds—the most extensive, abundant, and diverse biogenic carbonate habitats in the South Atlantic (*1*). The oil spill severely threatens these ecosystems, which comprise a staggering 2 x 10^{11} tons of carbonatic bank (*2*), stretch from 5°N to 27°S along the Brazilian coast, and cover a seabed potential area of 229,000 km^2 (*1*).

Brazil's rhodolith beds are recognized as an oasis of diversity (*3*). Although they harbor species of great economic and ecological value, they remain unprotected. The oil pollution will likely cause major socio-environmental and economic losses, similar to those caused by the Deepwater

Identify areas that should be prioritised for conservation

SCIENTIFIC REPORTS

OPEN

Overlooked habitat of a vulnerable gorgonian revealed in the Mediterranean and Eastern Atlantic by ecological niche modelling

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Joana Boavida[*,†], Jorge Assis[*], Inga Silva[*] & Ester A. Serrão

Factors shaping the distribution of mesophotic octocorals (30–200 m depth) remain poorly understood, potentially leaving overlooked coral areas, particularly near their bathymetric and geographic distributional limits. Yet, detailed knowledge about habitat requirements is crucial for conservation of sensitive gorgonians. Here we use Ecological Niche Modelling (ENM) relating thirteen environmental predictors and a highly comprehensive presence dataset, enhanced by SCUBA diving surveys, to investigate the suitable habitat of an important structuring species, *Paramuricea clavata*, throughout its distribution (Mediterranean and adjacent Atlantic). Models showed that temperature (11.5–25.5 °C) and slope are the most important predictors carving the niche of *P. clavata*. Prediction throughout the full distribution (TSS 0.9) included known locations of *P. clavata* alongside with previously unknown or unreported sites along the coast of Portugal and Africa, including seamounts. These predictions increase the understanding of the potential distribution for the northern Mediterranean and indicate

Rationale: **The distribution of corals remain poorly understood, potentially leaving overlooked distributions**, particularly in unsurveilled regions (bathymetric and geographic regions).

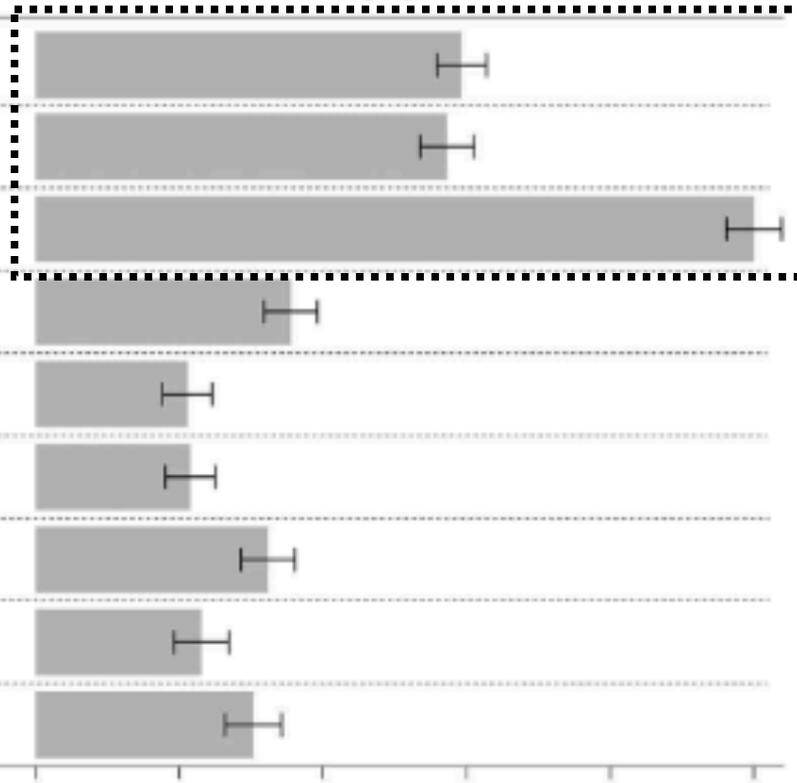
But this information **is crucial for corals' conservation.**

Goal: **Investigate the distribution of suitable habitats of an important structuring species for proper conservation.**

Methods

Occurrence records collected throughout the entire Mediterranean and Atlantic distribution and **modelled against high resolution environmental predictors extracted from Bio-Oracle**.

