

The evolution of thermal performance curves and life-history traits in responses to thermal selection

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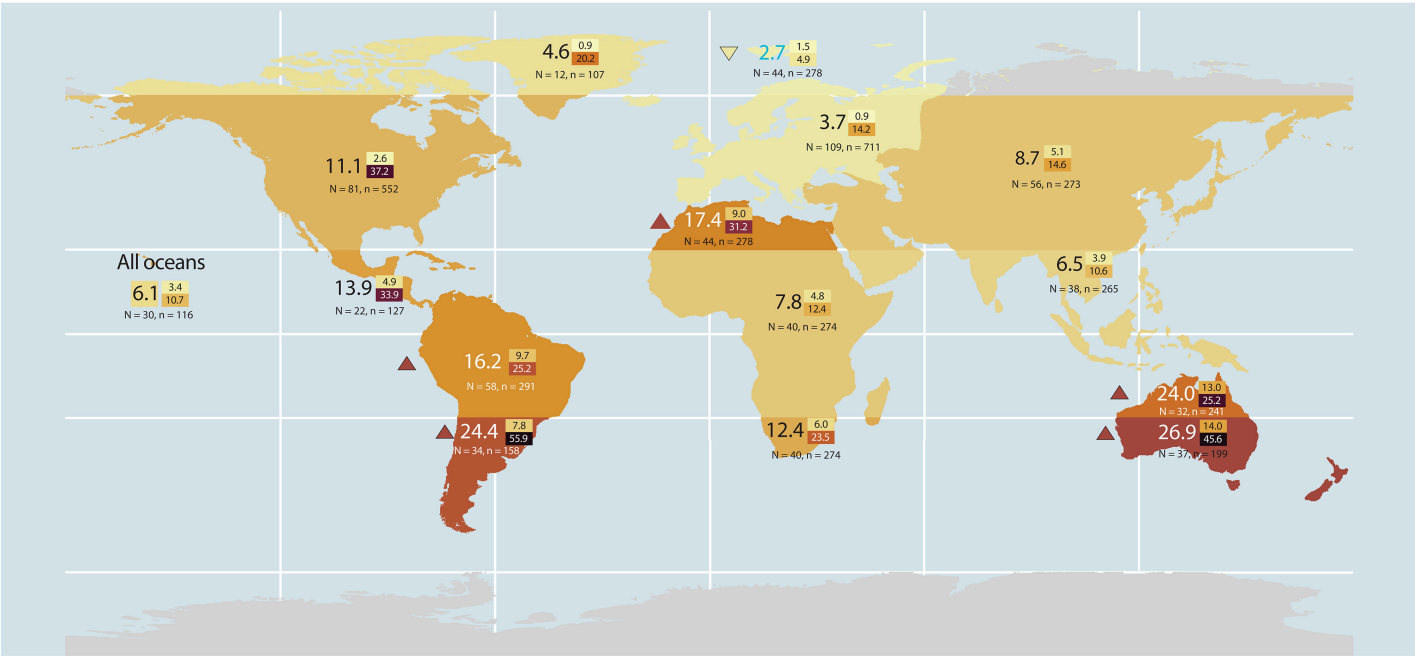
¹ISEM, University of Montpellier, CNRS, EPHE, IRD, Montpellier, France

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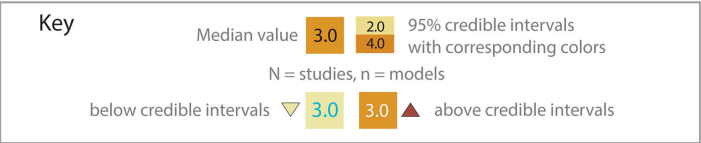
* Shared first-authorship

Lund Thermal Biology Symposium 2026

The climate crisis continues to push populations beyond their tolerable limits

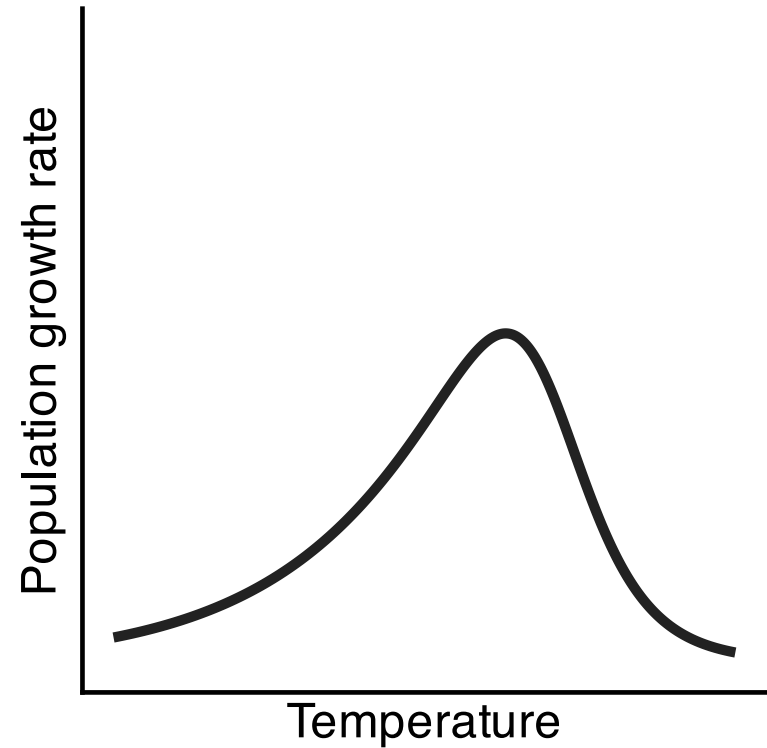


Extinction risk no data 0% 5% 10% 15% 20% 25%



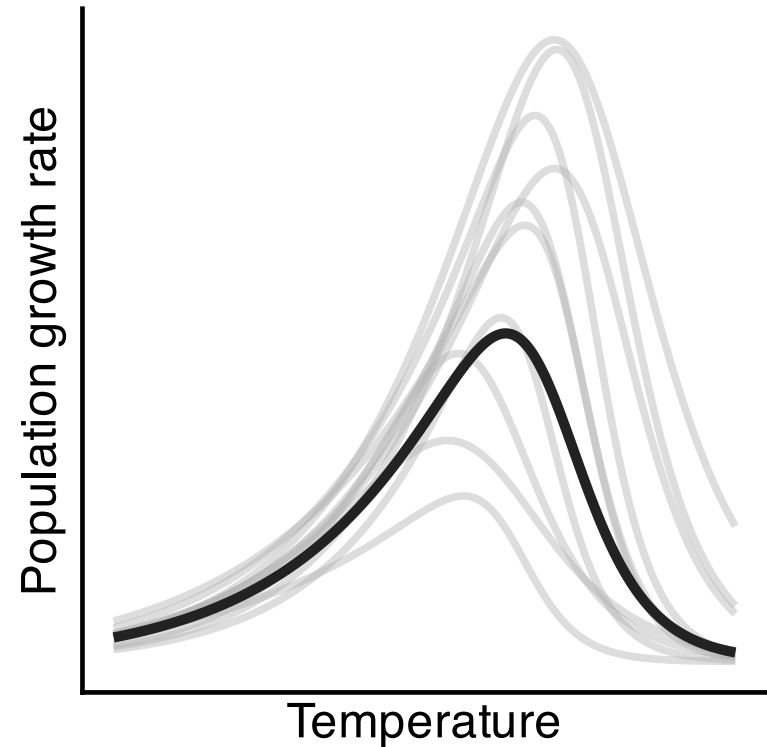
The temperature niche

- Range of (body) temperatures at which a (non-density limited) population shows positive growth.



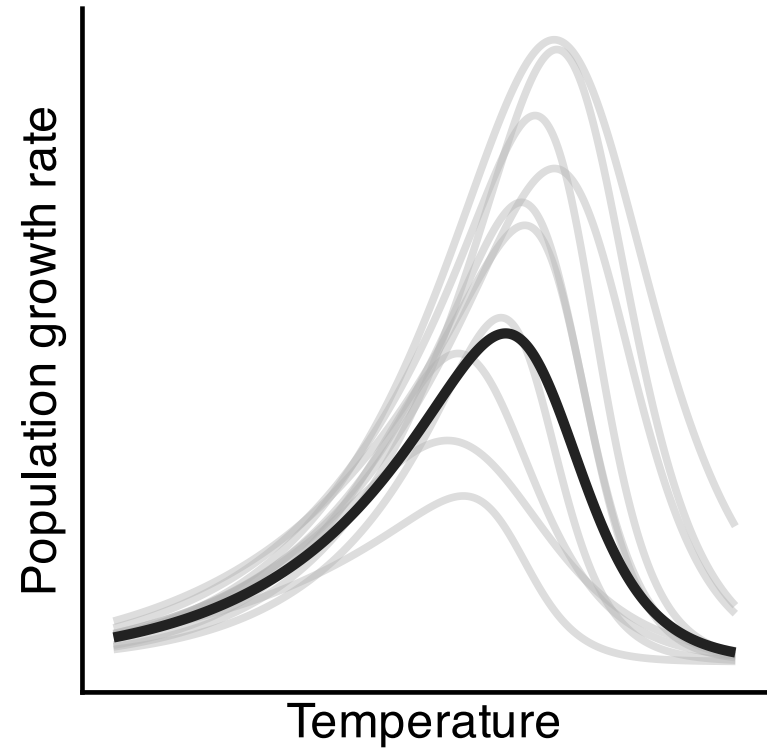
The temperature niche

- Range of (body) temperatures at which a (non-density limited) population shows positive growth.
- How does the temperature niche respond to thermal selection?



