Thermal performance approach improves the accurate prediction of species distribution in nature: the case of the mediterranean mussel *Mytilus galloprovicincialis* (Lamarck, 1819).

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Introduction

Biodiversity is widely acknowledged as a fundamental provider of ecosystem services, influencing productivity, nutrient cycling, resilience and resistance to disturbances. Conversely, climate change has emerged as a significant force shaping biodiversity by affecting individual life histories. The impacts of climate change - such as rising temperatures, acidification, and sea level rise - alter physiological, demographic, and community-scale processes by driving shifts in the distribution and functioning of key species. During the Mediterranean hot seasons, intertidal organisms, living on the edge between high and low tidal marks, are often exposed to considerable environmental fluctuations. These fluctuations influence individual body temperatures, leading to short-term (acclimation, phenotypic plasticity) or long-term (adaptation, selection, changes in distribution) responses. The Mediterranean mussel, *Mytilus galloprovincialis* (Lamarck, 1819), is a key species in marine ecosystems and a valuable bioindicator for environmental changes. These mussels have been extensively used as model organisms in physiological, genetic and ecological research. Furthermore, they are included in the European Marine Strategy Framework Directive (MSFD, Descriptor 9, EU 2008), and are recognised as important bio-indicators for assessing site-specific environmental conditions, helping to meet the EU Good Environmental Status (GES) criteria.

Methods

In this study, M**editerranean mussels (***Mytilus galloprovincialis)* of similar size (45-55 mm) were sampled from the Faro Lake aquaculture facility in Sicily, Italy, to investigate their **thermal performance curve (TPC)** using respiration rates as a proxy for individual metabolism. Fourteen different temperatures, ranging from 8°C to 34°C, were tested. Oxygen consumption was standardized based on individual dry weights. A total of 24 TPC models were fitted using nonlinear least squares regressions through the *rTPC* and *nls.multistart* R packages. The TPC model parameters were subsequently used to predict the potential occurrence of *M. galloprovincialis* under current climatic conditions and the RCP 4.5 scenario for 2050. Respiration rates were then converted into the **probability of occurrence** at different temperatures and at pixel level, using raster layers of seasonal environmental data (spring, summer, autumn, winter), generating four **thermal habitat suitability maps** for each scenario.

Results

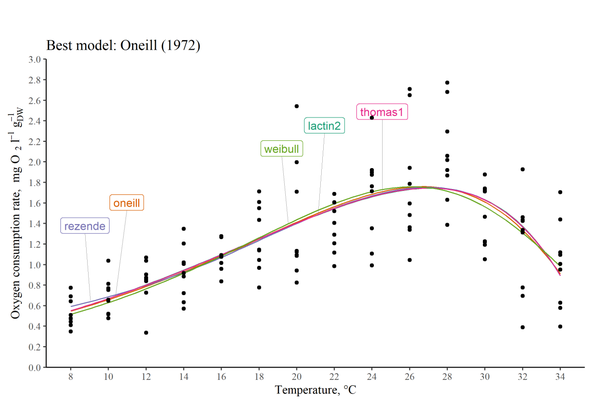

Fig. 1 Model selection

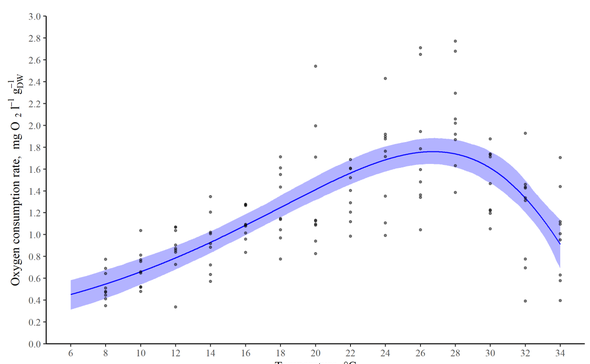

Fig. 2 TPC curve

Fitted models (Fig. 1) were compared using Akaike's Information Criterion (AIC), with the best model selected based on the lowest AIC value. This process identified the Oneill (1972) model as the best fit. Experimental results and modelling identified a left-skewed curve (Fig. 2), with the **thermal optimum (T_{opt})** at **26.7 °C** and the **critical thermal maximum (CT_{max}) at 36.06 °C**. These outcomes classify *M. galloprovincialis* as a thermo-tolerant species, well-adapted to warmer waters, particularly those of the Mediterranean Sea, where it lives near or slightly below its thermal optimum. Our results suggests that the entire Mediterranean basin may provide suitable conditions for *M. galloprovincialis*, though the potential seasonal occurrence may vary across the basin. The lowest suitability is observed in the **northern Adriatic Sea, in the Gulf of Lion** and **in the Marmara Sea** during **cold seasons** (Fig. 3). In contrast, projections under the RCP 4.5 scenario for 2050 indicate potentially higher suitability in the same sector (Fig. 4).