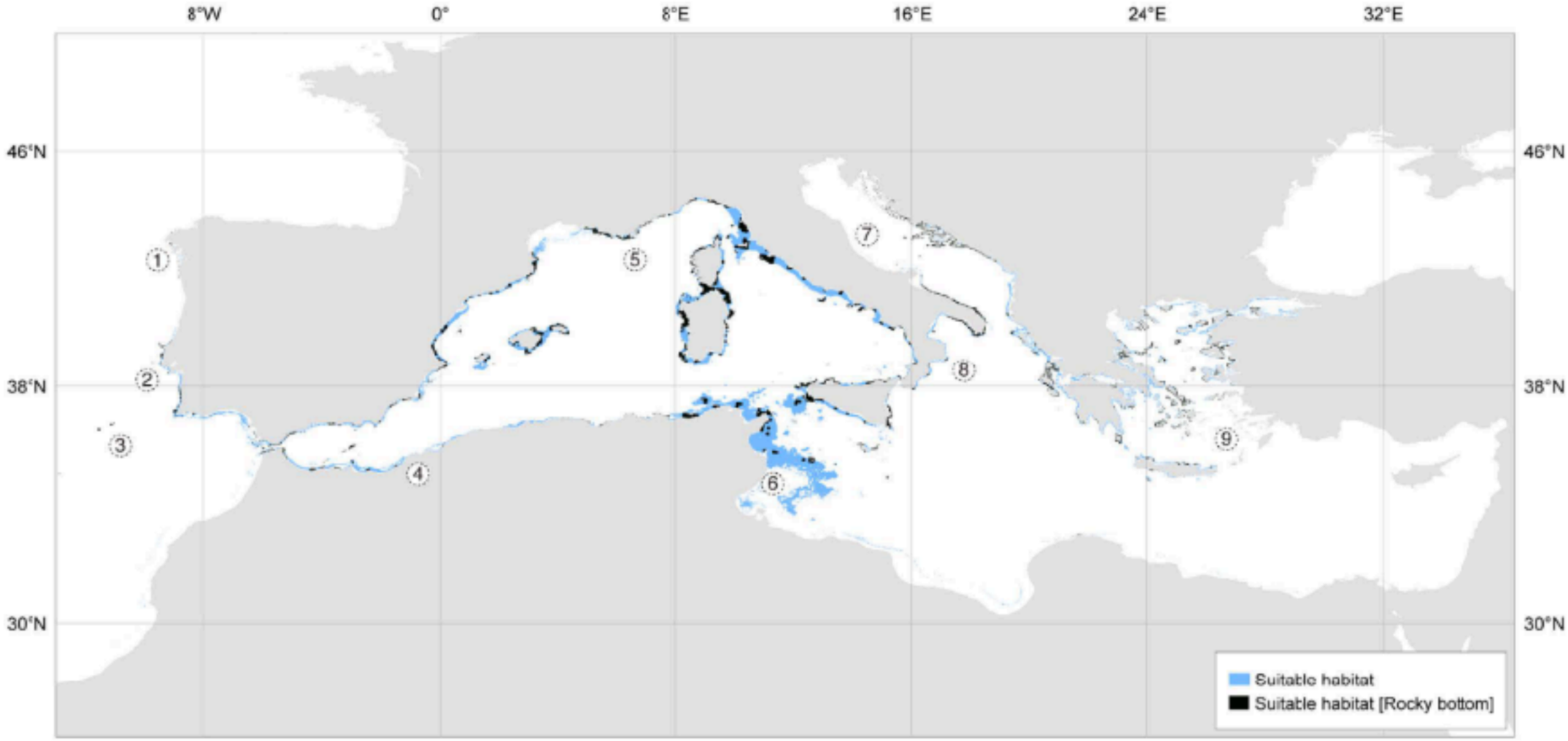
Predictor (unit)	Oc. range	LP model	LP literature	Relative contribution(%)
Temperature min. (°C)	11.4 - 16.0	<11.5	<12.0 [1,2]	
Temperature max. (°C)	14.1 - 24.4	>25.5	>25.0 [1,3,4]	
Slope (degree)	$3.2e^{-2}$ - 22.2	<0.1	steep [1]	
Silicate max. (µmol/L)	1.6 - 19.9	>20.1		
Productivity min. (gC/m^3/day)	$7.5e^{-6}$ - $3.3e^{-3}$	$<4.0e^{-6}$		
Phosphate min. (µmol/L)	$1.6e^{-4}$ - 0.5	$<2.2e^{-5}$	< 0.08 [5]	
Phosphate max. (µmol/L)	$2.4e^{-2}$ - 0.77	>0.6		
Nitrate min. (µmol/L)	$1.0e^{-6}$ - 5.2	$<7.2e^{-7}$	< 2.0 [5]	
Nitrate max. (µmol/L)	$2.5e^{-3}$ - 10.9	>5.4		



