Non-linear growth-temperature relationship leads to opposite response to warming in cold versus warm populations

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PICES Annual Meeting, Seattle, 2023

Acknowledgements

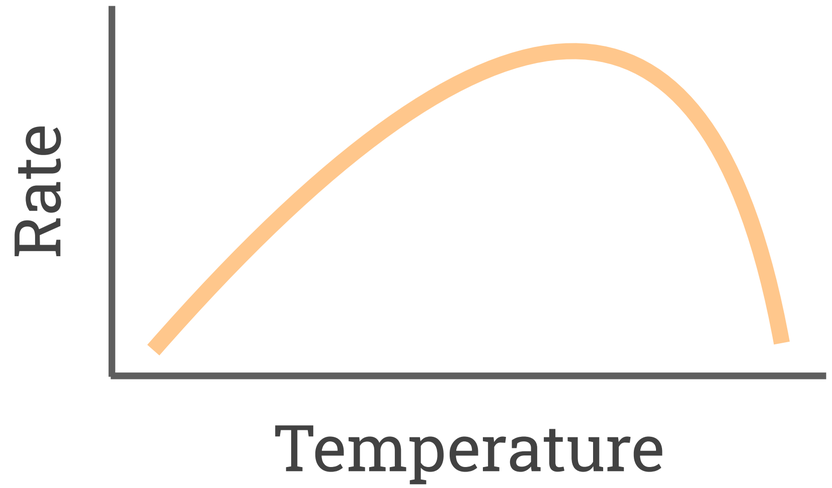
- PICES
- WGGRAFY
- Funding from the Swedish Research Council Formas
- Co-authors
- People involved in the huge data collection effort

Jan Ohlberger

Anna Gårdmark

Questions

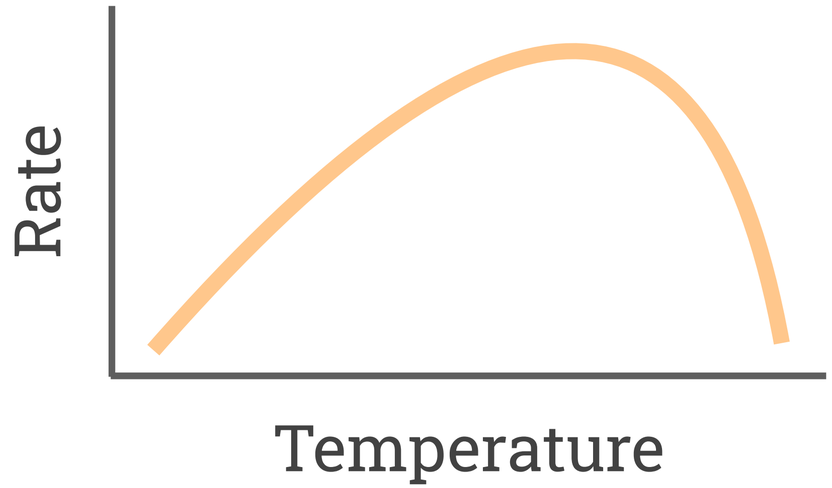
- Physiological responses to warming are not linear



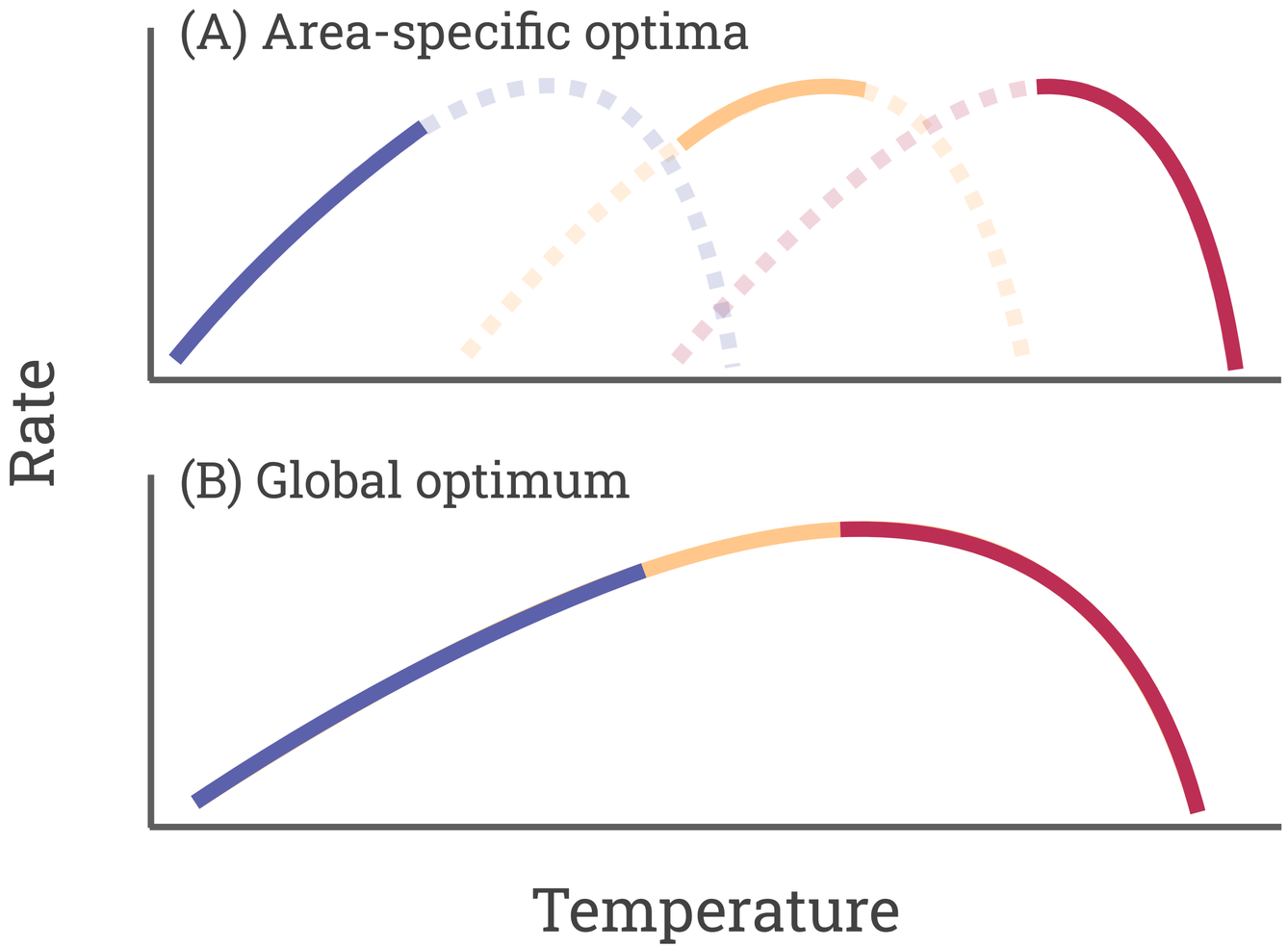
Questions

- Physiological responses to warming are not linear

- Do responses to temperature differ among populations within species?