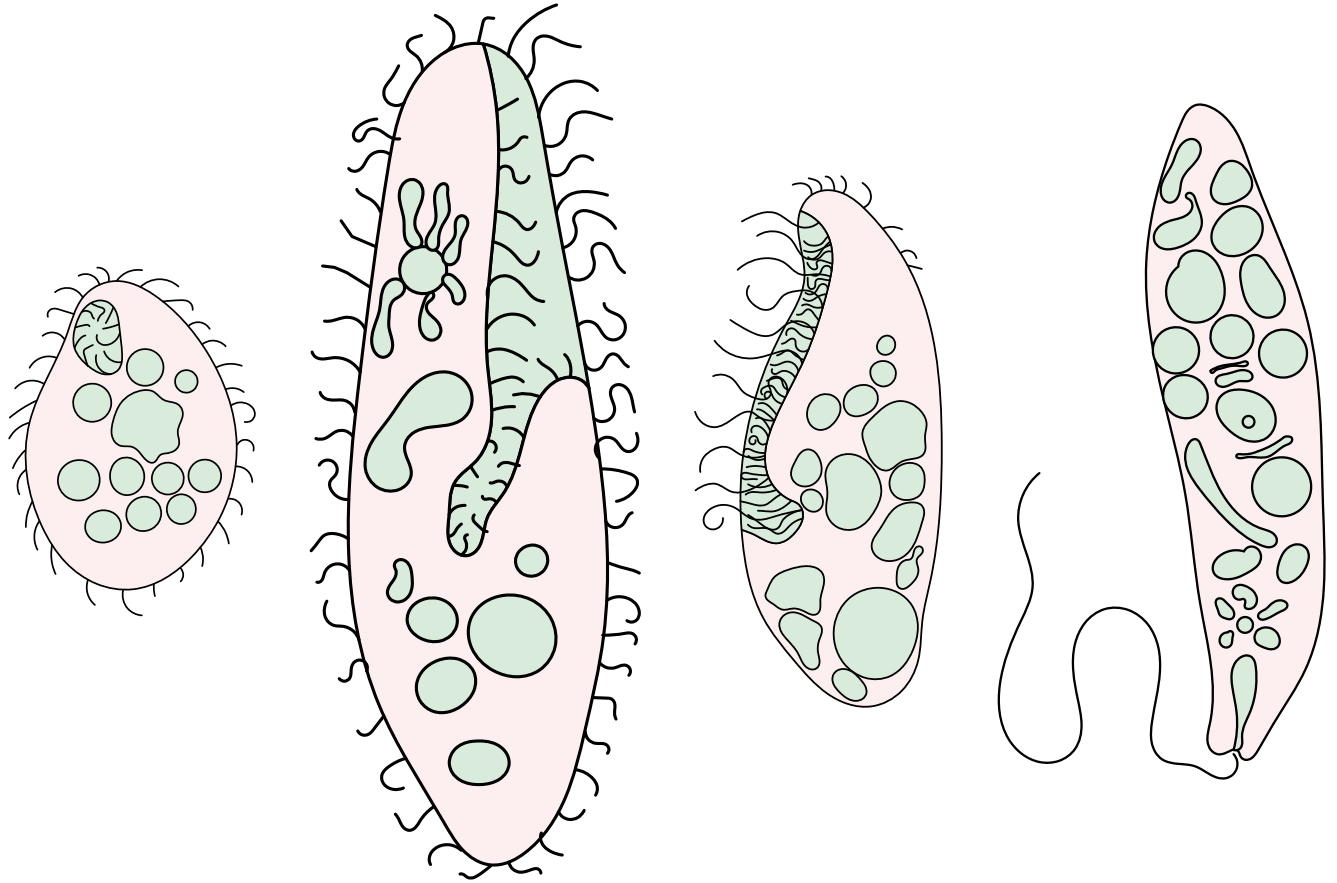
The temperature niche

- Range of (body) temperatures at which a (non-density limited) population shows positive growth.
- How does the temperature niche respond to thermal selection?
- Predictability?
- Universality?



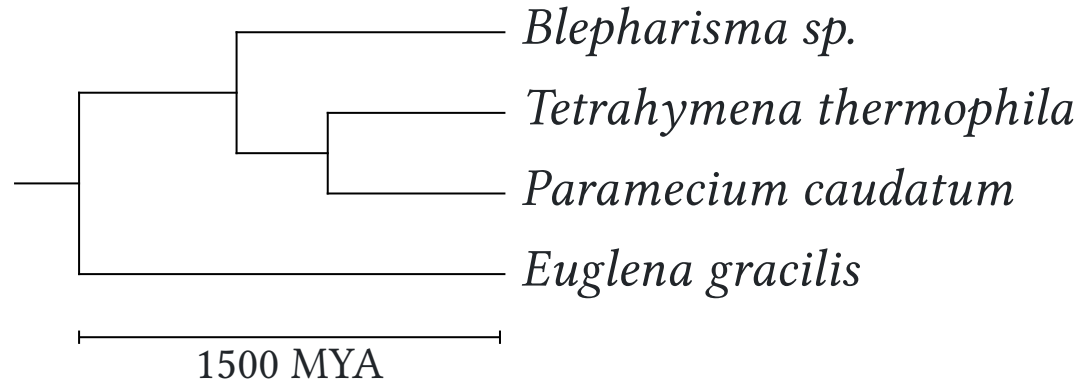
We studied four diverse protist species

- *Tetrahymena thermophila*
 - 50um bacterivore
- *Paramecium caudatum*
 - 330um bacterivore
- *Blepharisma* sp.
 - 200um omnivore
- *Euglena gracilis*
 - 20-100um mixotroph



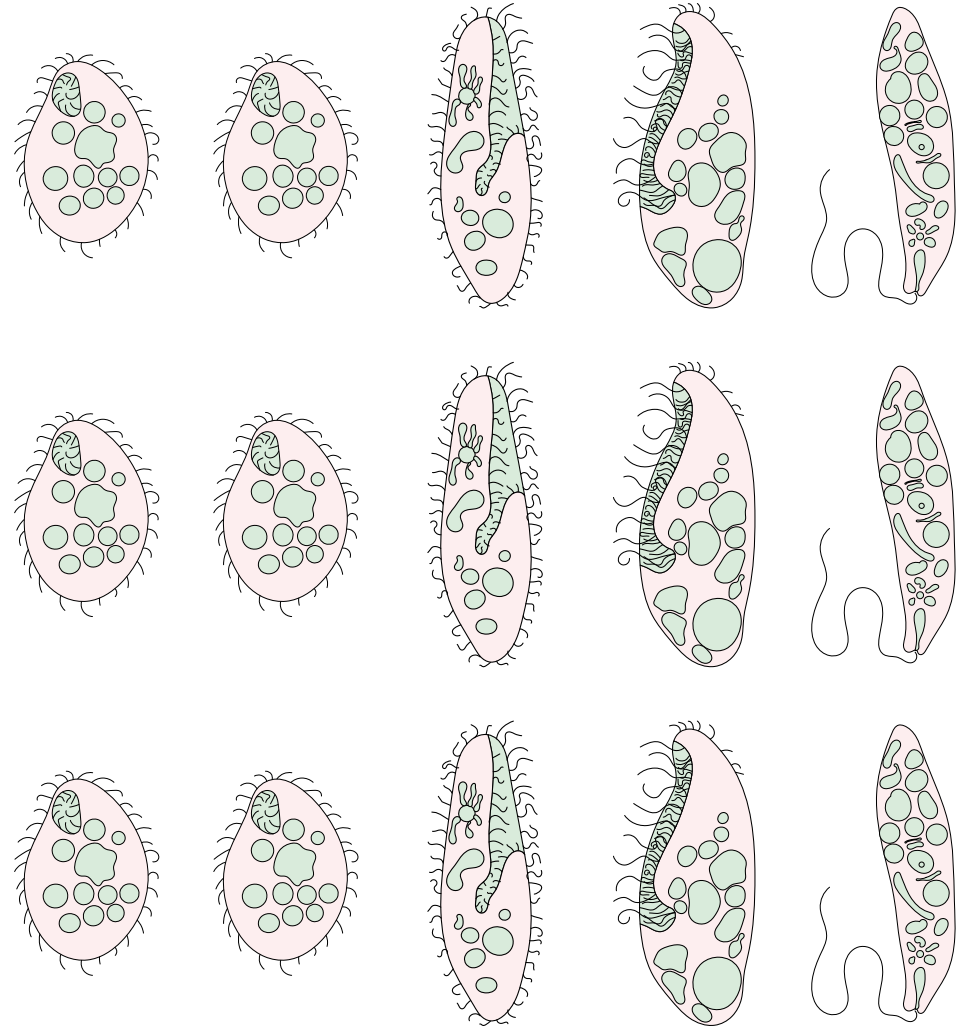
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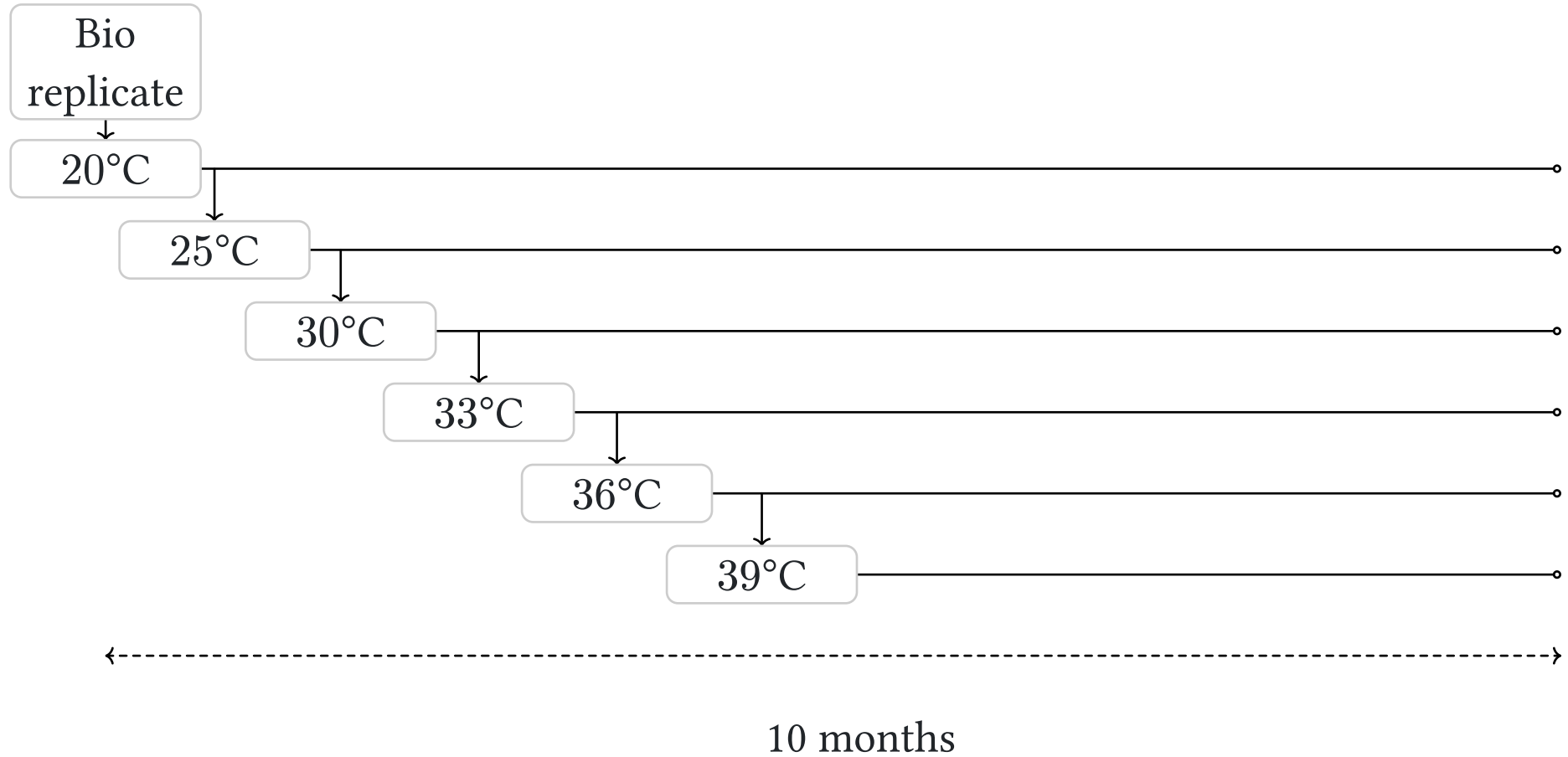


