Acclimation capacity of tropical and temperate coastal organisms

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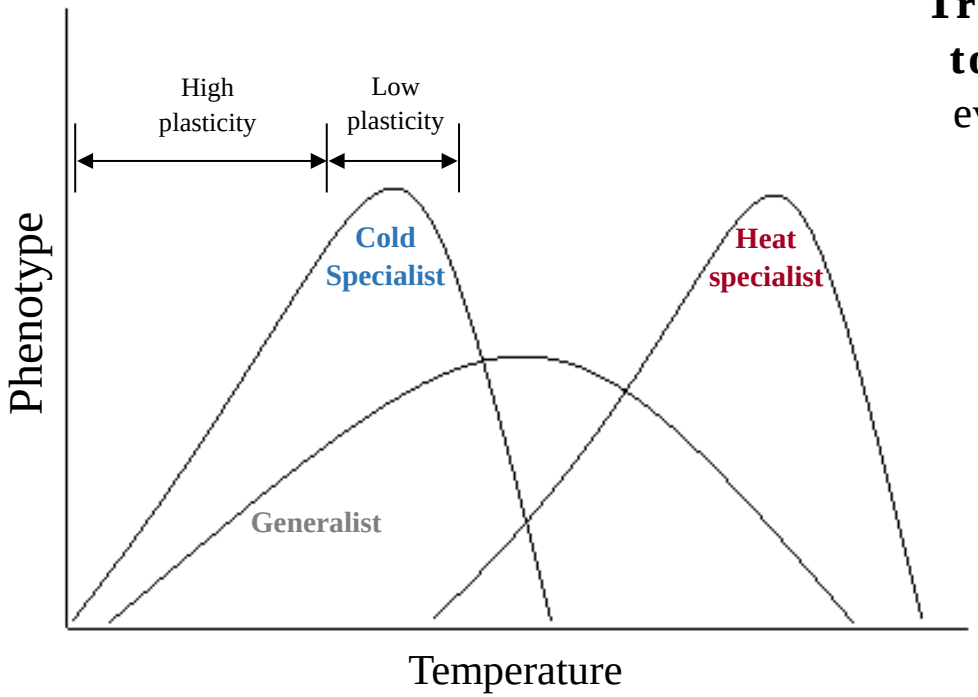
Introduction

Climate warming fingerprint on Earth's ecological systems is already clearly visible.

- Impacts upon species **distribution**, **phenology** and **physiology** have been predicted and demonstrated by numerous publications.
- **The predicted further warming of 3°C by the end of this century** raises concerns about future climate change impacts upon ecosystems and biodiversity.

Understanding the **thermal limits** of organisms and the plasticity of those limits enables us to argue about what will happen to their **distribution and abundance** during climate change.



Adapted from Angilletta (2009) Thermal adaptation. A theoretical and empirical synthesis. Oxford University Press

Tropical species may be less tolerant to environmental change, since they evolved in thermally stable habitats, i.e. have a narrower tolerance range.

However, the vulnerability towards a rise in temperature will depend mostly on organisms' **acclimation capacity**, which remains unknown for most species.

Thermal acclimation can be described as...

"Any phenotypic response to environmental temperature that alters performance and plausibly enhances fitness."

(Angilletta, 2009)

- It implies the **detection** of an environmental signal, the **transduction** of this signal into a cellular response, and the **activation** of molecules (e.g. genes, ribosomes, enzymes) that cause a change in the phenotype.

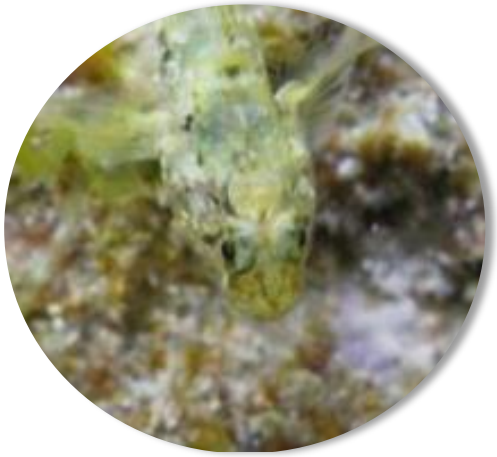
Thus, it comprises regulated responses to diel or seasonal changes in temperature, so as to

match physiology to the current environment.