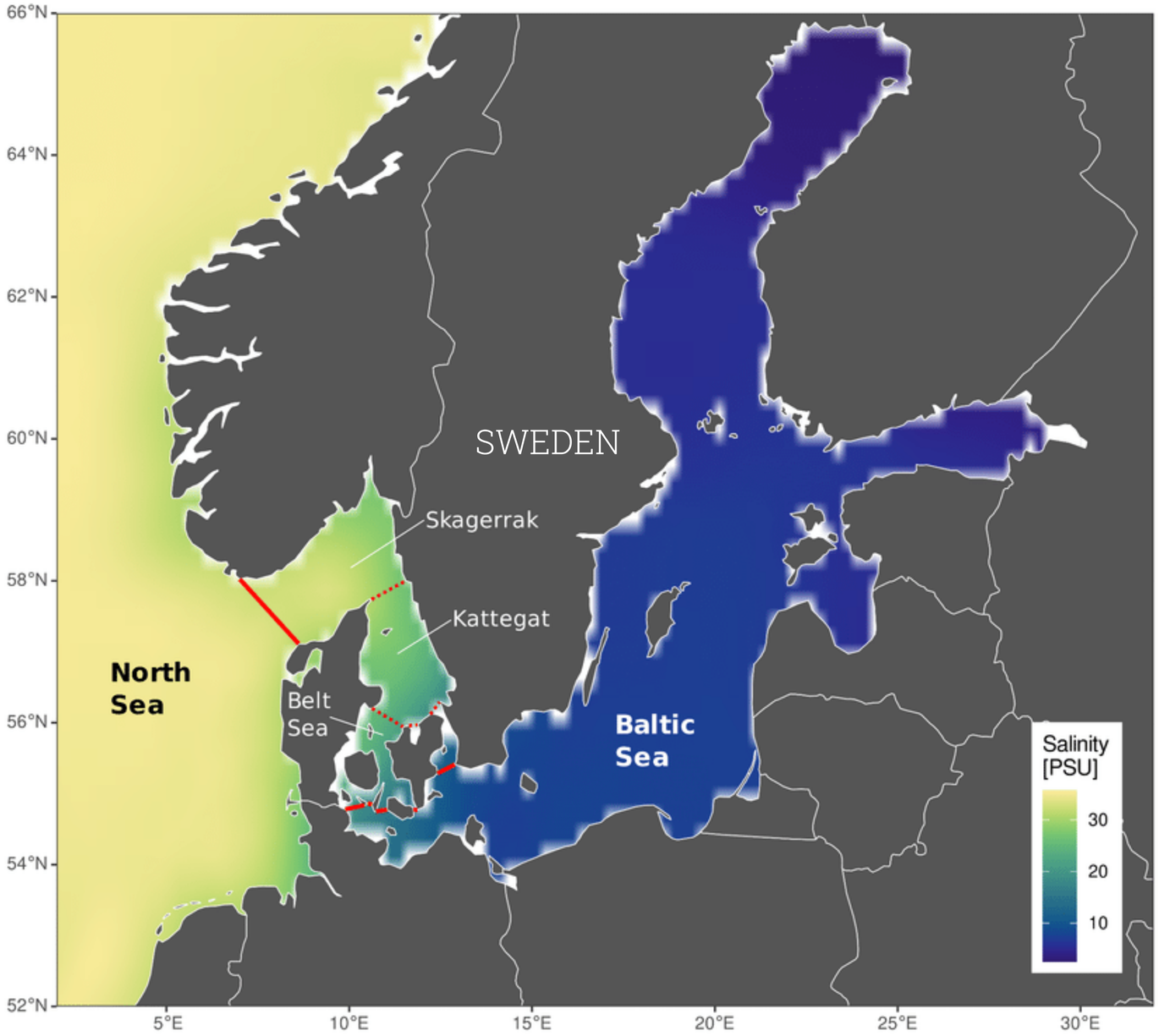
Local adaptation?