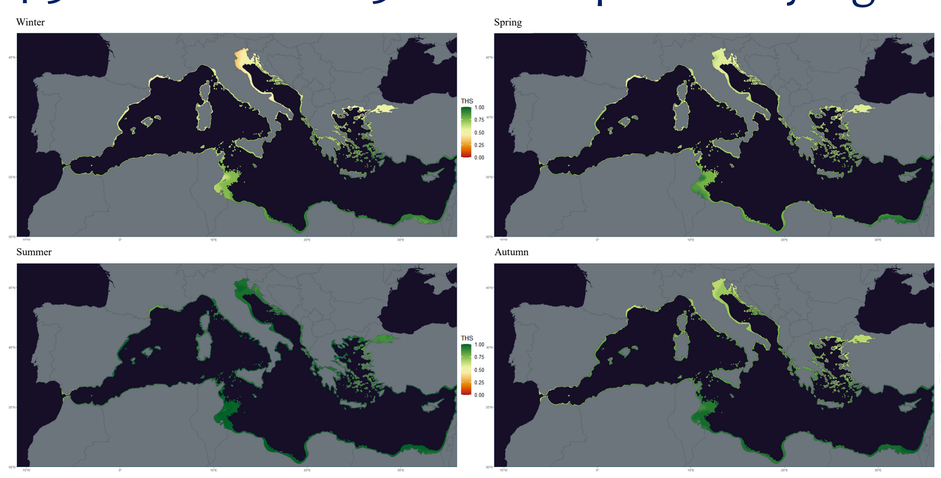

Fig. 3 Current scenario (2021-2023 data)

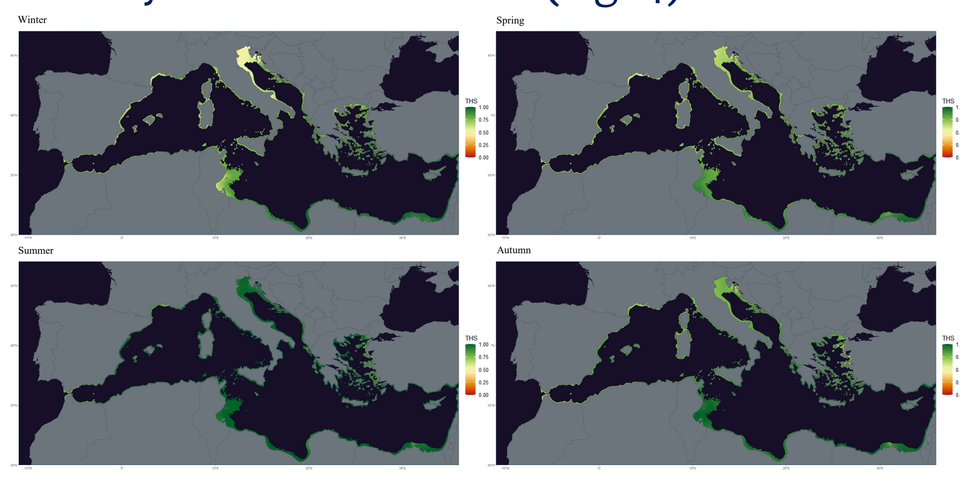

Fig. 4 2050 RCP 4.5 Scenario

Conclusions

Temperature is a key factor in regulating biological processes across all levels of ecological organisation. Thermal performance curves capture this relationship by quantifying how an ectotherm's **body temperature** affects its **performance** or **fitness**, thereby **predicting individual responses** to environmental fluctuations. In the context of climate change, understanding species' thermal thresholds is crucial for assessing the impact of temperature on **Life History traits** and individual performance, both from a **conservation** standpoint and within an **aquaculture** framework.

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