Three biological replicates established from clonal lines

- Five speices/strains
 - Two *Tetrahymena* strains
- 15 evolutionary independant lines



Ratchet design selection regime

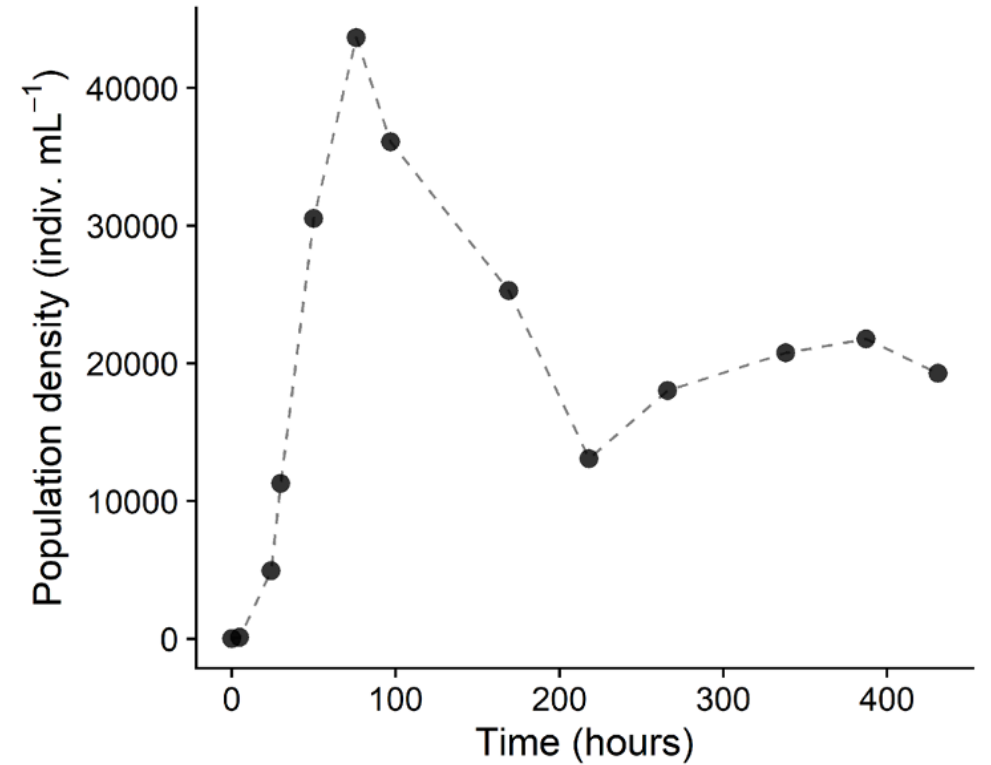


After approx. 10 months of the selection regime:

- Each line assayed at 10 temperatures
 - 5, 10, 15, 20, 25, 30, 33, 36, 39, 40 C

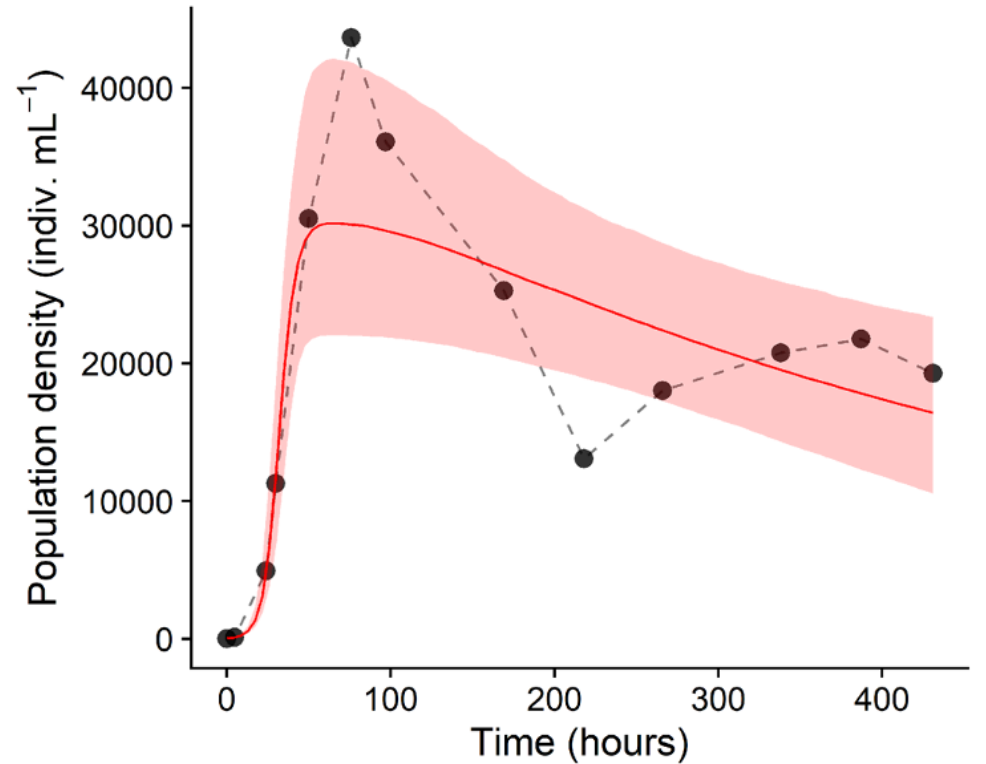
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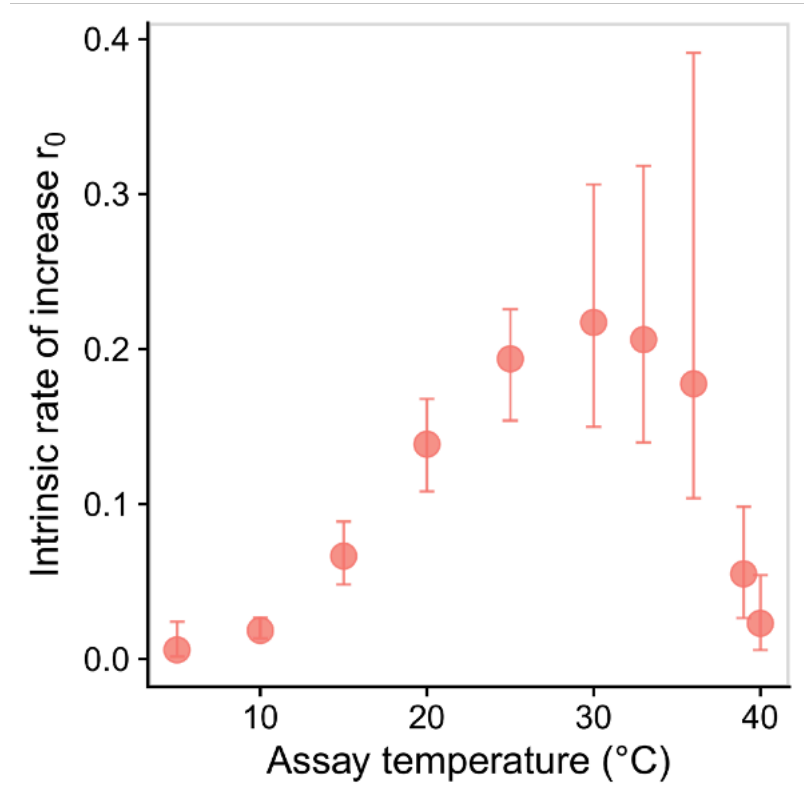
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- Fit growth model, extract r_0 estimates and uncertainty