The ability to acclimate results from existing phenotypic plasticity in populations

and it's an important mechanism for coping with environmental temperature changes.

- This is a **common attribute in species that experience pronounced seasonal variations in temperature**, such as the ones inhabiting temperate mid-latitudes.



One of the habitats where climate change impacts are likely to strike first is the **intertidal zone**.

- **Many intertidal organisms are currently living close to their thermal limits.** This means that intertidal communities may be especially vulnerable to further increases in habitat temperature.
    - Such vulnerability may vary across latitude and will depend mainly on an organism's thermal tolerance and acclimation capacity.
    - Such knowledge remains unknown for most species.

Objectives of the Study

Compare tropical and temperate coastal organisms' capacity to acclimate

their upper thermal limits when exposed to:

1

Long-term increases in temperature

- 30 days at "control temperature +3ºC", representing the **future summer temperature**

2

Short-term increases in temperature

- 10 days at "control temperature +6ºC", representing **future heat waves**


Lisboa, Portugal
Study Areas
São Paulo, Brazil
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Google earth
Data das imagens: 10/4/2013 4°52'43.15"N 26°08'57.49"O elev 0 m altitude de visuali


Lisboa, Portugal
Temperate Zone

Tropical Zone

São Paulo, Brazil

Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO

Google earth

Data das imagens: 10/4/2013 4°52'43.15"N 26°08'57.49"O elev 0 m altitude de visuali

Species

Tropical

Temperate

Palaemon northropi

Palaemonidae

Palaemon elegans

Pachygrapsus transversus

Grapsidae

Pachygrapsus marmoratus

Parablennius marmoreus

Blenniidae

Coryphoblennius galerita

Bathygobius soporator

Gobiidae

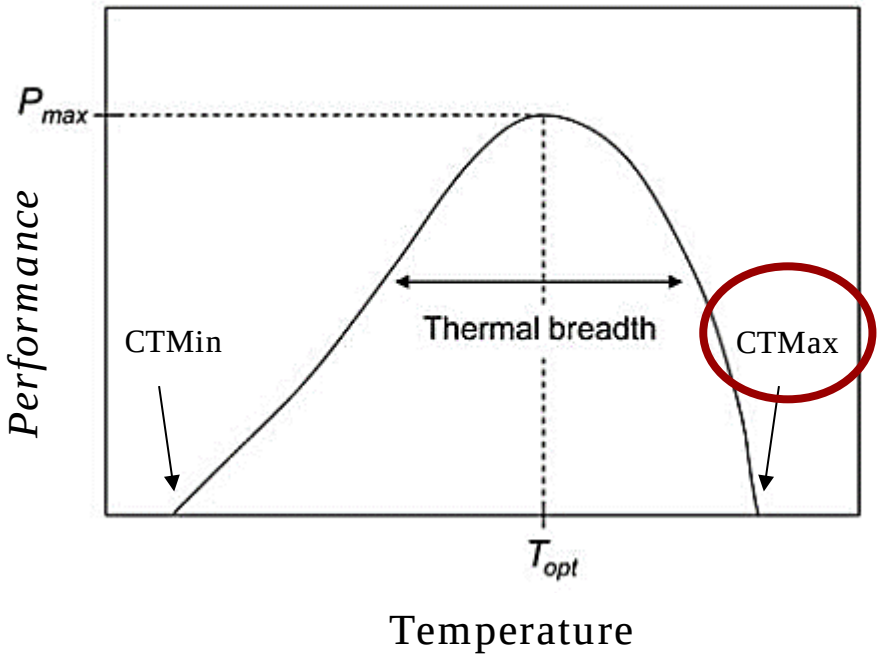
Pomatoschistus microps

Methods

To determine species' upper thermal limits, the

Critical Thermal Maximum

method was used.



