Thermal Tolerance Landscapes Forecast Landscape-scale Mortality Of A Gorgonian Coral During Marine Heatwaves

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INTRODUCTION

- Marine heatwaves (MHWs) are extreme thermal events exacerbated by climate change.
- Predicting biological responses under extreme MHWs without historic analogs requires **a mechanistic modeling approach**.
- **The red gorgonian *P. clavata* has been particularly affected by MHWs** in the western Mediterranean, exhibiting extensive colony necrosis in response to heat stress.
- Understanding population dynamics in response to MHWs requires an understanding of 1) **the mortality from individual MHW events**, and 2) the **likelihood of populations experiencing a severe event**.

GOALS

1. What are the 'riskiest' heatwaves, as determined by MHW exposure probability and mortality severity?
2. What features of MHWs contribute most to increasing colony necrosis?

APPROACH

Thermal Tolerance Landscapes (**TTLs**; Rezende et al. 2014)

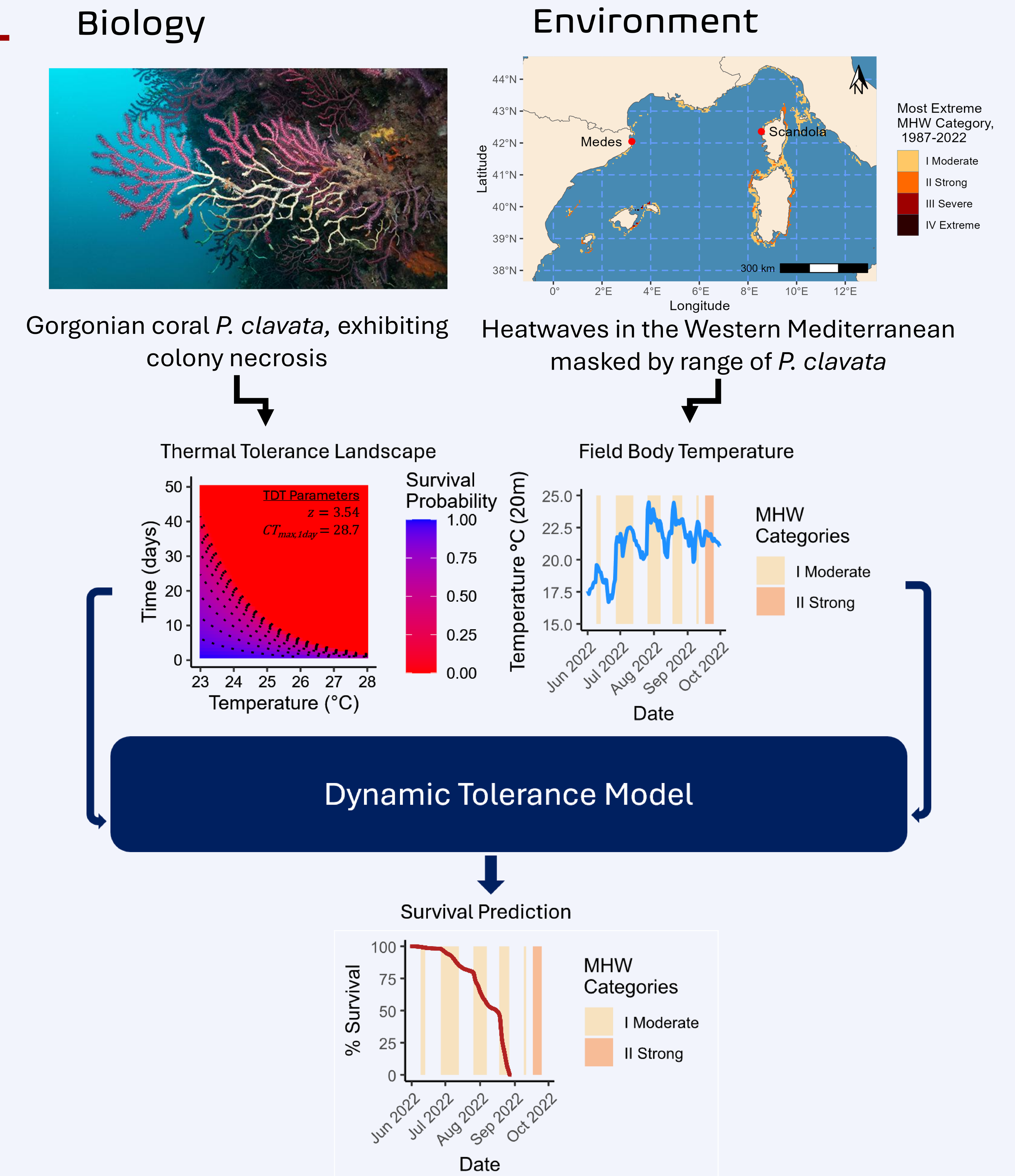
- **Response-surface approach** to describing mortality probability.
- Described by a **semilogarithmic relationship** between time τ and temperature T: $log10(\tau) = \beta_0 + \beta_1 T$