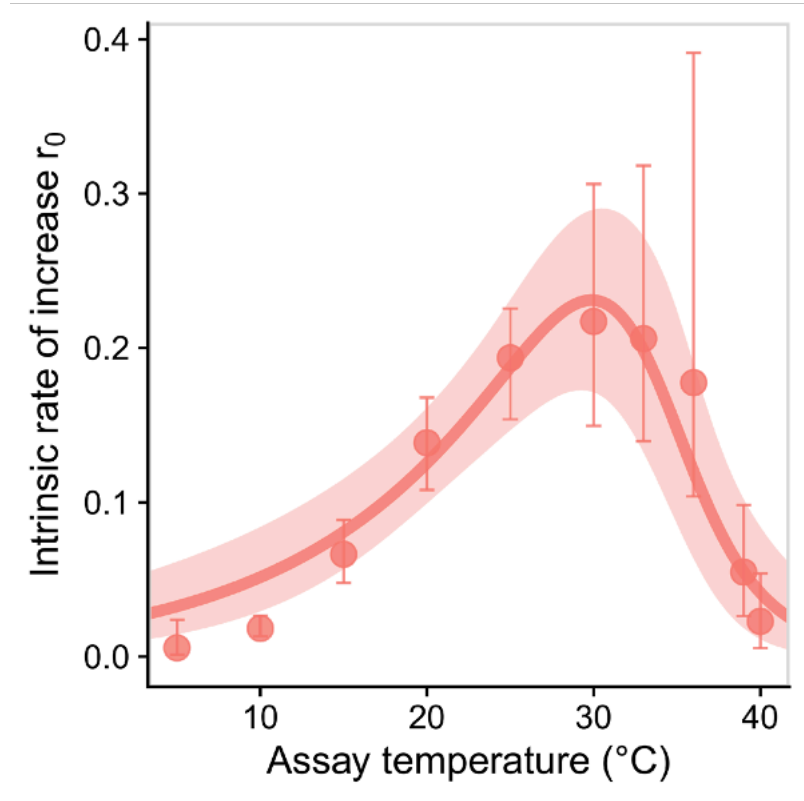
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- Use r_0 estimates to fit TPC (thermal niche)



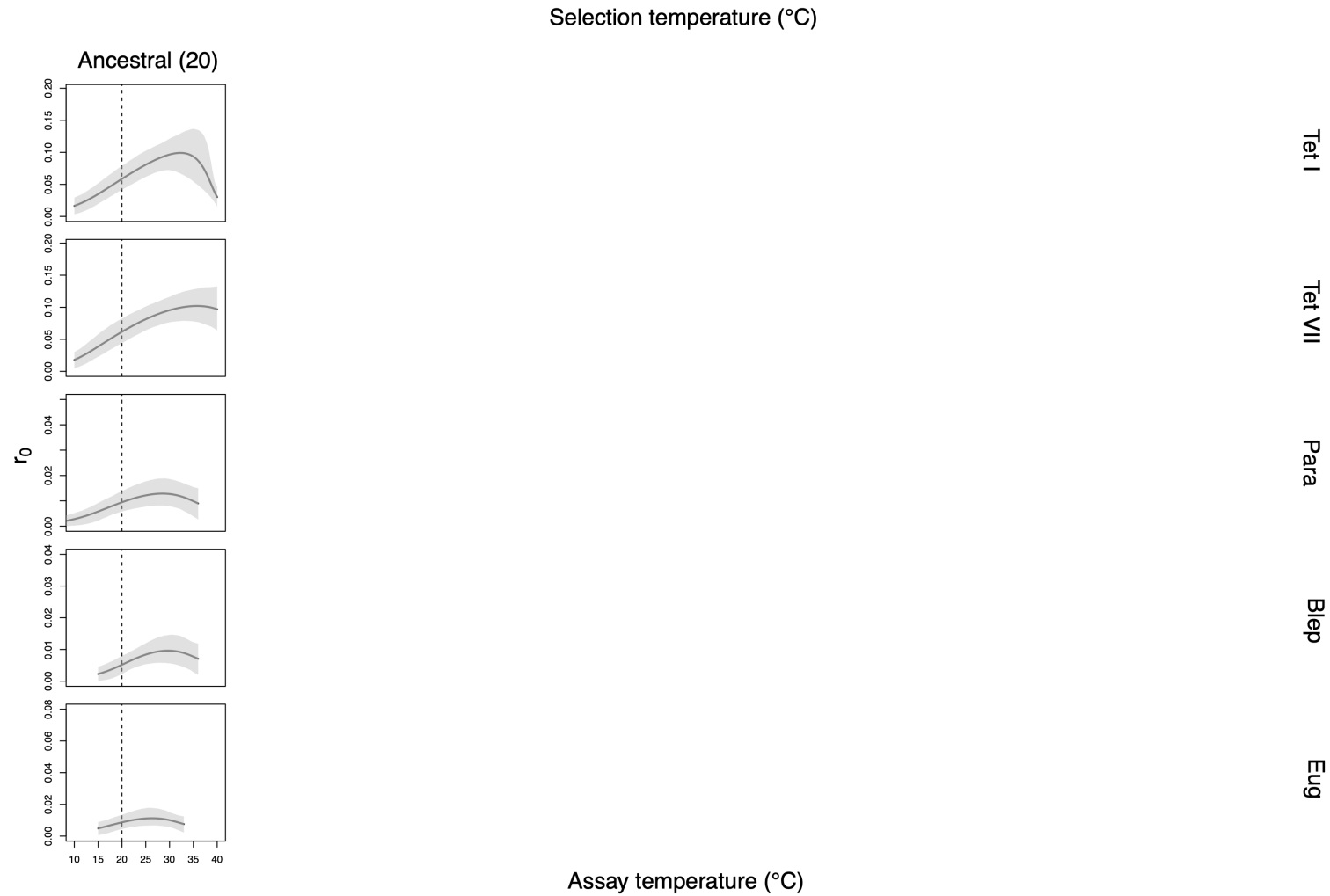
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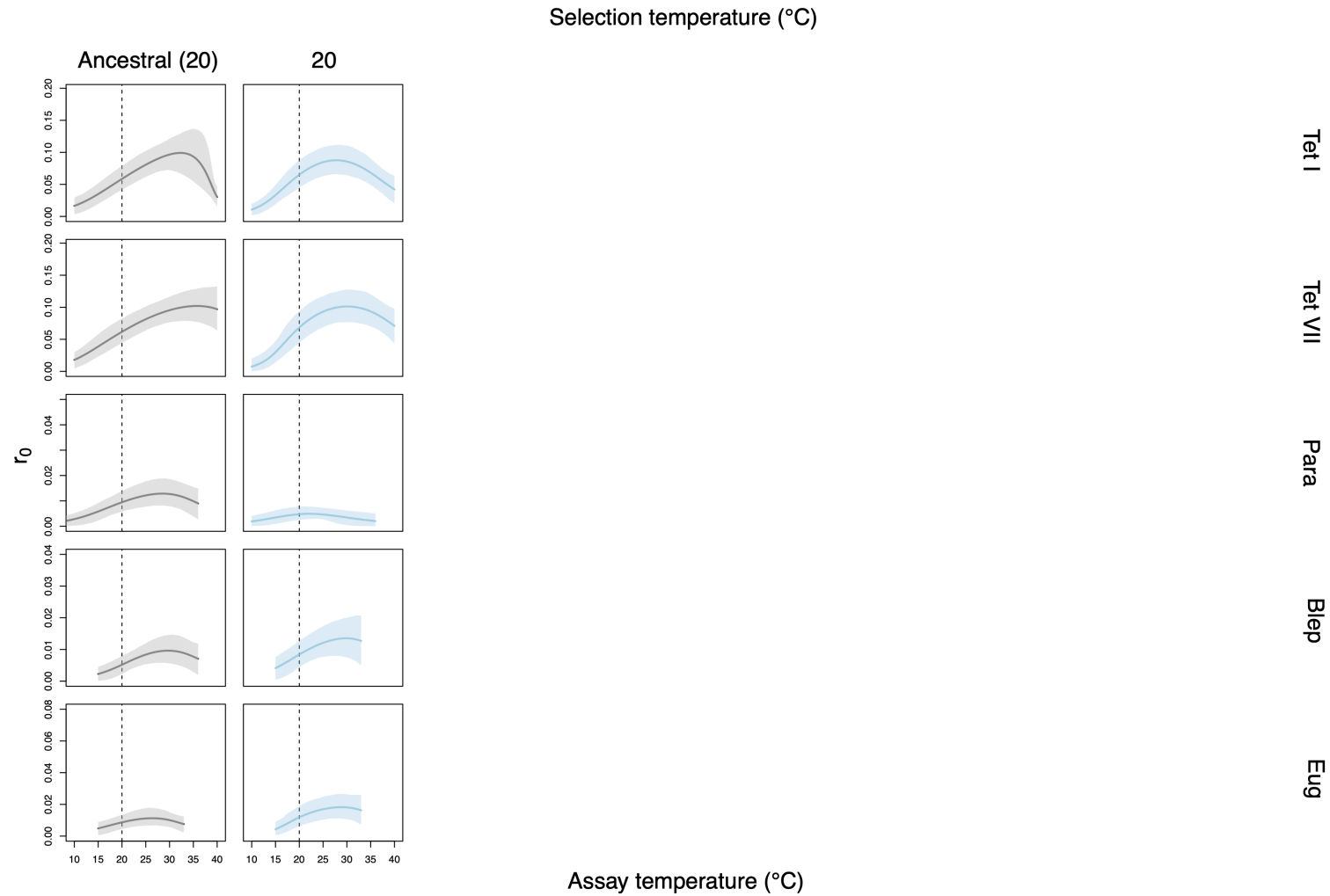


Did their temperature niche respond to selection?