Study system & data

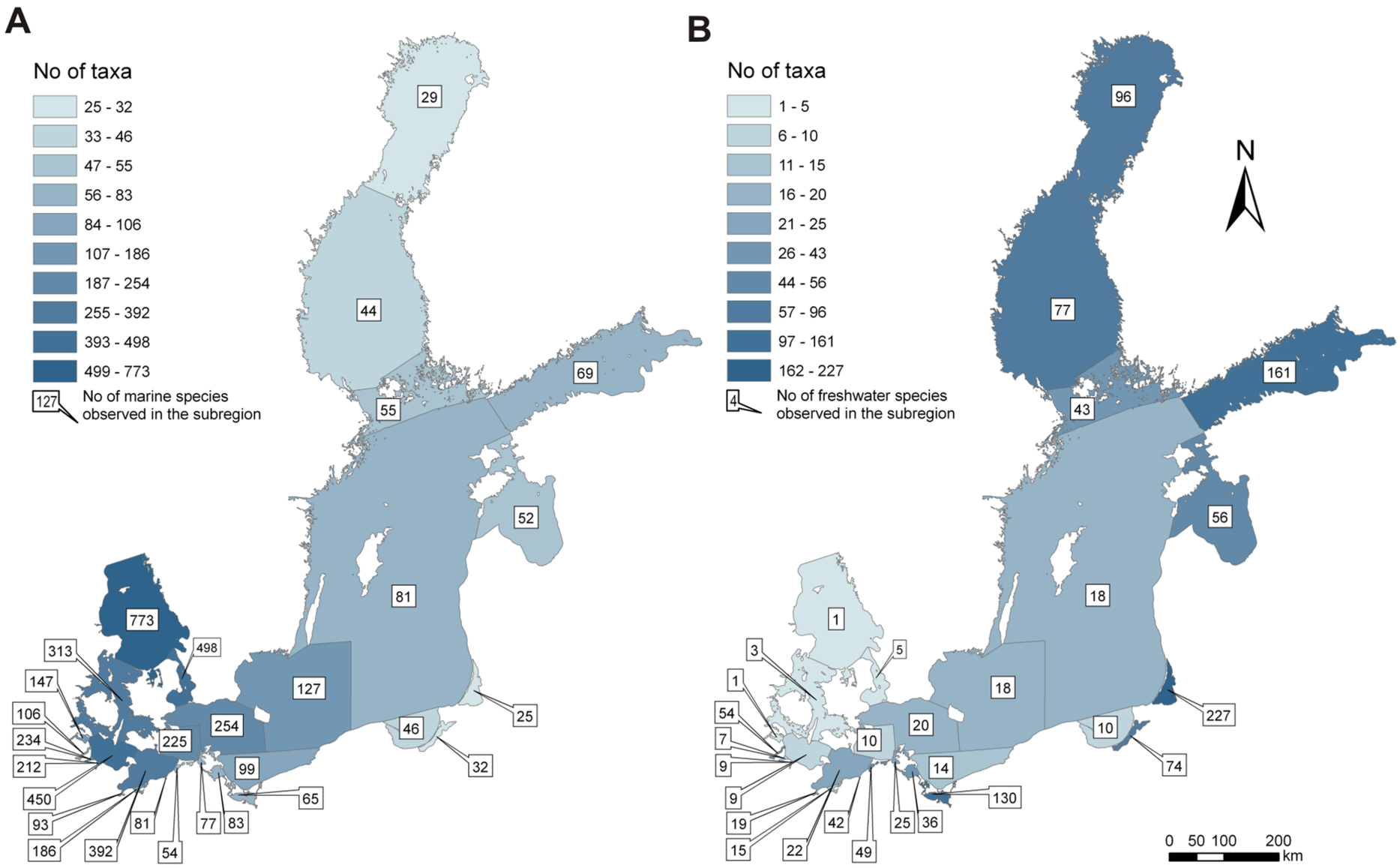
Baltic Sea

- Shallow, brackish water inland sea



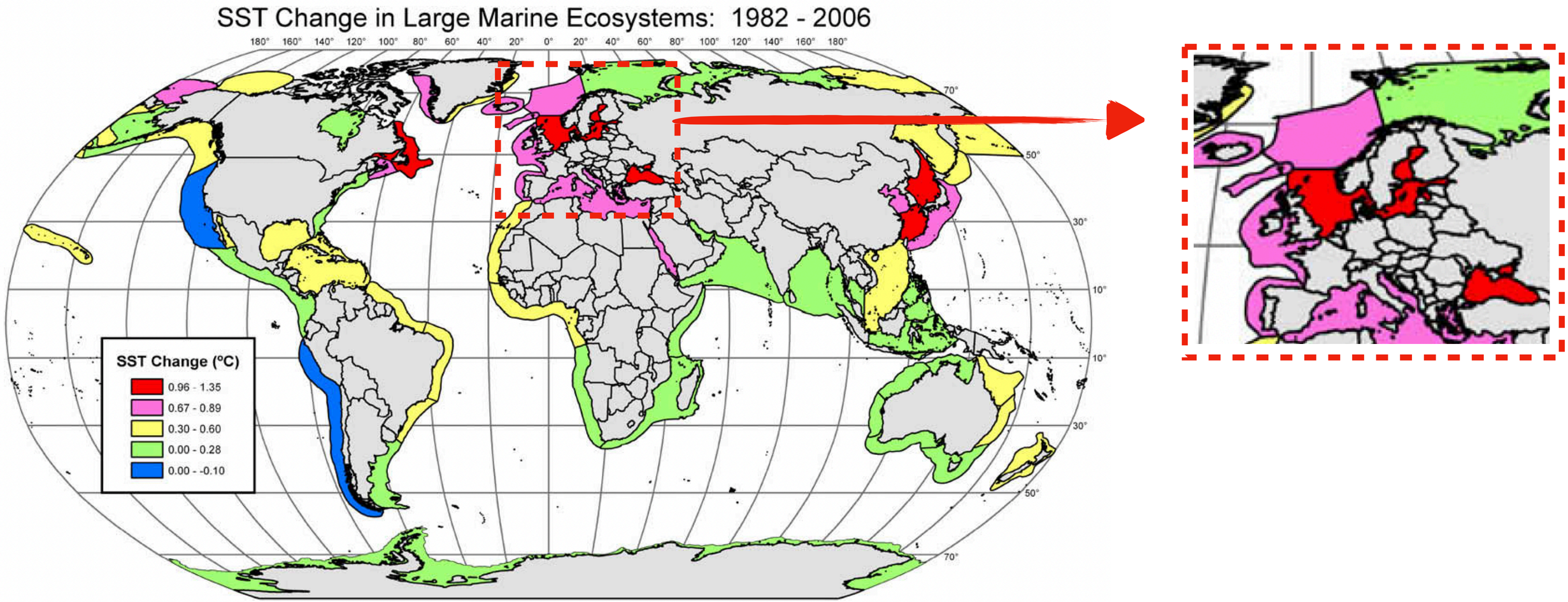
Geburzi et al., (2022) bioRxiv

Gradient of freshwater & marine species



Ojaveer et al., (2010) PLOS One

Rapid warming in the Baltic Sea

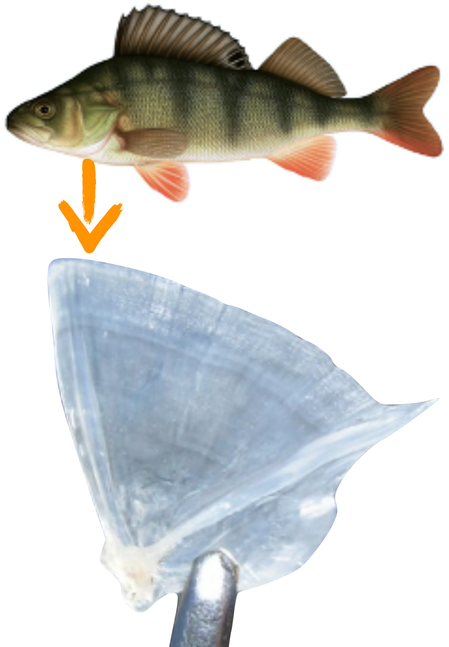


Belkin (2009) Progress in Oceanography

Biological data

Biological data

- Back-calculated length-at-age from operculum bones
- 145,715 data points
- 24,337 individuals
- 10 stations over 57°–66° Lat
- Oldest cohort 1953
- Average time series length: 32 years