Predicting dynamic survival

- We constructed a TTL (data from Crisci et al. 2011) for the Mediterranean gorgonian *P. clavata.*
- We used a **dynamic tolerance model to predict survival *S*** over modeled and observed ocean temperature: $S_n = \sum_{i=1}^{n} \tau_i \cdot 10^{\beta_1 (T_i - T_n)}$

Measuring thermal risk

- We used **temperature data at a standard depth** (Copernicus MedPhysics, 20m) across the western Mediterranean, **extracted 125,745 MHWs within the species range** (ENM from Figuerola-Ferrando et al. 2025) across 38 years, and **predicted colony necrosis over each MHW.**
- We calculated **MHW event density across mortality severity categories and conducted an elasticity analysis** to determine when MHW magnitude and duration proportionally drive greater mortality.



RESULTS

1 What constitutes a risky heatwave?

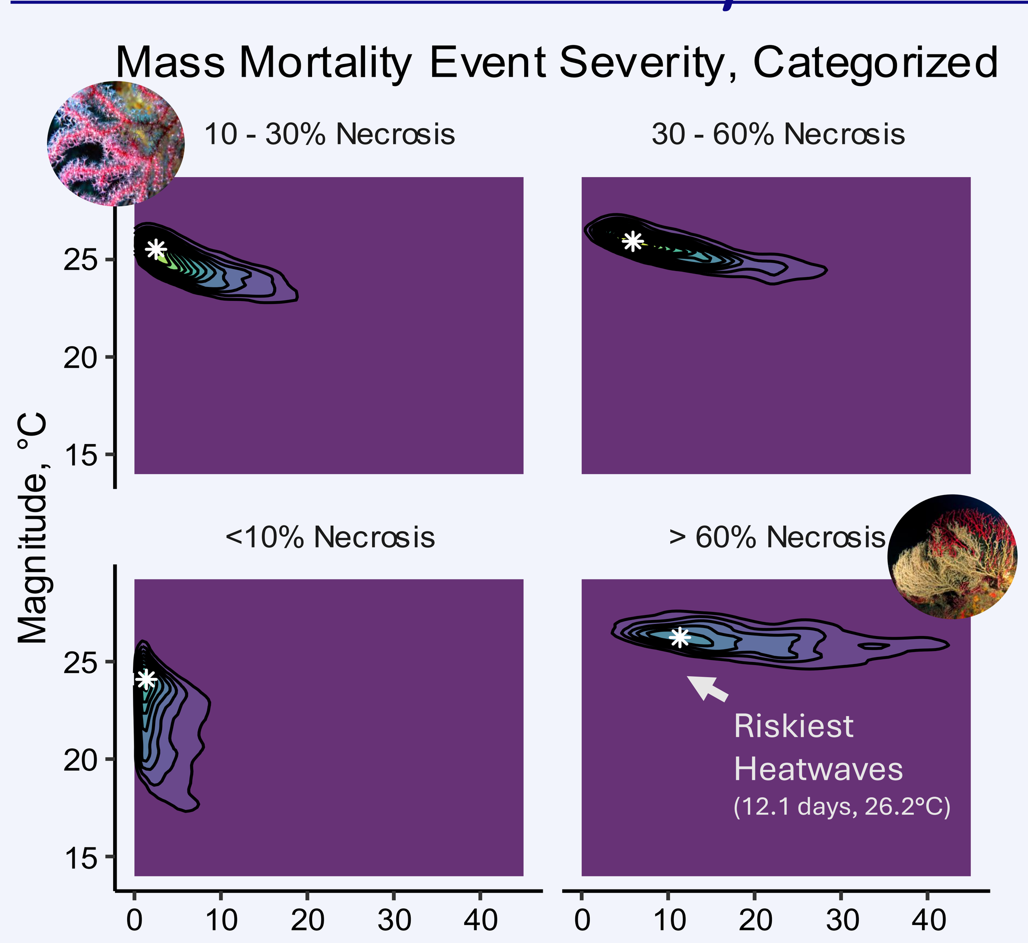


Figure 1. Density plots of MHWs in the western Mediterranean, grouped by modeled colony necrosis. White stars indicate density peak of each category.