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- The CTMax is determined by **gradually increasing temperature until a critical point is reached** (e.g. loss of the righting response, muscle spasms).
- Animals are exposed to a constant rate of water-temperature increase of **1°C h^{-1}**, with constant aeration and observed continuously, until they reach the end-point.

- Two **acclimation trials** were carried out as follows:

1) Long-term trial

- Organisms were acclimated for **30 days** at 3°C above the control temperature, i.e. 29°C for tropical organisms and 23°C for temperate ones.

Followed by a

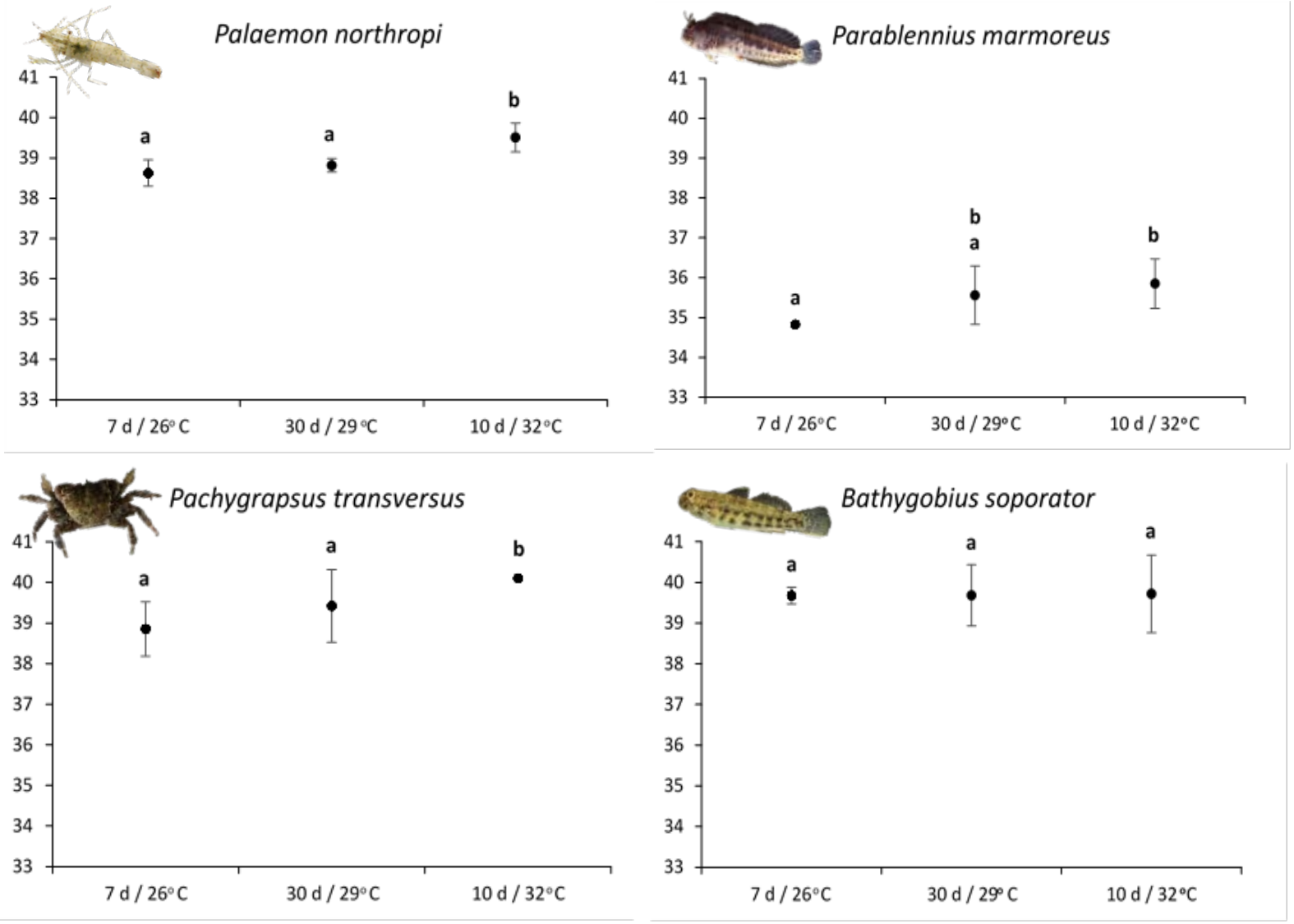
2) Short-term trial

- Organisms were acclimated for **10 days** at 3°C above the previous trial temperature, i.e. 32°C for tropical organisms and 26°C for temperate ones.