[1] Garrabou et al. (2002); [2] Gori et al. (2013); [3] Kipson et al. (2012); [4] Bally & Garrabou (2007)
[5] Peaks in mean annual values for the Medes islands in the Mediterranean (Ballesteros, 2006)

Results

Models showed that **temperature (11.5–25.5°C) and slope (steep underwater walls) are the most important predictors shaping the distribution of the coral.**



Results

Predictions increase our **understanding in the northern Mediterranean**, and in **previously unknown habitats along Algeria, Alboran Sea and adjacent Atlantic**, which **encouraged deep diving exploration** (NGS) to confirm its existence.

Predict the impacts of global climate change

SCIENTIFIC REPORTS

OPEN

Major shifts at the range edge of marine forests: the combined effects of climate changes and limited dispersal

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Global climate change is likely to constrain low latitude range edges across many taxa and habitats. Such is the case for NE Atlantic marine macroalgal forests, important ecosystems whose main structuring species is the annual kelp *Saccorhiza polyschides*. We coupled ecological niche modelling with simulations of potential dispersal and delayed development stages to infer the major forces shaping range edges and to predict their dynamics. Models indicated that the southern limit is set by high winter temperatures above the physiological tolerance of overwintering microscopic stages and reduced upwelling during recruitment. The best range predictions were achieved assuming low spatial dispersal (5 km) and delayed stages up to two years (temporal dispersal). Reconstructing distributions through time indicated losses of ~30% from 1986 to 2014, restricting *S. polyschides* to upwelling regions at the southern edge. Future predictions further restrict populations to a unique refugium in northwestern Iberia. Losses were dependent on the emissions scenario, with the most drastic one shifting ~38% of the current distribution by 2100. Such distributional changes might not be rescued by

Rationale: **Global climate change may produce local population extinctions.** An important case study are Atlantic marine forests of macroalgae, which are important ecosystems that need to be conserved.

Goal: **Predict future shifts in the distribution of marine forests.**

Methods

Records collected by field sampling and **modelled against high resolution environmental predictors.**

Results

Future predictions showed populations restricted to a unique refugium in northwestern Iberia, with losses by 2100 in Africa, SW and NE Iberia.

Losses dependent on the emission scenario, with the most drastic one shifting RCP8.5 leading to extinction in the orders of ~38% by 2100.

Evaluate new areas for invasive species

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How experimental physiology and ecological niche modelling can inform the management of marine bioinvasions?

