Sizing the effects of temperature on fish

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Introduction

Size-at-maturation and maximum size are key traits, defining ecoloical niches and driving ecological interactions[1]. Temperature has been identified in various contexts as a key driver of organism size (Bergman's rule, Temperature size rule…)[2]. Climate change may therefore have strong effects on organism size and follow on effects at population and ecosystem levels, but no clear framework to understand effects of temperature.

Aim: Develop a eco-physiological model to predict effects of changing temperatures on organism size over ecological and evolutionary time-scales

Model

We set up a weight (w) based model consisting of mass and oxygen balance equations:

Feeding - type 2 response with parameters for maximum consumption rate γ and maximum intake h, modulated by feeding activity τ:

$$f = \frac{\tau\gamma w^p \Theta}{\tau\gamma w^p \Theta + T_h^c h w^q}$$

Mass balance: Intake is assimilated with loss from heat increment ϕ and absorbtion β. Metabolic loss due to standard and feeding activity (τ) metabolic costs

$$P = (1-\beta-\phi) f T_h^c h w^q - k(1+\tau\delta) T_M^c w^n$$

Oxygen balance: Oxygen sets the limit for metabolism via the cost of metabolising one gram of feed ω relative to the potential oxygen supply $f_{O_2} w^n$:

$$P_{0_2} = f_{O_2} w^n - \omega(\beta f_C T_h^c h w^q + k(1+\tau\delta) T_M^c w^n)$$

Mortality: Weight based with base mortality m_0 and activity related mortality m_τ.

$$M = (m_0 + \tau m_\tau) w^{1-p}$$

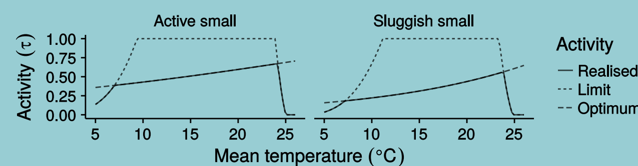
τ is optimised at any temperature via Gilliam's rule (argmax$_\tau\{\mathbf{P/M}\}$)

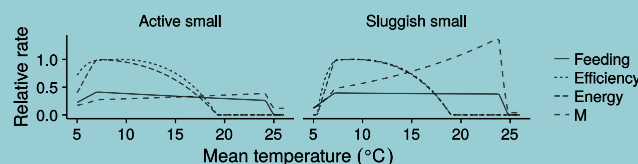
Ecological dynamics

With increasing temperature, most organisms will increase activity τ to offset increased metabolic costs.

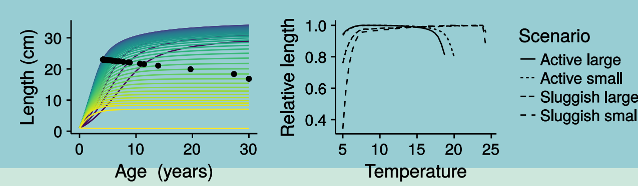
Feeding level, available energy and mortality are impacted by response to temperature

Oxygen sets metabolic limits at extreme temperatures





Temperature affects size via evolved reaction norm on ecological time-scales:



Traits

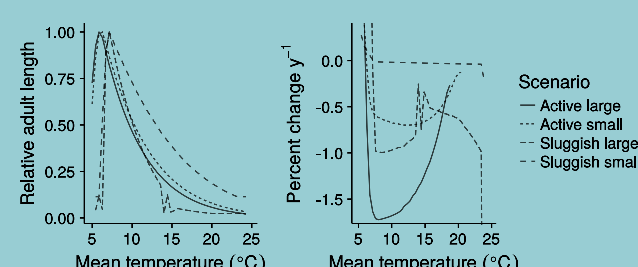
Two strategists: minimising mortality M or maximising energy gain P

P strategy: * Maximise intake at the cost of higher standard metabolism to feeding maintain activity and larger gut. * Live with higher M

M strategy: * Minimise M by minimising dangerous feeding activty, minimise resting metabolism

Evolutionary impact

Size-at maturation reacts strongly to temperature changes in the model, however, changes are small on ecological time-scales ($$1mm per year)



Acknowledgements

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All code for this poster is accessble from github.

References

1. Andersen, K. H. & Beyer, J. E. Asymptotic size determines species abundance in the marine size spectrum. *The American Naturalist* **168,** 54–61 (2006).

2. Atkinson, D. Temperature and organism size: A biological law for ectotherms? *Advances in ecological research* **25,** 1–1 (1994).