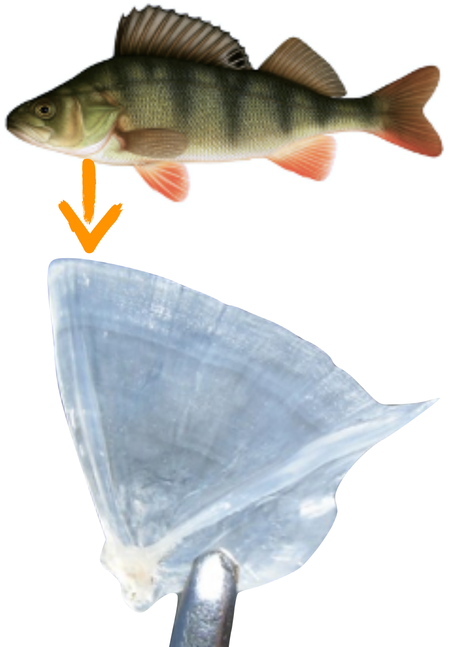


Biological data

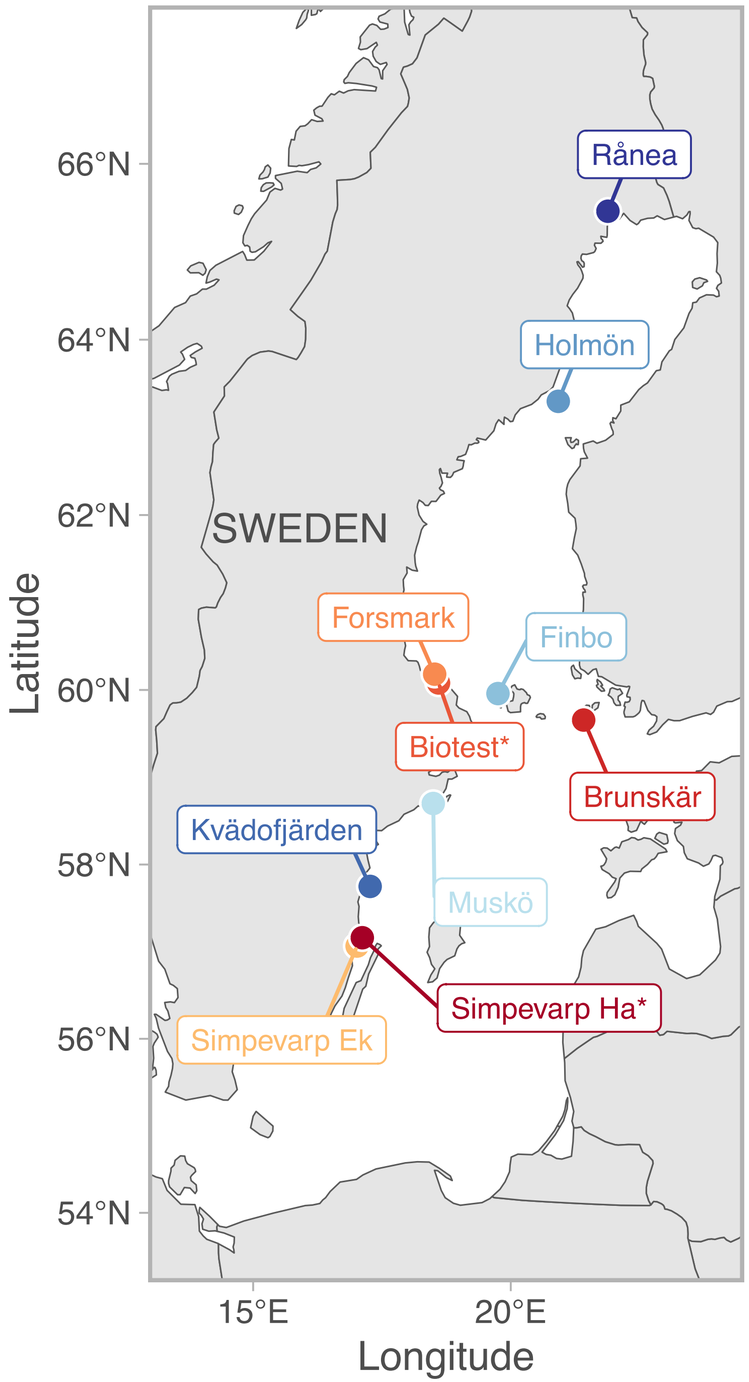
- Fit VBGE models to each individual

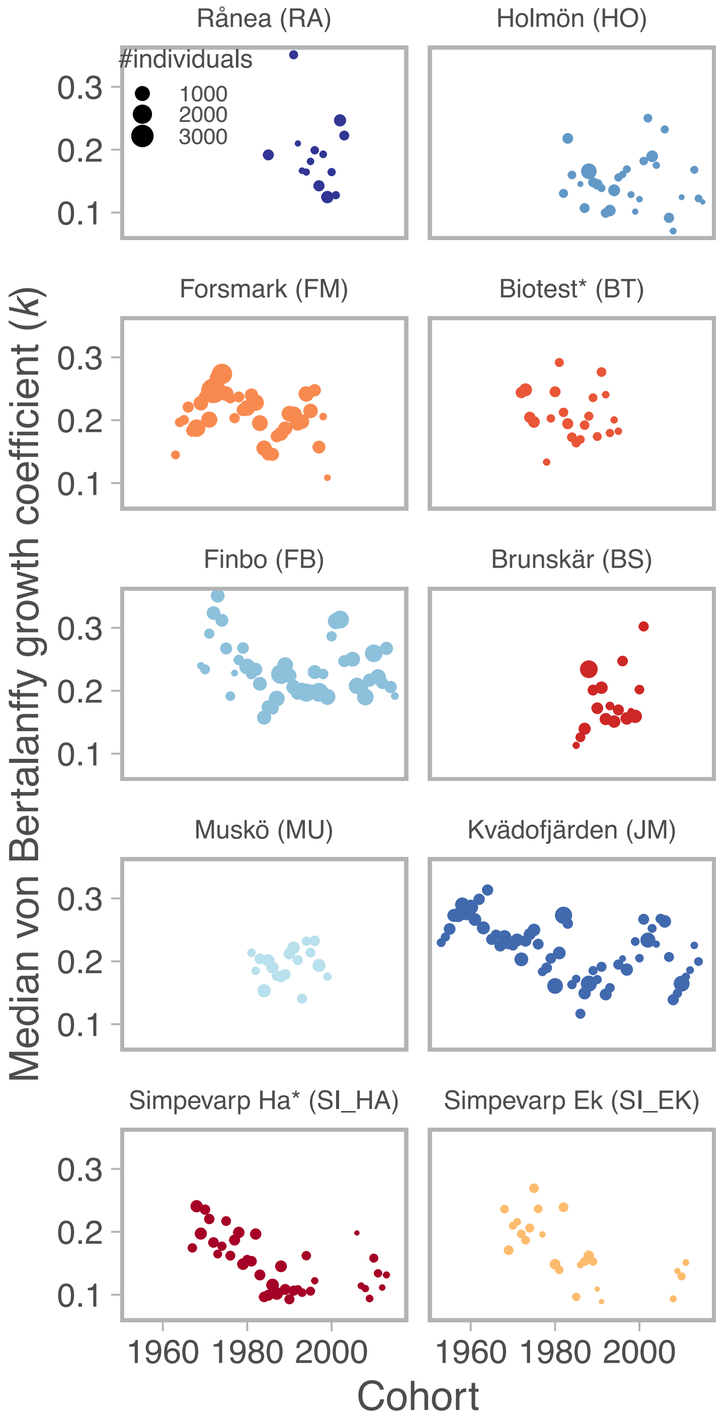
$$L_t = L_\infty(1 - \exp(-\mathrm{k} \times \mathrm{age}))$$