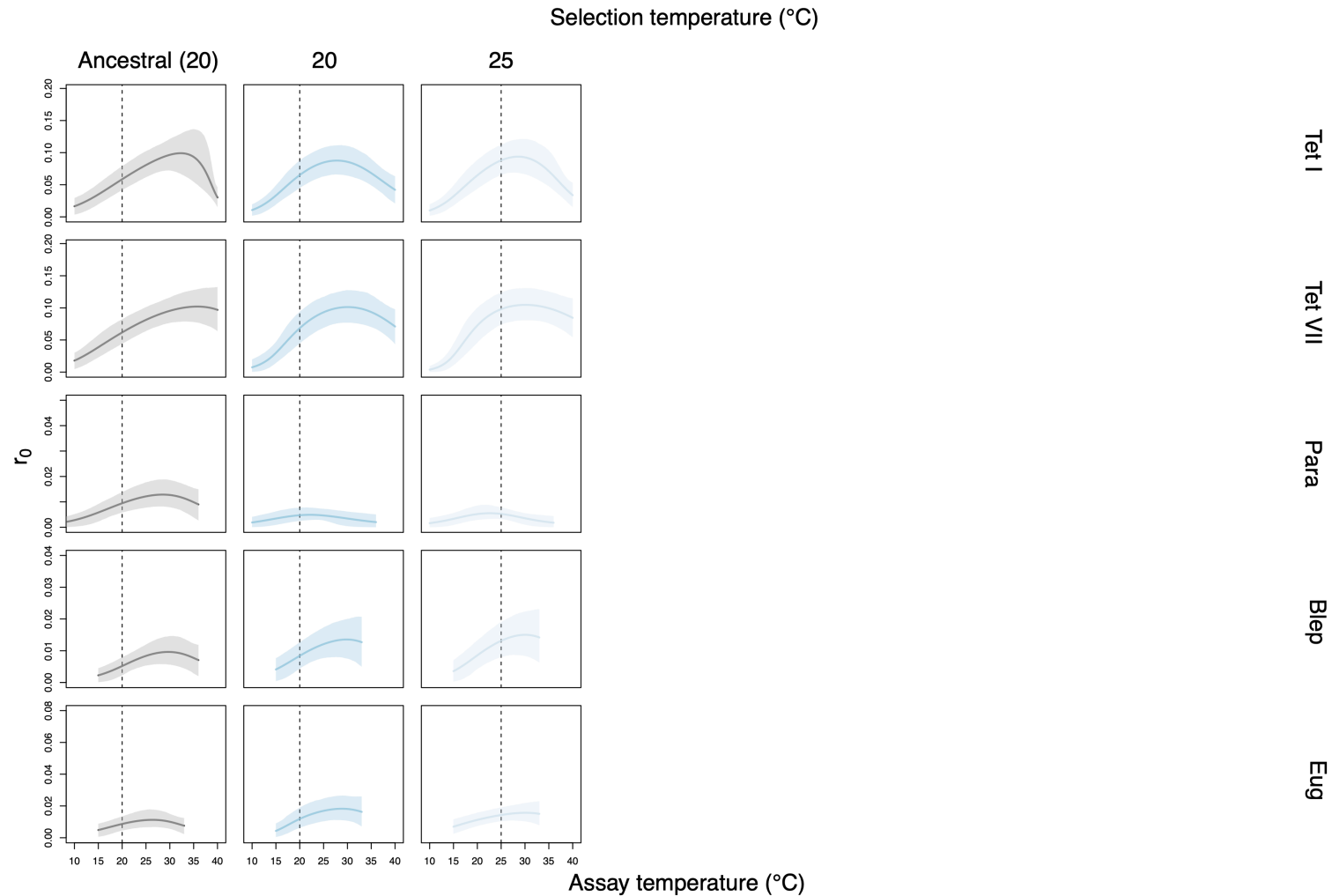
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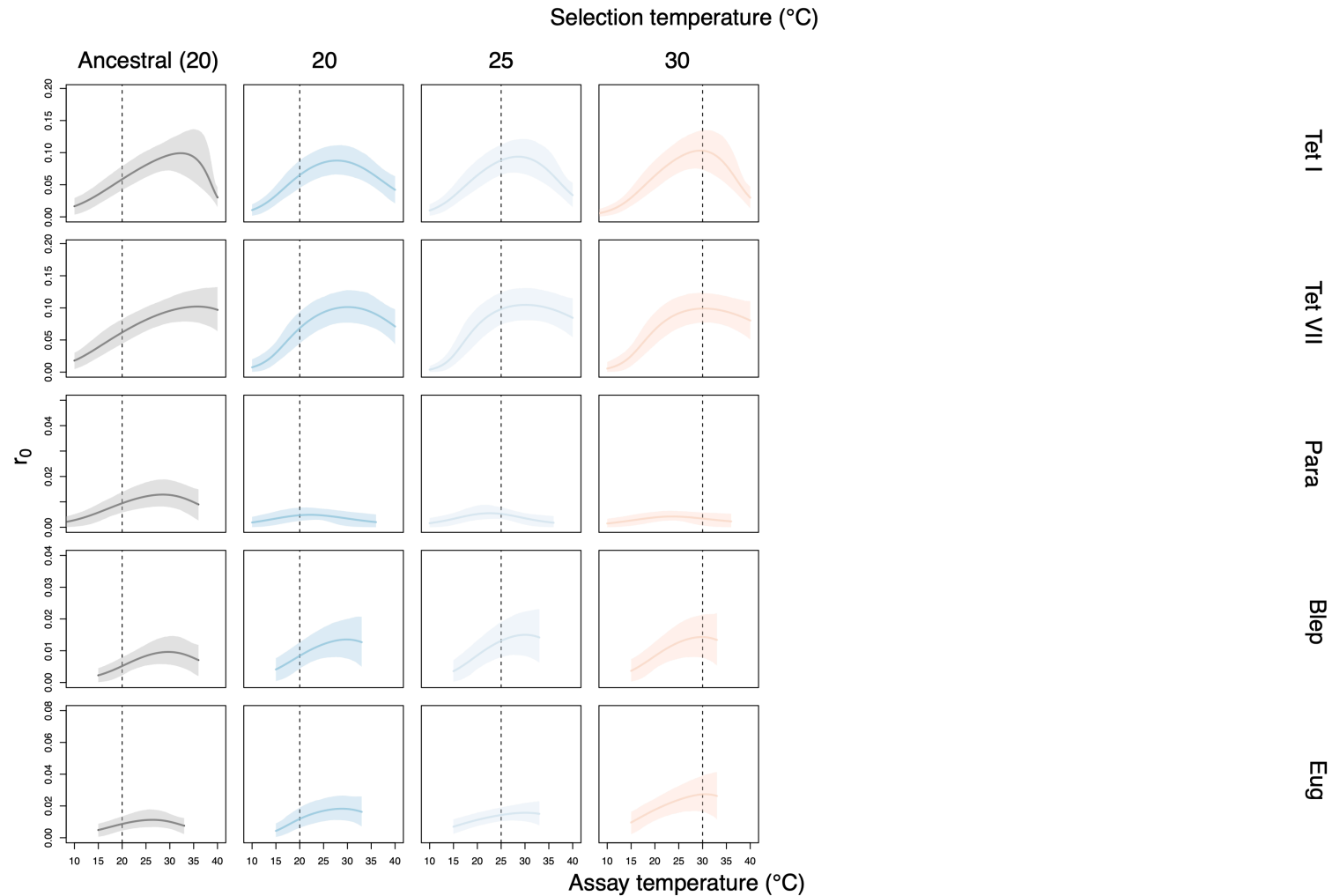
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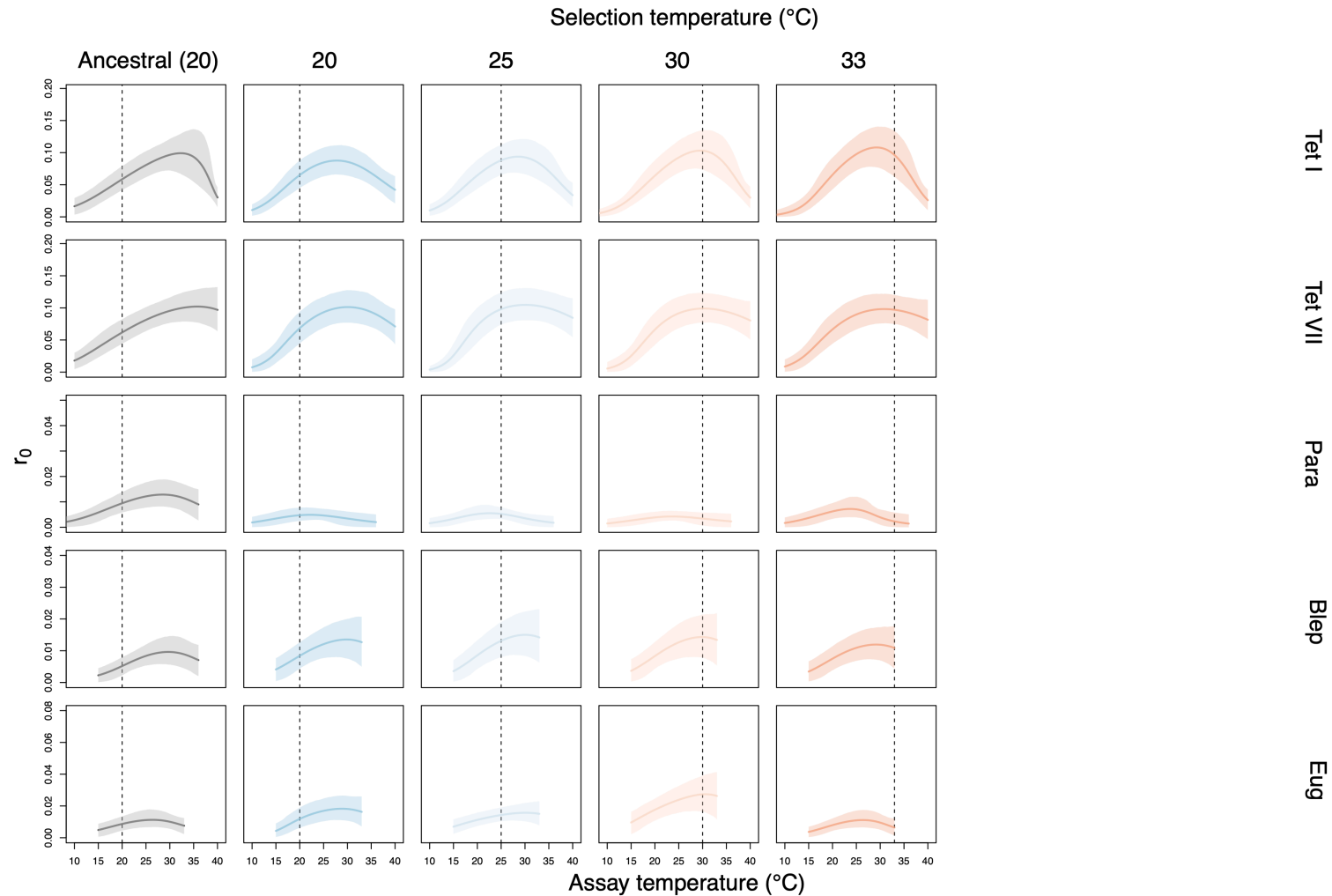
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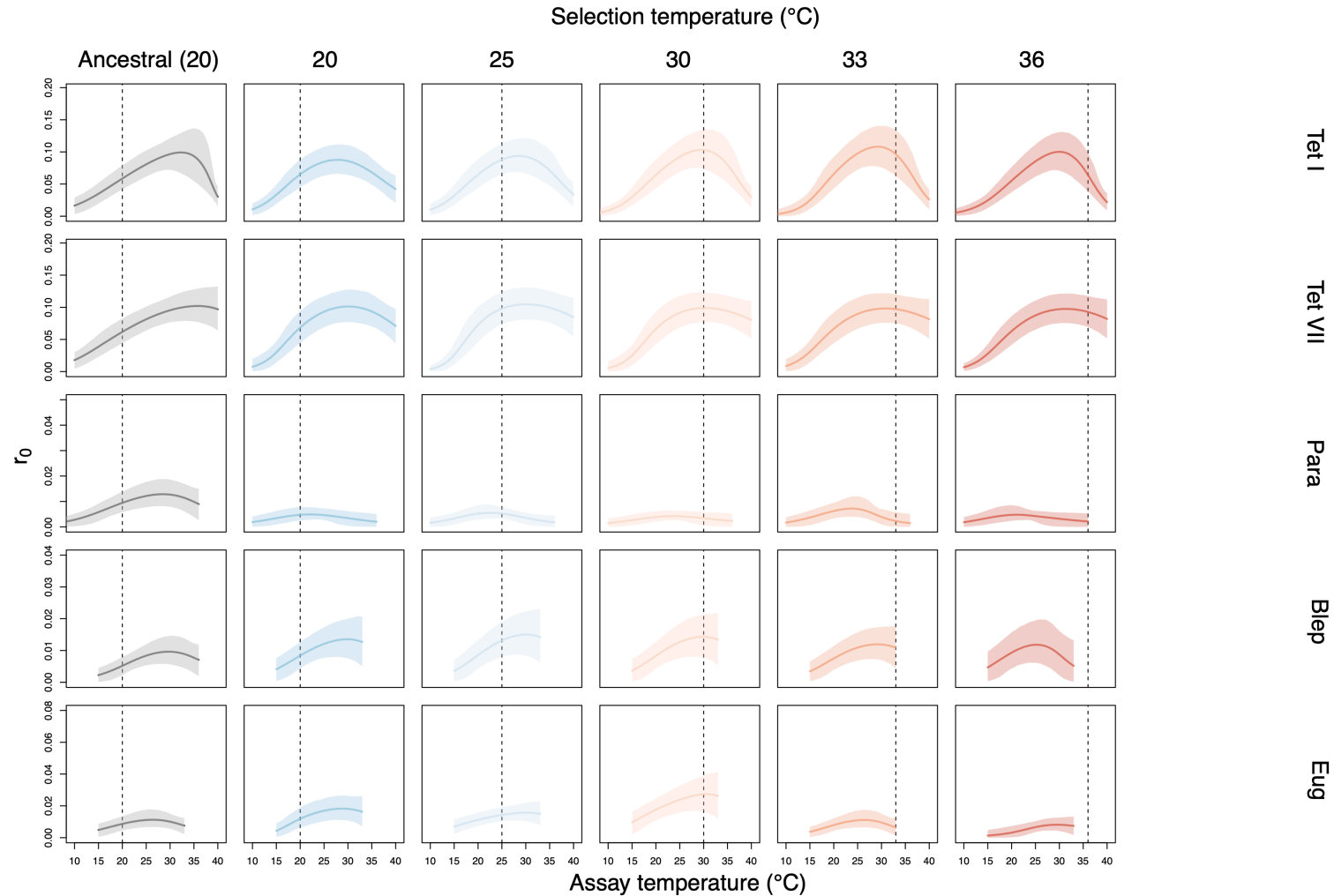