2 When does time and temperature matter the most?

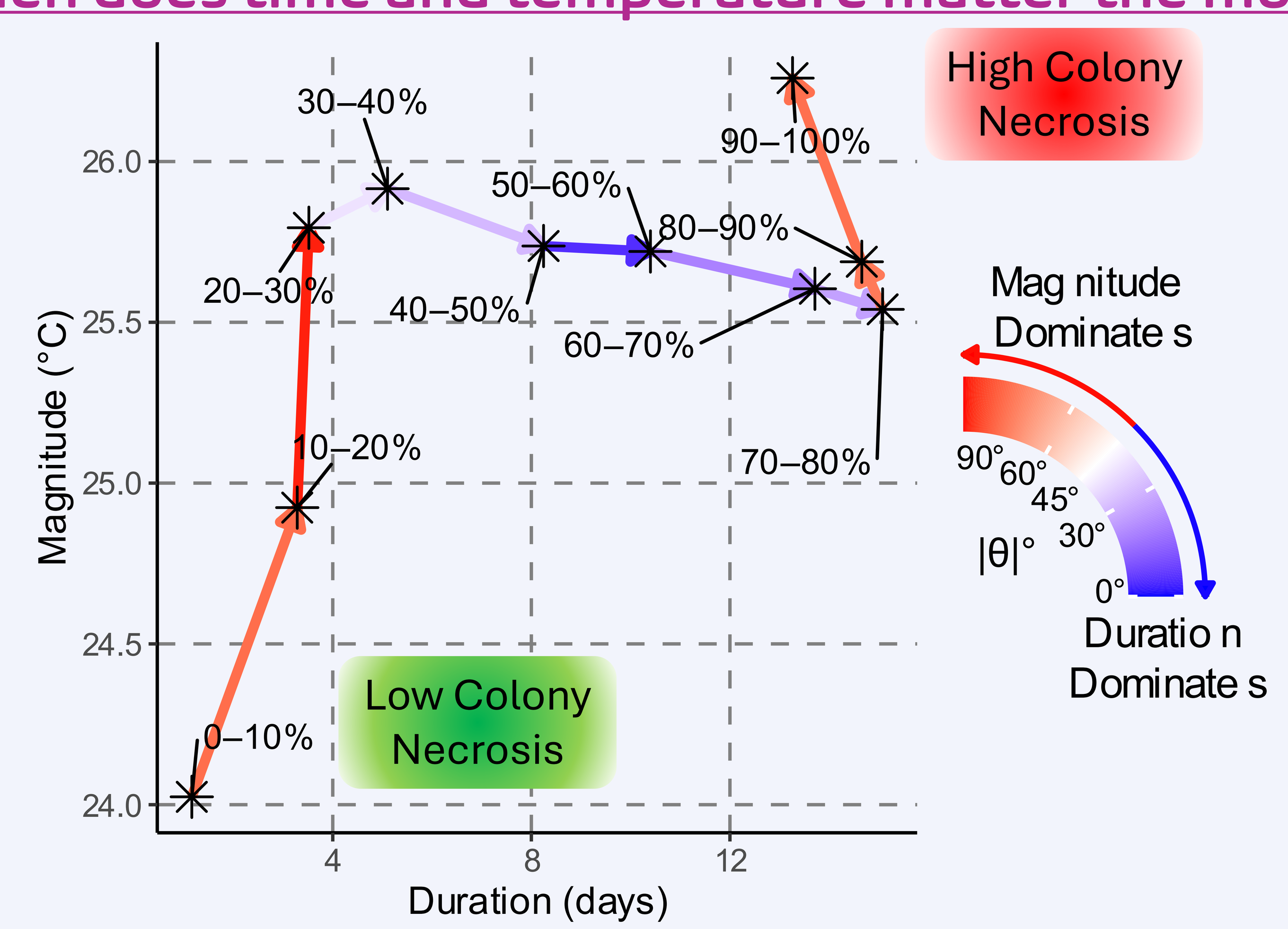


Figure 2. Trajectory of MHW density peaks (black stars), binned by 10% modeled necrosis intervals. Arrow color indicates elasticity angle (θ) of the vector between intensifying necrosis density peaks.

CONCLUSIONS

- **Diverse heatwaves can result in similar biological impacts.**
- **MHWs have an upper temperature boundary setting initial mortality, but severe mortality events are driven by lengthening MHWs.**
- **Thermal risk for organisms is a function of likelihood and effect – forecasts of climate exposure must account for both.**
- **Ongoing work: Validating model with field survey data, identifying spatial patterns of refuge and risk.**

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