- Calculate median by cohort and area

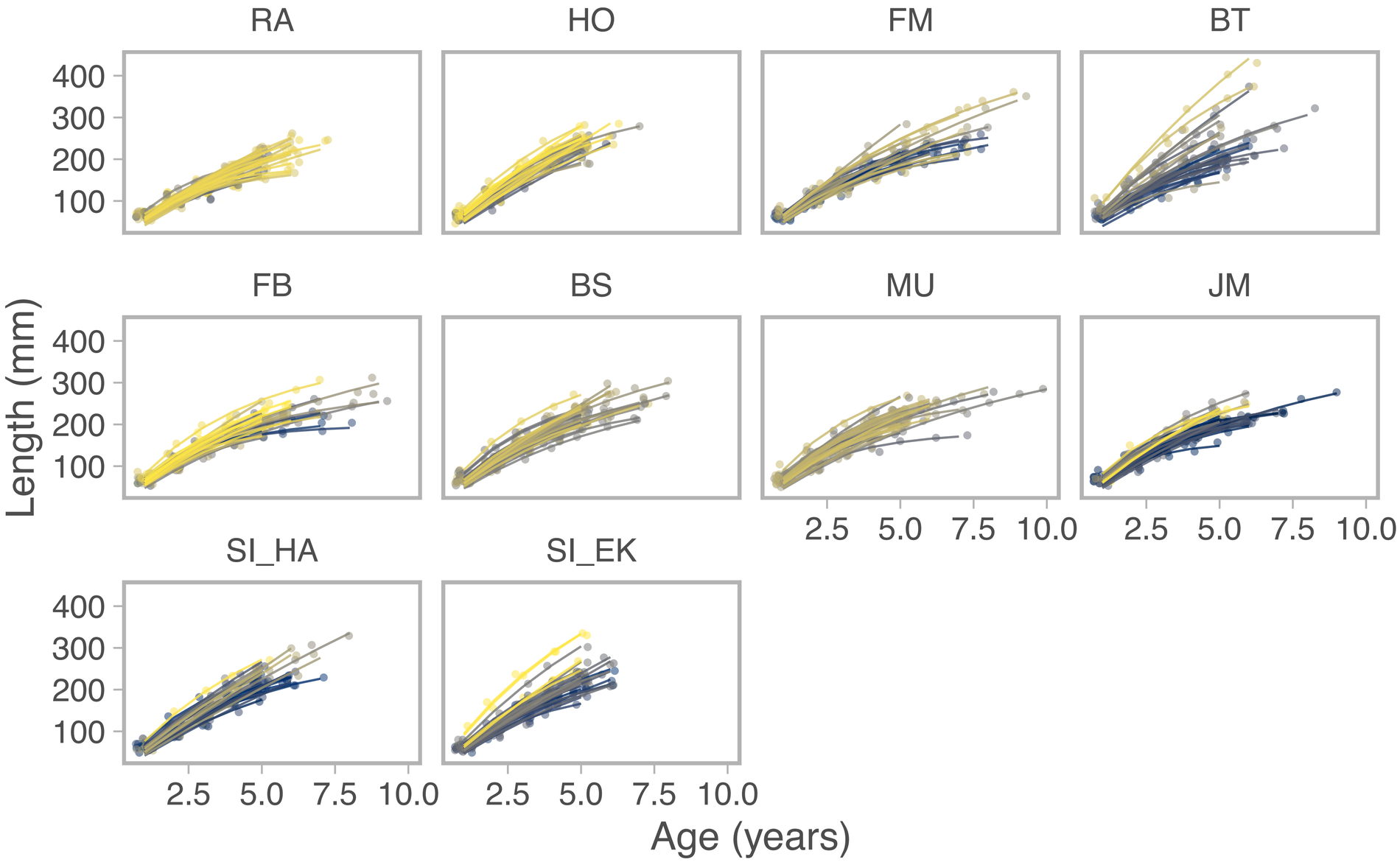


Monitoring stations & sample size

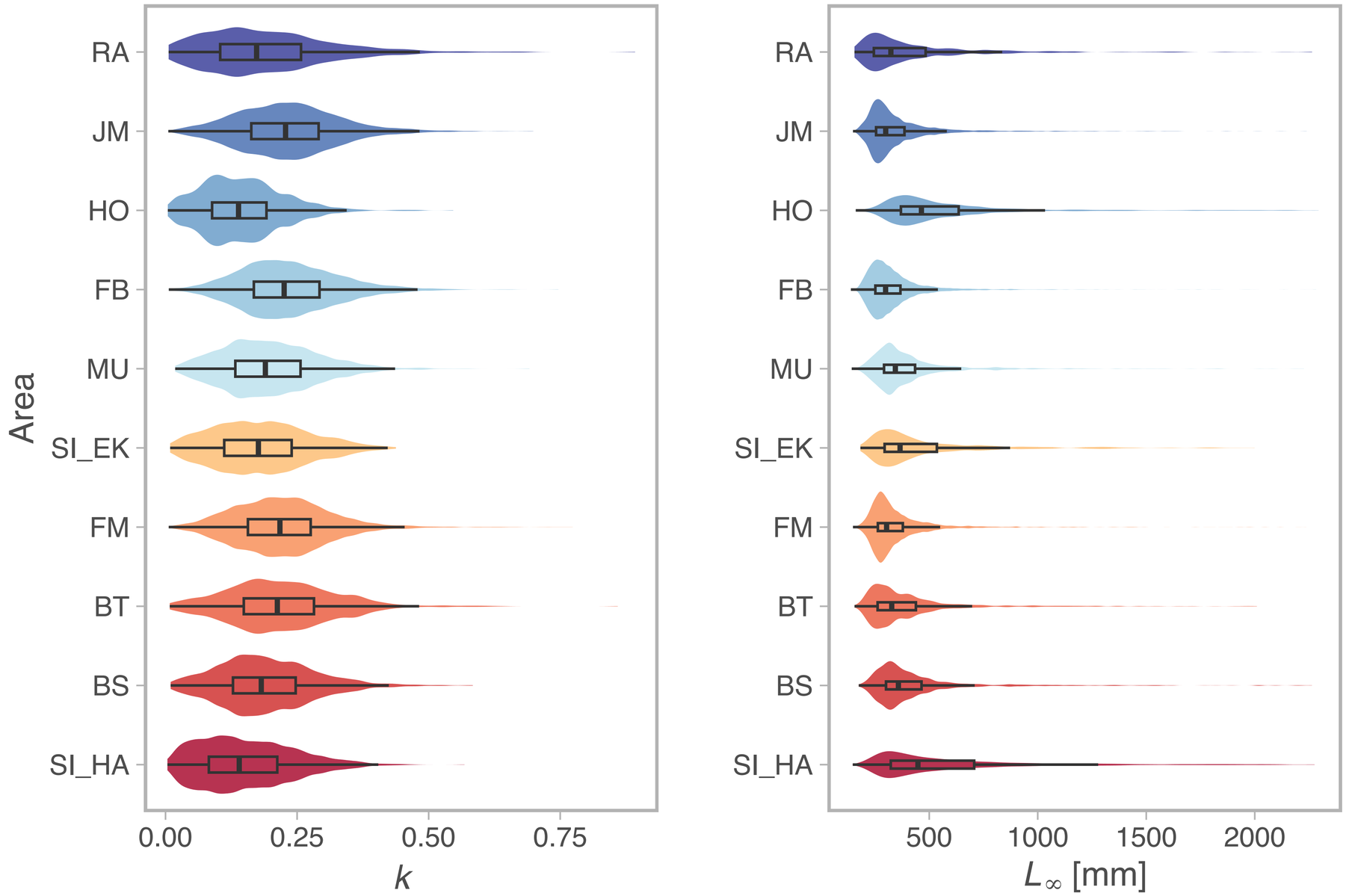




Example VB fits



VB Parameters by area



Temperature data

Temperature data

- Manually measured during fishing
- Temperature loggers (daily)