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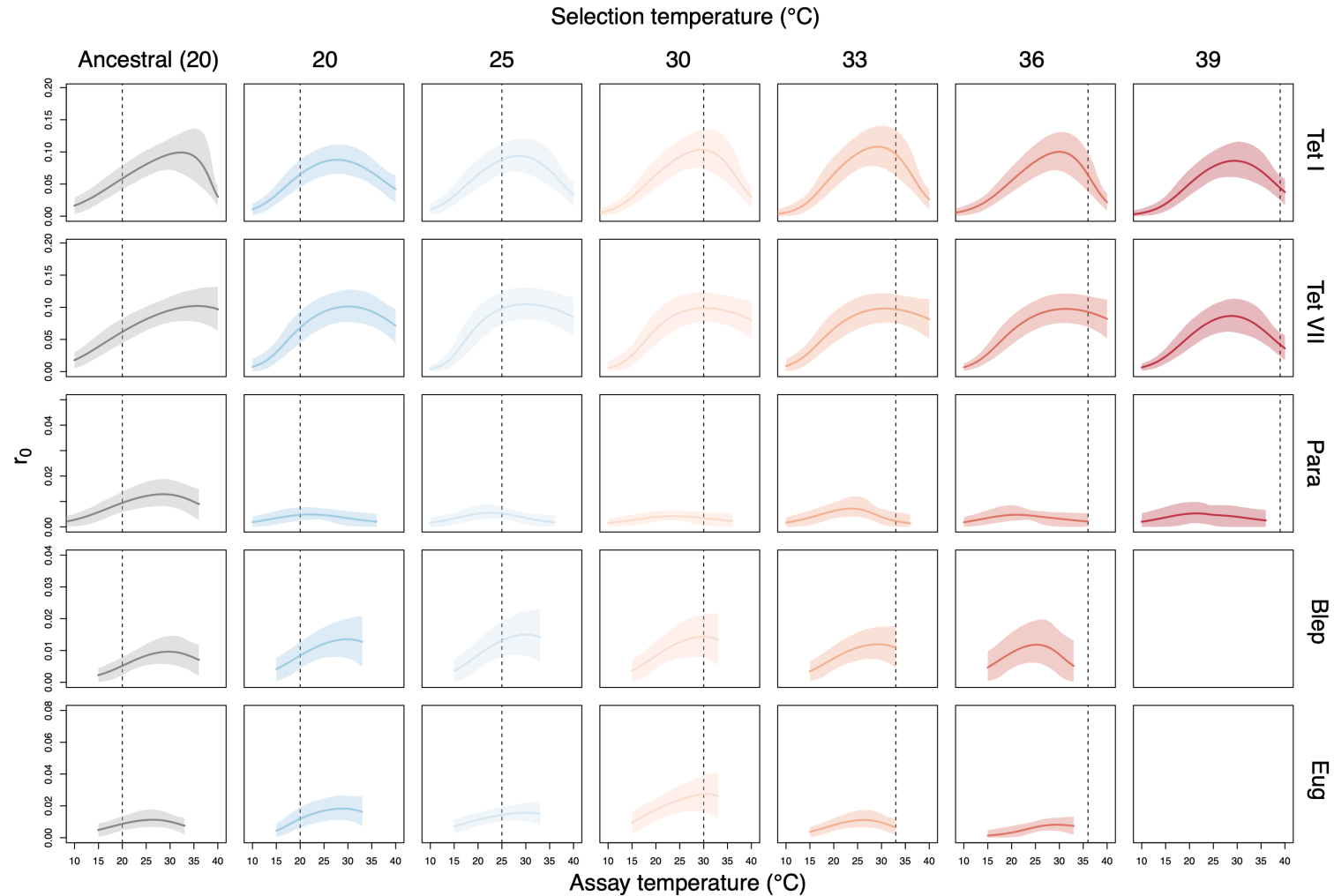
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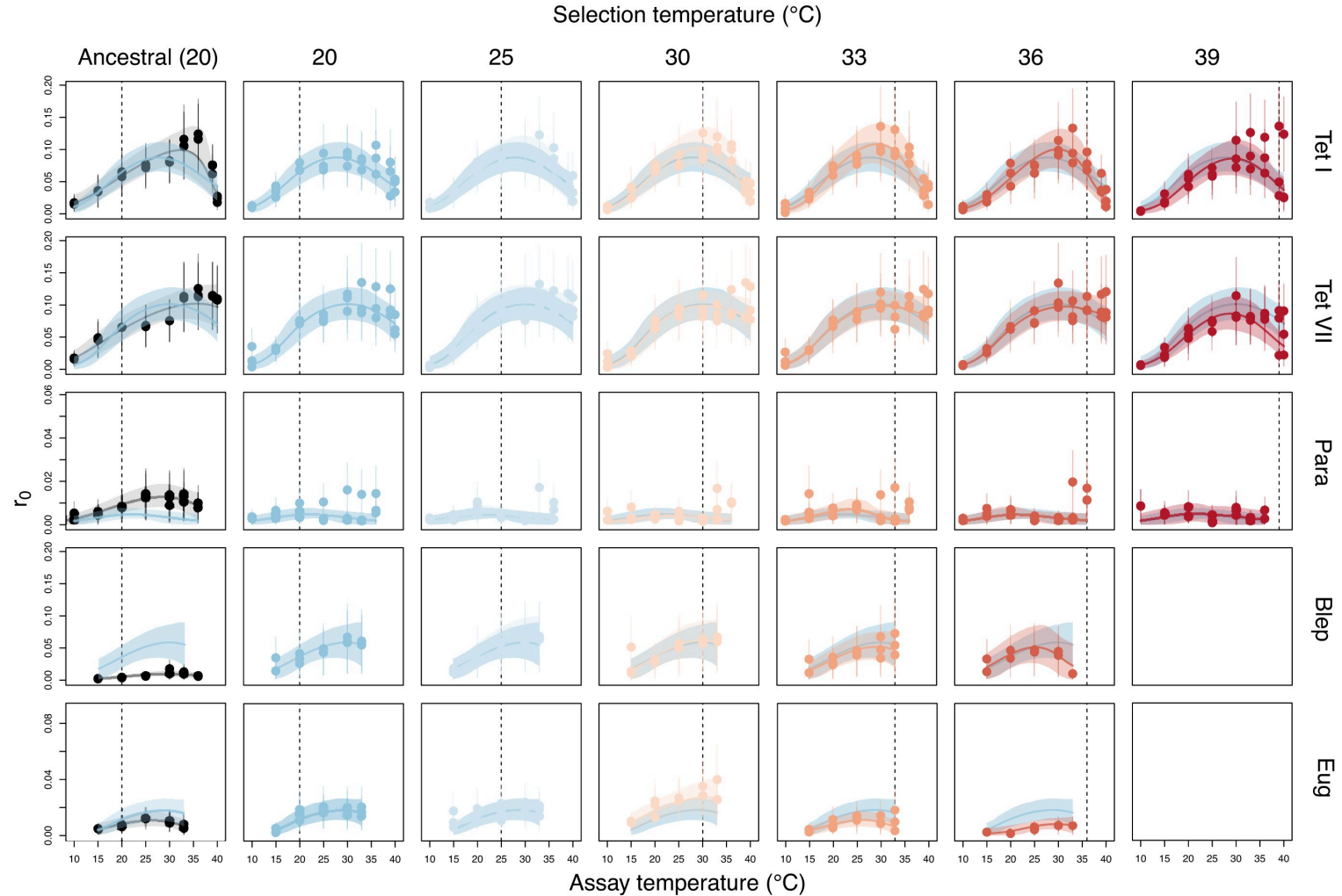
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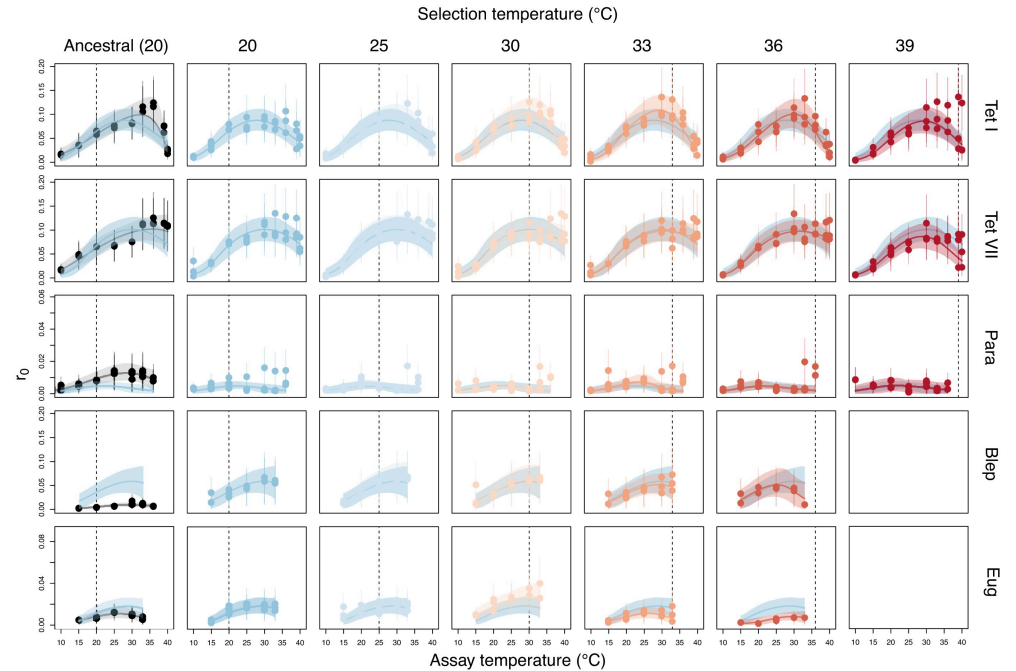
Did their temperature niche respond to selection?