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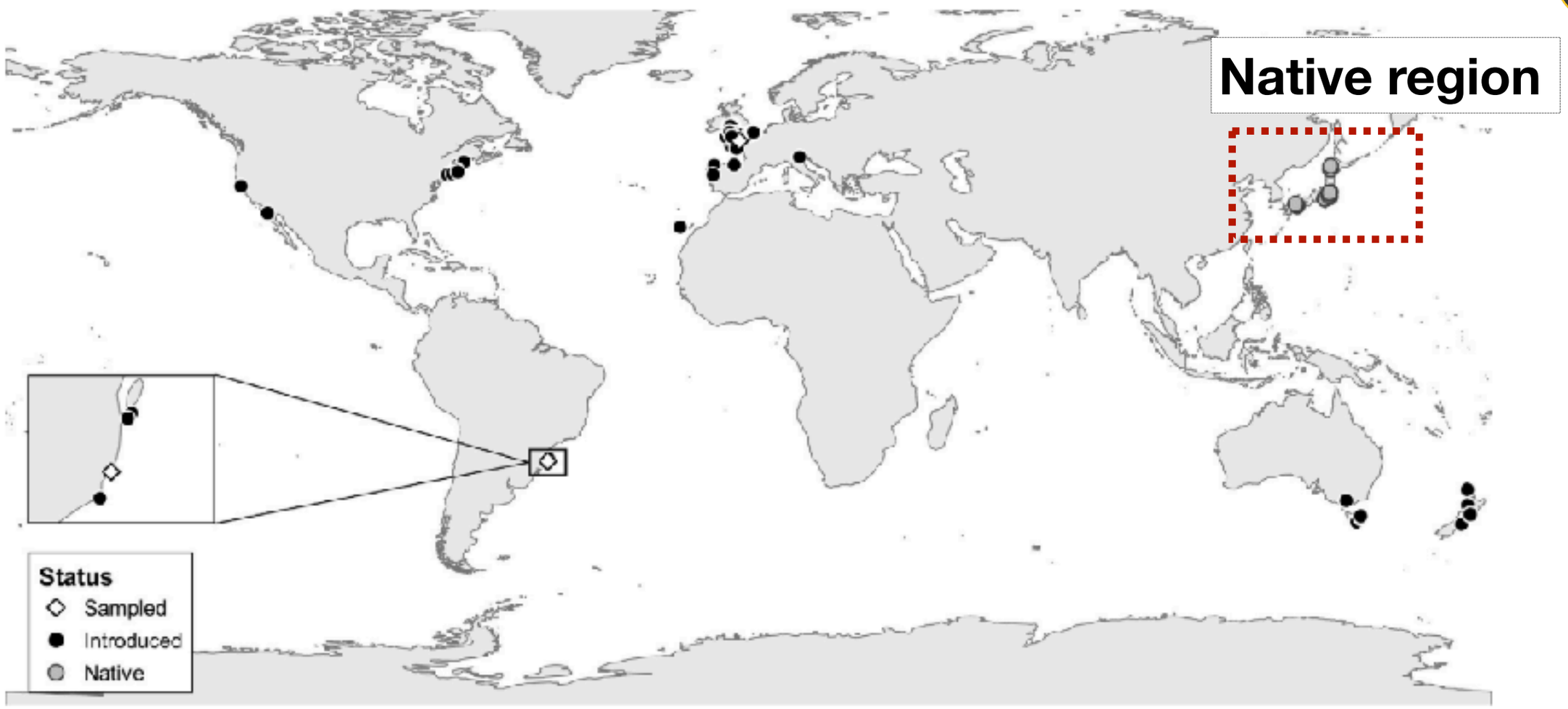
HIGHLIGHTS

- An Ecological Niche Model was built to explore the distribution of an invasive alga.
- Model results were crosschecked with ecophysiological evaluations.
- *G. furcata* has higher habitat suitability in warm temperate and temperate regions.
- Management and conservation