- ERSST

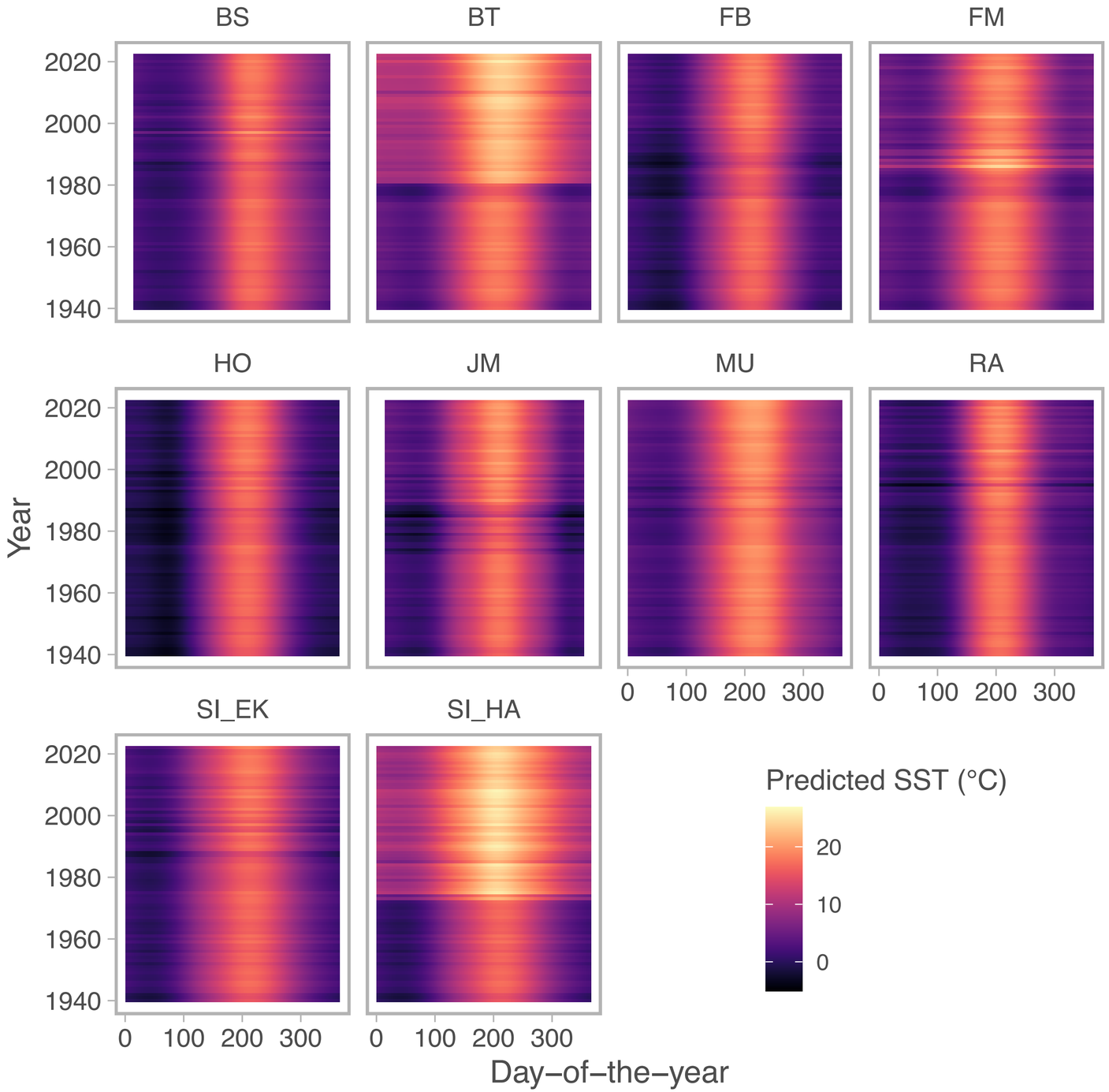
Temperature data

- Fit models to reconstruct time-series of temperature {sdmTMB}
- Predict daily temperatures and calculate annual averages

$$SST_i = \text{Student-t}(\nu, \mu_i, \sigma)$$
$$\mu = \alpha_t + s(day) + source$$