$$\textbf{Acclimation capacity} = CTMax_{Trial} - CTMax_{Control}$$

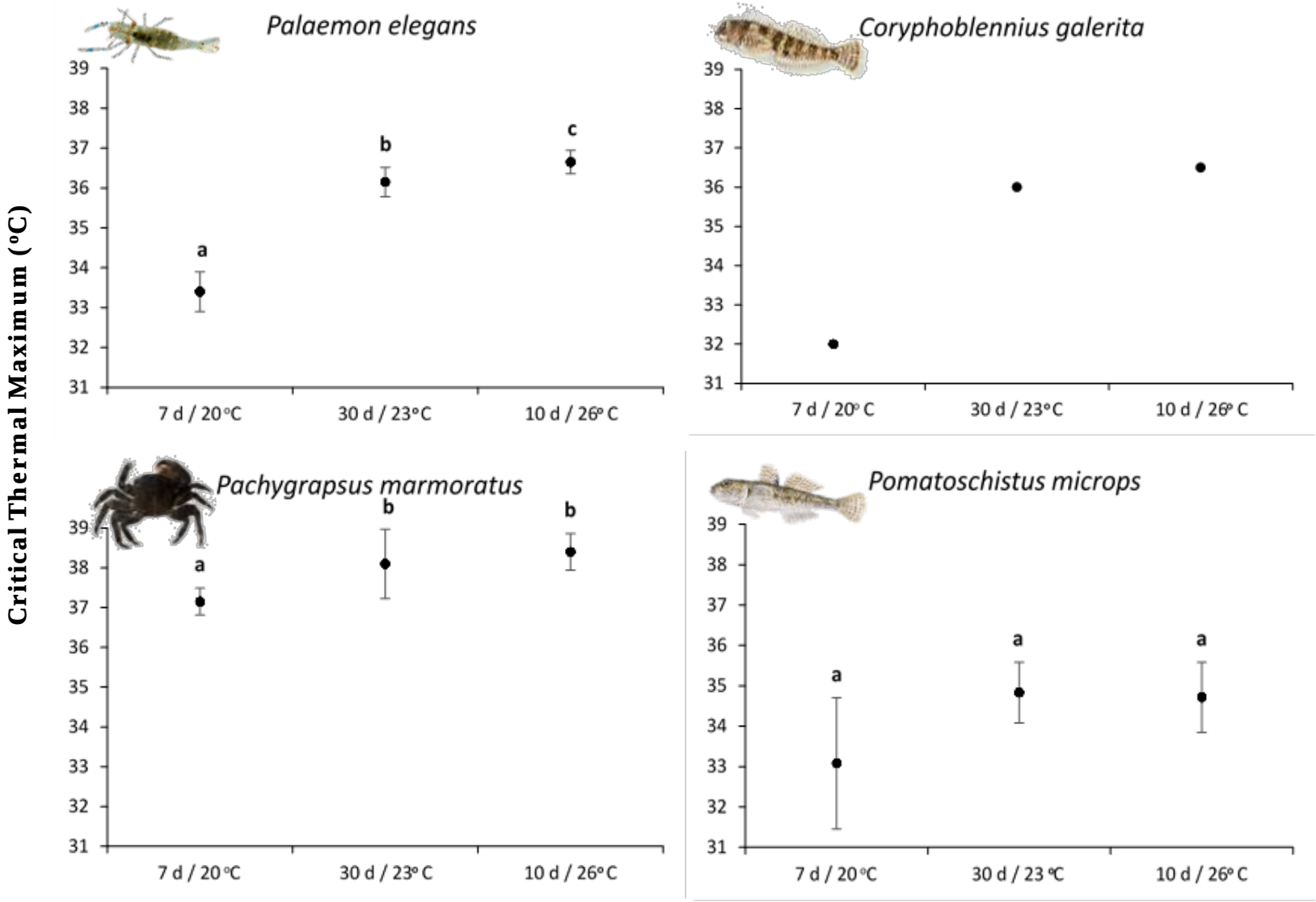
Results

Tropical species

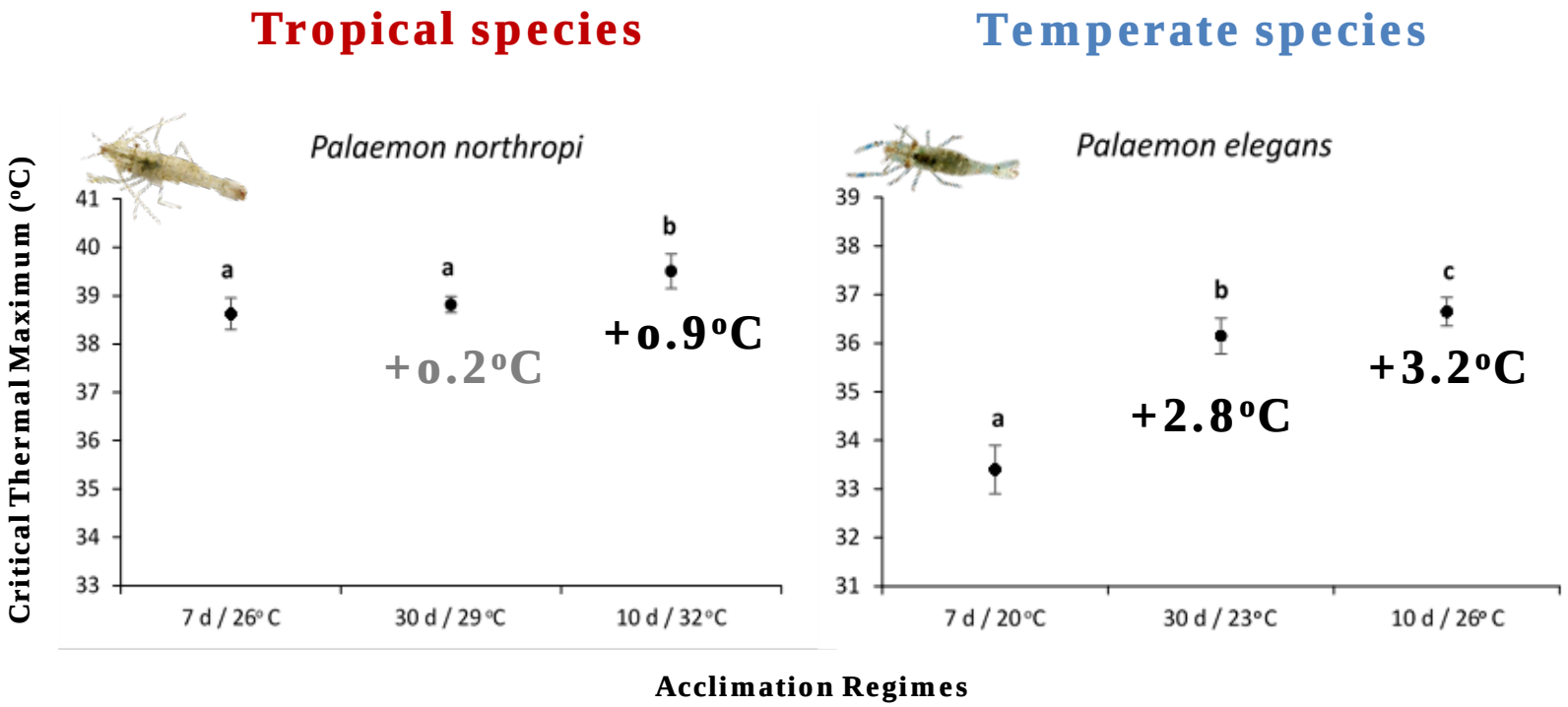


Results

Temperate species

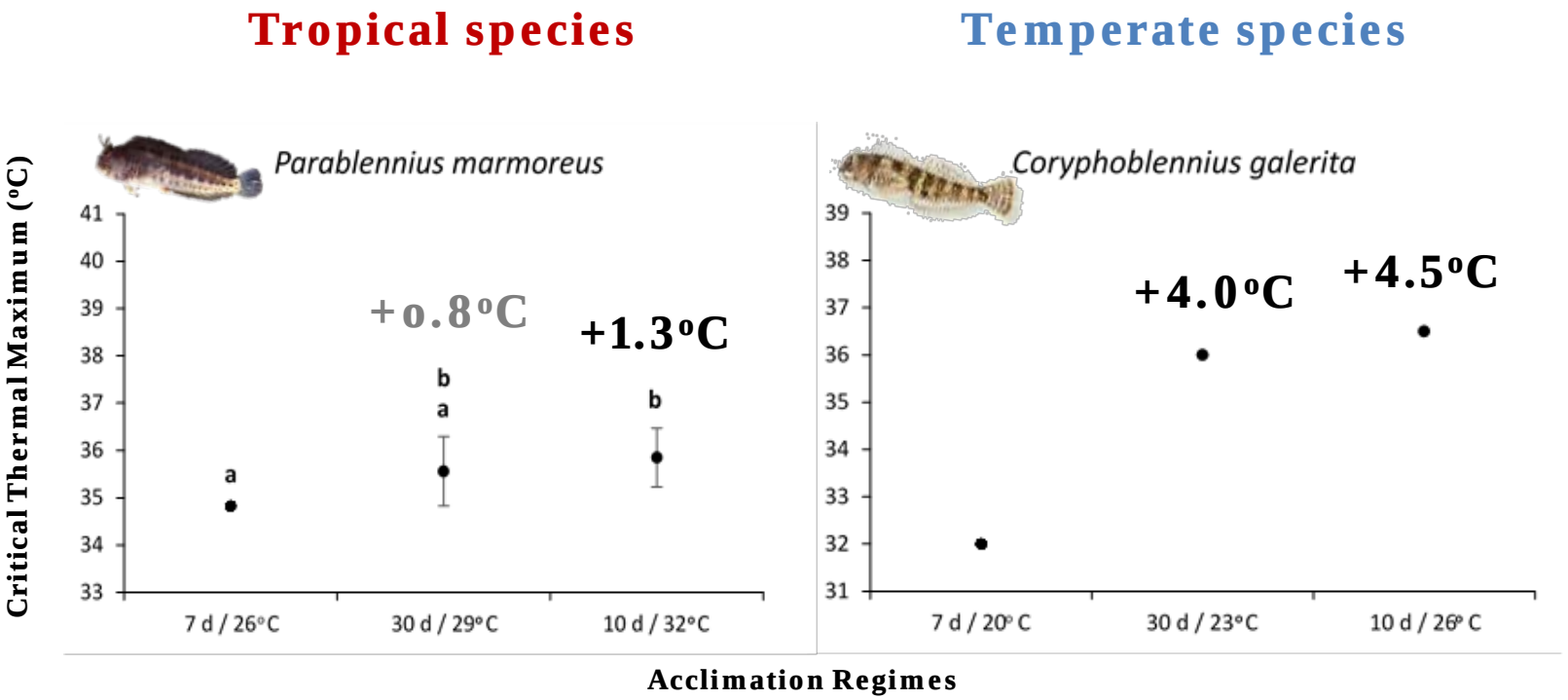


Results



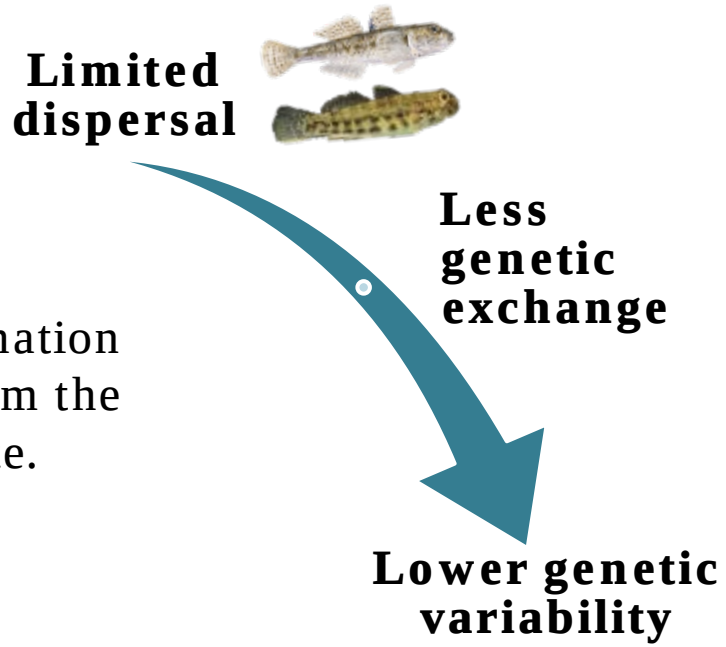
- The temperate shrimp showed a higher acclimation capacity than its tropical con-generic.

Results

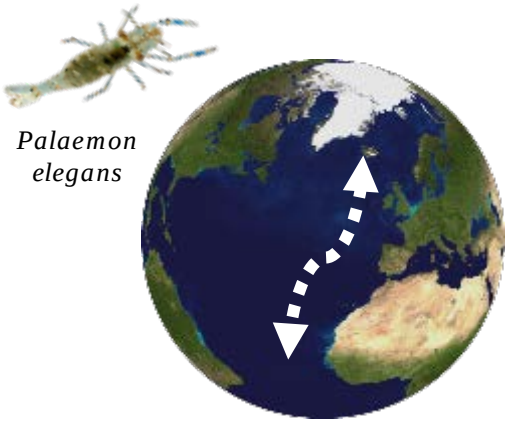


- The temperate blenny showed a higher acclimation capacity than its tropical counterpart.

Discussion



- All species tested have some acclimation capacity, with the exception of the fish from the **Gobiidae family**, which did not acclimate.