GRAPHICAL ABSTRACT

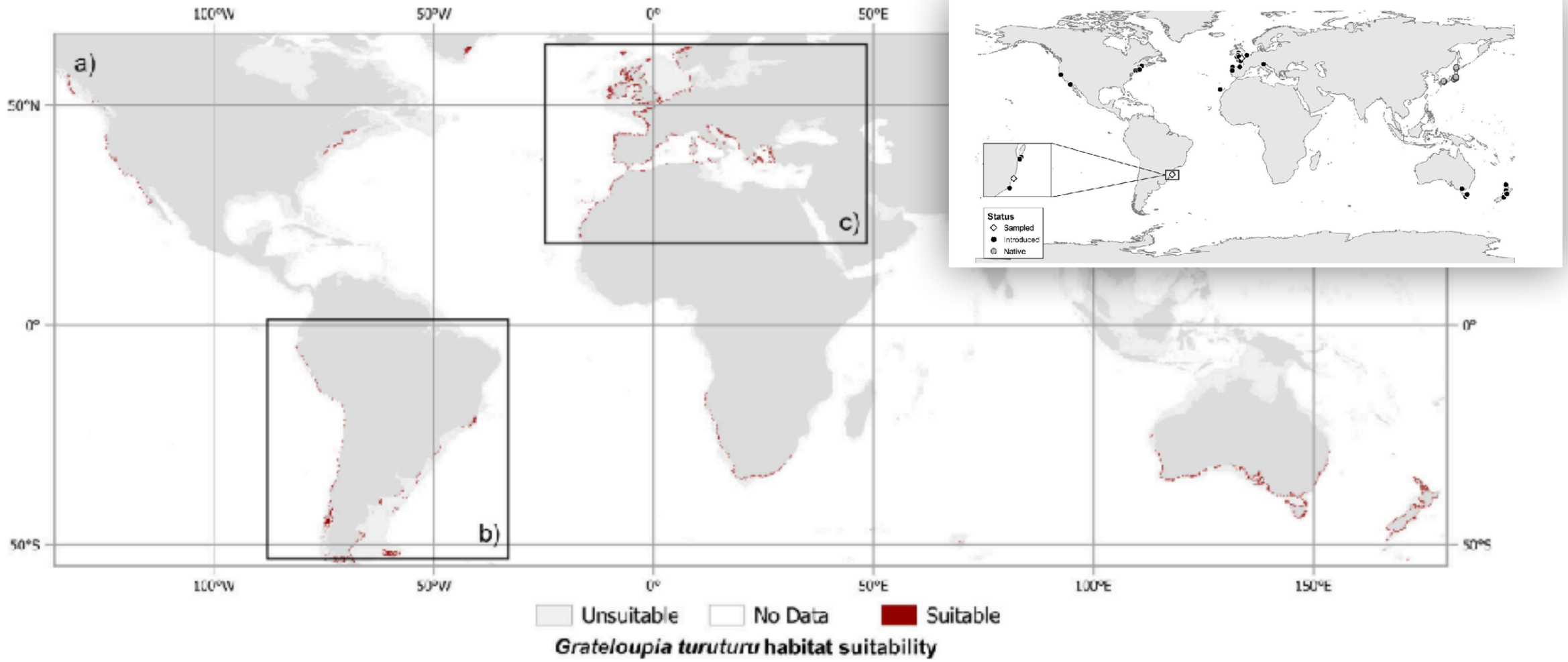
Rationale: **Providing information about species with high invasive potential is crucial to inform management decisions** aiming to prevent their arrival and spread. *Grateloupia turuturu*, one of the most harmful invasive species capable of causing massive biodiversity losses.

Goal: **Infer the potential global distribution of G. turuturu to assess potential areas of new introductions**.



Methods

Records collected by field sampling and the available literature, and **modelled high resolution environmental predictors extracted from Bio-Oracle**.



Results

High suitability in temperate and warm regions around the world, with **focus on areas where this species still doesn't occur.**

Management initiatives must be fostered **to mitigate anthropogenic transport and promote eradication**, with **focus in the South America, South Africa and Western Australia.**