‘sdmTMB’ (Anderson et al., 2021)

Temperature predictions



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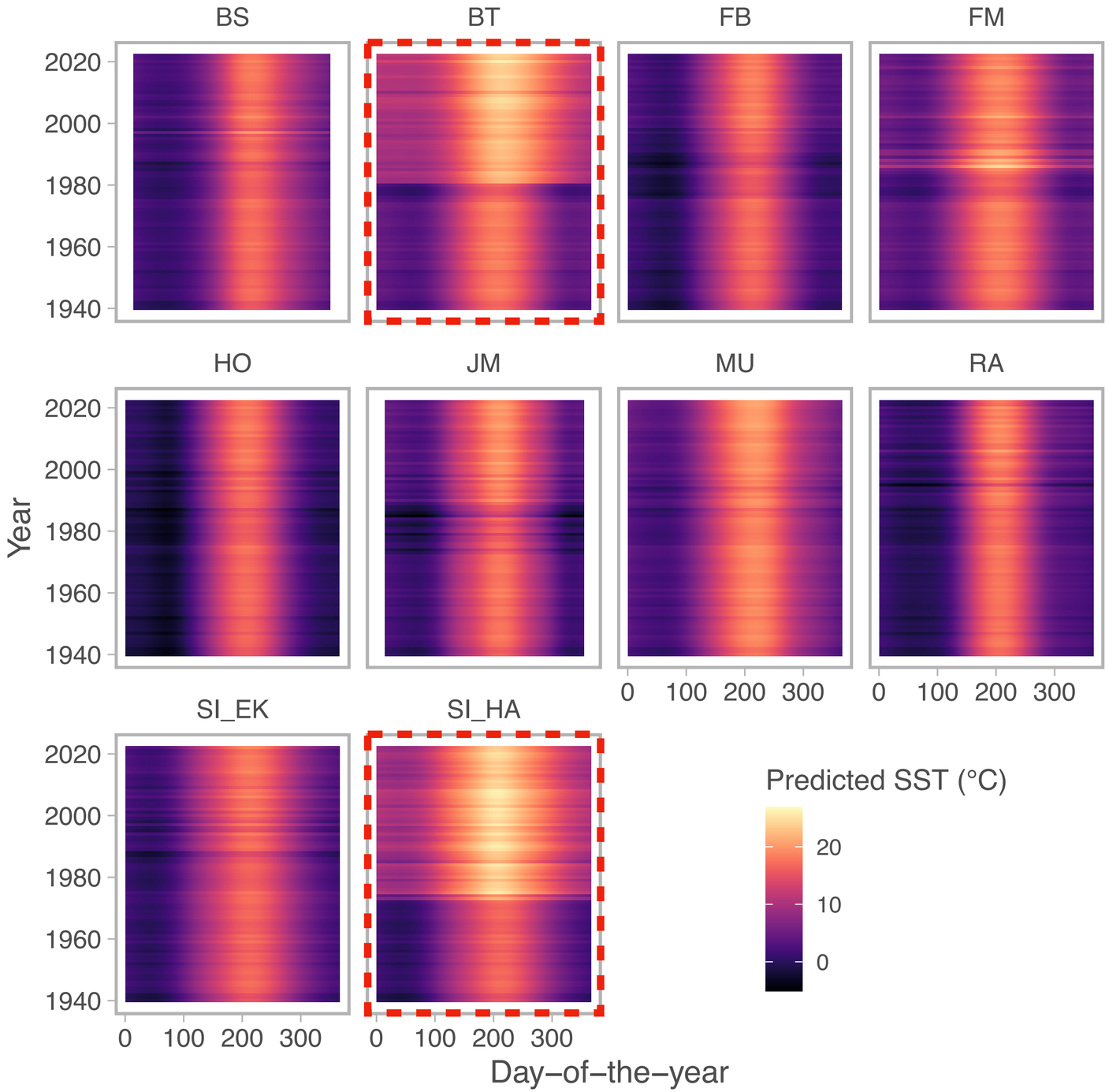
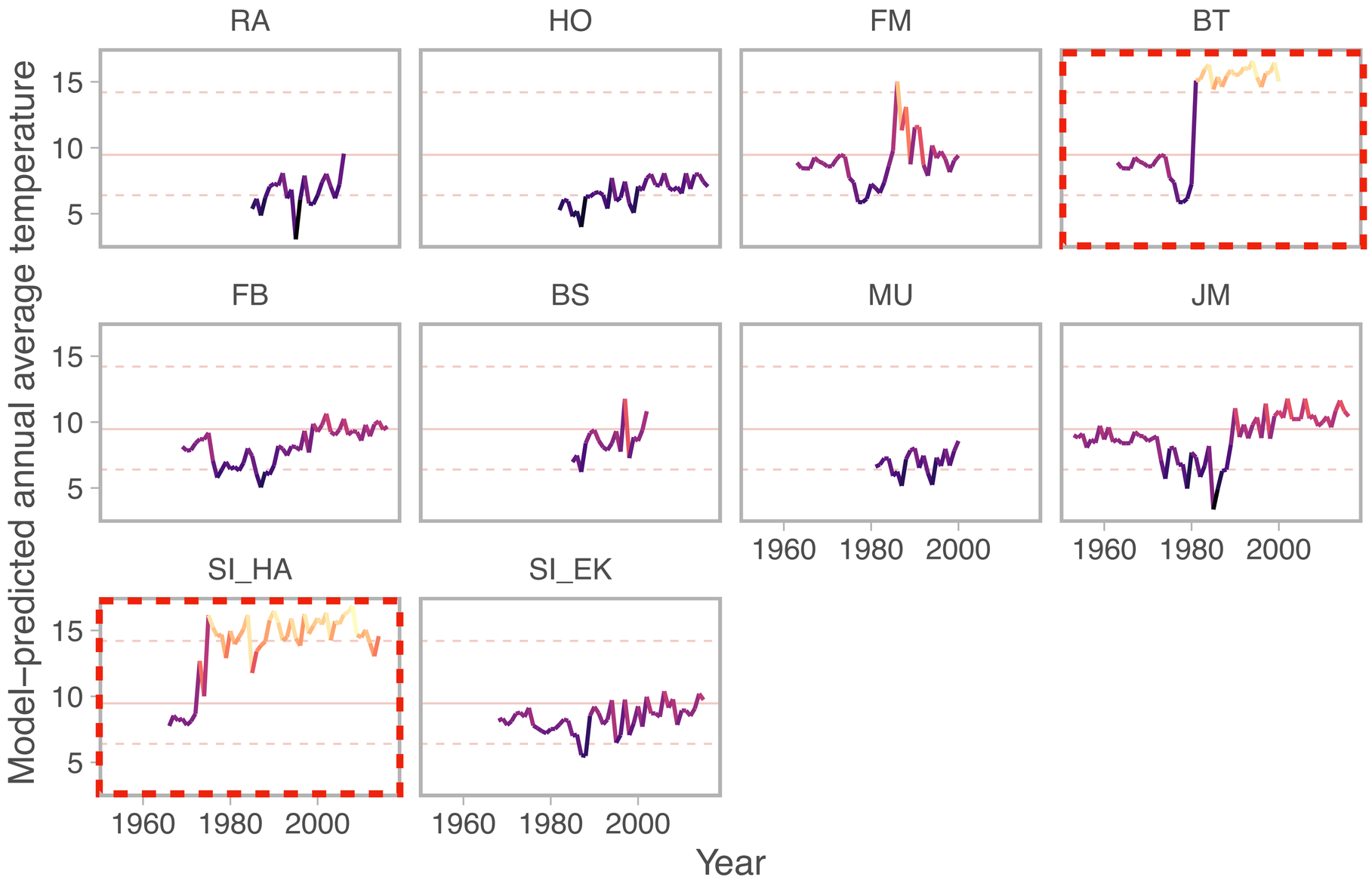