Weak to no signatures of temperature niche change

Unexpected:

- Large effective population sizes
- Many generations
- High mutation rate



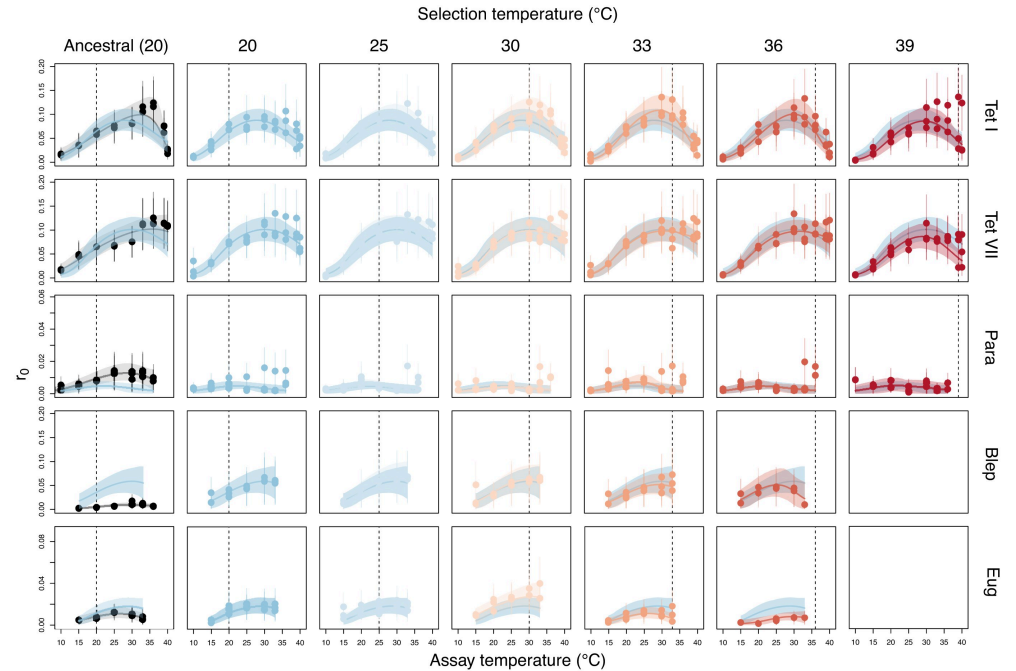
Weak to no signatures of temperature niche change

Unexpected:

- Large effective population sizes
- Many generations
- High mutation rate

However:

- No sexual reproduction
- No recombination
- No standing genetic variation

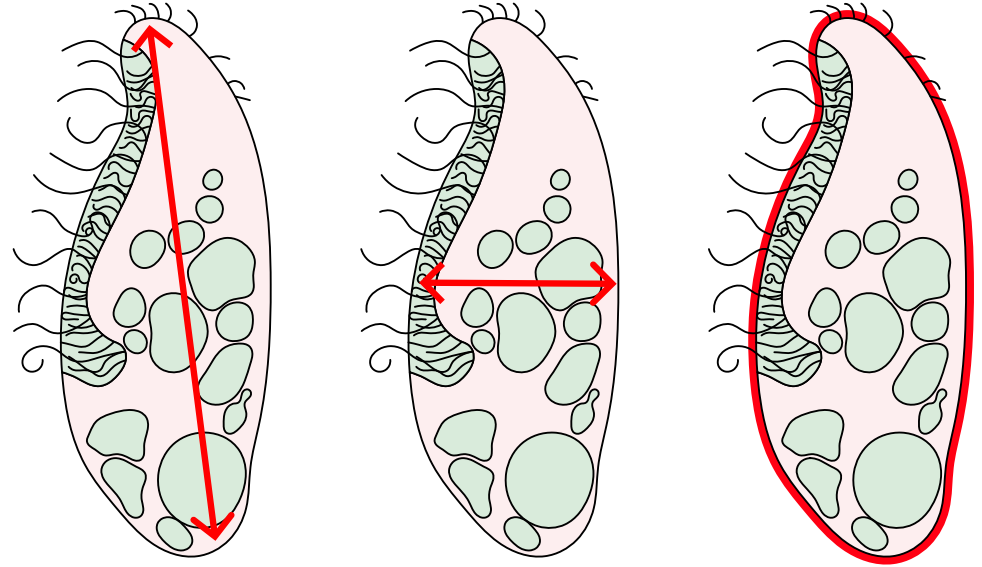


Did other traits respond to selection?