Species with broad geographic ranges have a greater ability to adjust physiologically, i.e. acclimate.

- **Tropical intertidal organisms** are already experiencing maximum habitat **temperatures above their thermal limits** during the warmest summer days, while temperate ones are not.

- This **thermal stress** may already be pressuring these organisms towards higher thermal limits.

Additionally, given that tropical species' acclimation capacity is limited, it is likely that

the impacts of climate warming will be evident sooner in the tropics than in the temperate zone.

- Our work corroborates studies with other species, such as salamanders (Feder, 1978), lizards (Tsuji, 1988) and porcelain crabs (Stillman, 2002, 2003), that indicate that:

Species with the greatest tolerance to high temperatures display the smallest acclimation capacity.

These will be the most susceptible species to the smallest increases in habitat temperature.

- ***Bathygobius soporator*** had a **CTMax of nearly 40°C**, the highest reported here, however this species showed no acclimation capacity.

Given that this is the **same temperature recorded in tide pools during heat waves** in southeastern Brazil (personal observation) further increases in habitat temperature may impact these intertidal fish if they cannot adapt and/or disperse to more favorable habitats.

- The short-term temperature extremes that an organism can tolerate will depend on its **phenotypic plasticity.**

- However, in the long run, evolutionary shifts in thermal limits will depend on the presence of **additive genetic variance**.

"Species with adequate genetic variation to generate phenotypes with different thermal tolerances may prove to be winners in a warming world."
(Somero, 2010)

Will the rate of evolutionary adaptation be fast enough to keep up with the rate of environmental warming?

Thank you for your attention!

Acknowledgments:

This study had the support of the Portuguese Foundation for Science and Technology through the funding of the project PTDC/MAR-EST/2141/2012 - **WarmingWebs - Role of biodiversity, species thermal tolerance and food web structure in the response to climate change: Temperate versus tropical ecosystems.**