After approx. 10 months of the selection regime:

Morphological trait assay:

- Major axis
- Minor axis
- Area



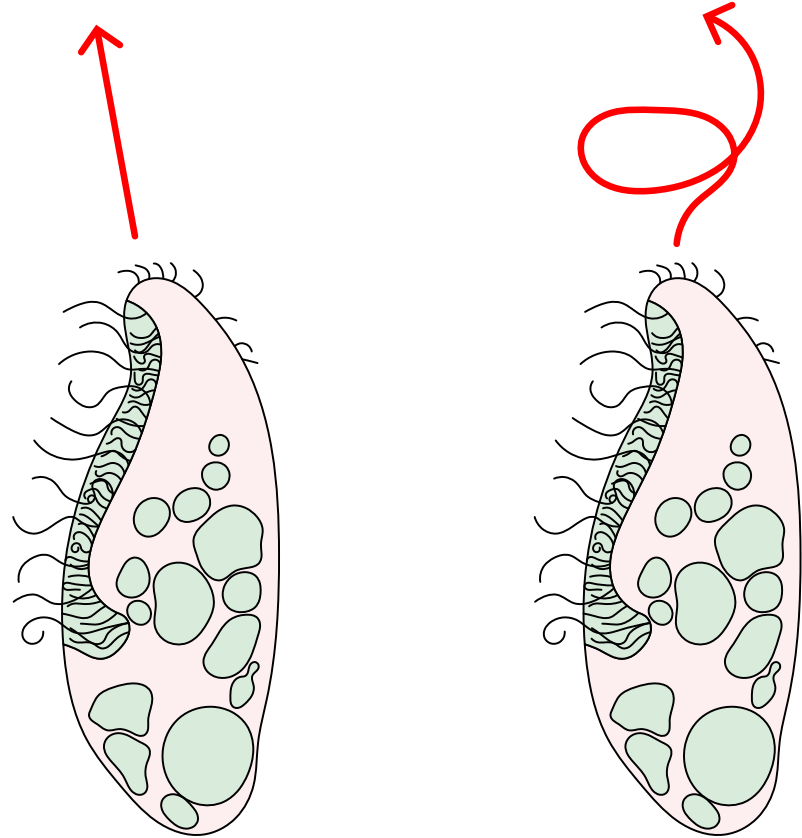
After approx. 10 months of the selection regime:

Morphological trait assay:

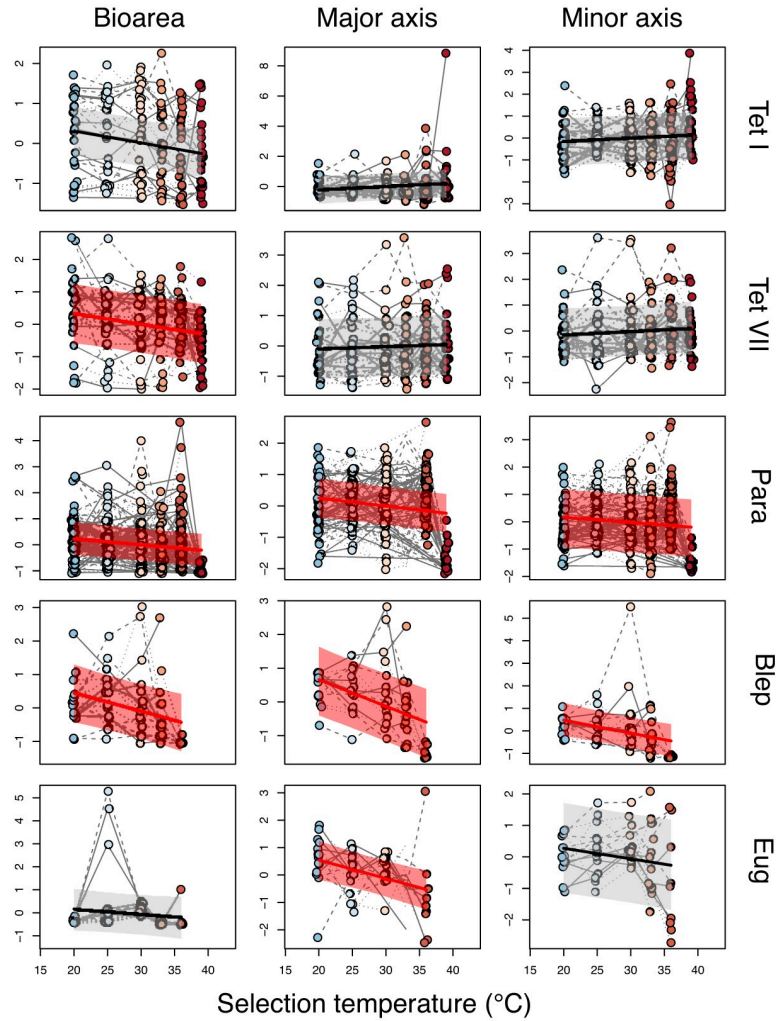
- Major axis
- Minor axis
- Area

Movement behaviour assay:

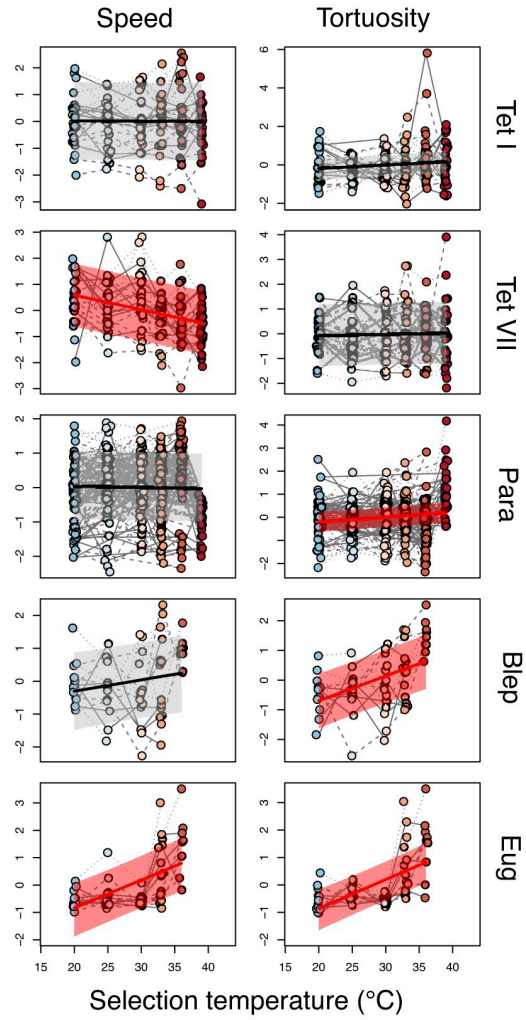
- Speed
- Tortuosity (propensity to change direction)



Consistant evolution of reduced body size in larger species



More explorative swimming behaviour in larger species



For all the bits I glossed over:



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The evolution of thermal performance curves and life-history traits in responses to thermal selection

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G.Z., I.R.M., and S.P.M. shared first authorship.

Abstract

Thermal performance curves (TPCs) capture how population growth depends on temperature. When temperatures increase, such as during global change, TPCs may evolve to match new environmental temperatures. While previous studies mostly focus on population growth rate TPCs, evolution can also be strongly trait-dependent and require a multi-trait analysis. Here, we empirically tested how TPCs and multiple demographic, life-history and movement traits evolve by selecting four freshwater protist species at increased temperatures starting from clonal populations. After ten months of selection, populations showed a signature of evolutionary responses to the highest selection temperatures in different traits depending on the species. Particularly, we found consistent evolutionary reductions in body size in the three species having the largest cells and evolved changes in movement behaviour in all species. In contrast, we observed few modifications in population growth rate TPCs. These results suggest that adaptation, via evolution of TPCs, might involve the concurrent evolution of several traits. However, this may be species-specific and difficult from de-novo mutation alone, suggesting that natural populations that do not have sufficient standing genetic variation might have to rely on other means of mitigating the effects of climate change, such as dispersal.

Keywords: thermal niche, experimental evolution, climate change, global change, adaptation

Introduction

In ecology and evolutionary biology we strive to understand how populations respond to novel environments (Merilä & Hendry, 2014; Mouquet et al., 2015; Urban et al., 2016). Populations that experience substantial environmental stress, such as global climate change, must either adapt to the stress or disperse away from the stress, otherwise they will face population decline and an increased risk of extinction (Gienapp et al., 2008; Parmesan, 2006; Thomas et al., 2004; Urban et al., 2024).

One central aspect of global climate change is increasing temperatures and global warming (Hansen et al., 2006). Temperature is an environmental variable that affects nearly all biological processes, from the molecular and biochemical dynamics of enzymes (Gillooly et al., 2001) to population growth rates, spatial patterns and diversity of populations and communities (Angilletta, 2004; Kingsolver, 2009; Wiens et al., 2006).

To be able to predict the effects of global climate change on populations, it is imperative to understand if and how adaptation to increased temperatures can occur, how quickly evolution can act, and if these adaptations are associated with trade-offs or correlated responses more generally that would impact other traits which may limit their effectiveness (Bennett & Lenski, 2007; Hoffmann et al., 2023). For instance, advancements in the field of metabolic ecology allow us to predict how ecological rates (e.g., population

growth rates, developmental rates) scale with temperature and related factors (e.g., body size) through the use of semi-mechanistic models (Brown et al., 2004).

Thermal performance curves (TPCs), which describe the thermal plasticity (or temperature niche) of a trait across a range of temperatures, are a powerful tool to investigate the impact of warming under controlled conditions (Deutsch et al., 2008; Schulte et al., 2011). Here, we specifically define the temperature niche, or thermal performance curve (TPC), of an organism as the range of body temperatures at which a non-density limited population will show positive population growth (Govodzik, 2018). The TPC, and the reaction norms of other traits (e.g., developmental rates, fecundity, body size), is typically unimodal in ectotherms, and is often described by the temperature value at which the trait is maximised by (the thermal optimum, T_{opt}), and the range of temperatures at which an organism can respond (the width) (Amarasekare & Savage, 2012; Kingsolver et al., 2011; Grimaud et al., 2017). Further, the same shape (approx. left skewed unimodal distribution) of the temperature niche appears across a wide-range of ectotherm taxa (Dell et al., 2011; Deutsch et al., 2008; Kingsolver, 2009), likely due to the highly conserved nature of the physiological and biochemical processes that underlie these reaction norms (Brown et al., 2004; Gillooly et al., 2001; Have, 2002).

Multiple empirical studies have investigated TPC evolution: For instance, using outdoor mesocosms, Wang et al.

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With thanks to:



Giacomo
Zillo



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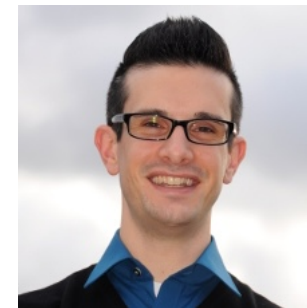
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