Annual average temperatures



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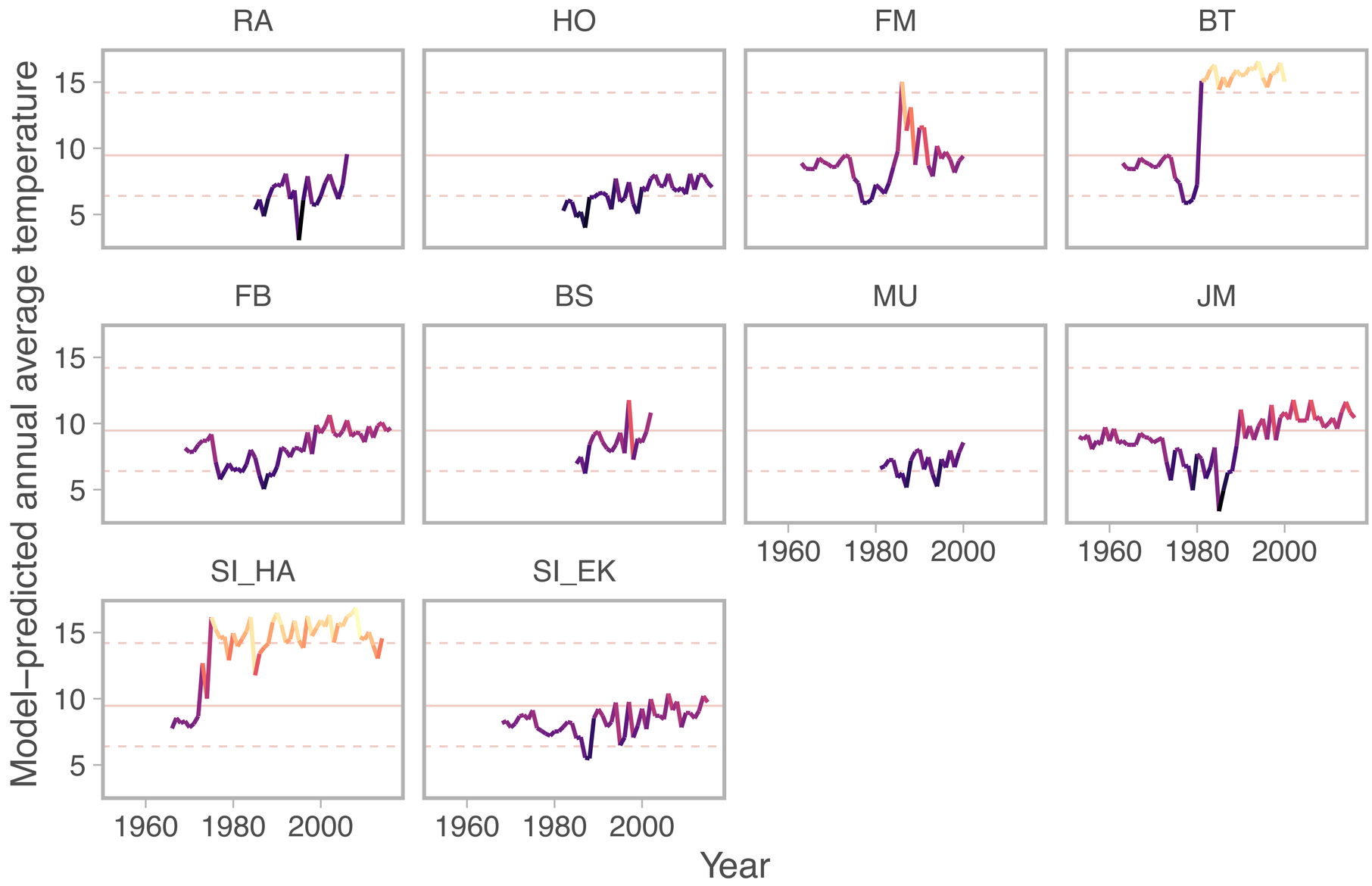


Growth~Temperature

Growth~Temperature

- Fit Sharpe-Schoolfield model to k {brms}

$$k_i = \text{Student-t}(\nu, \mu_i, \sigma)$$

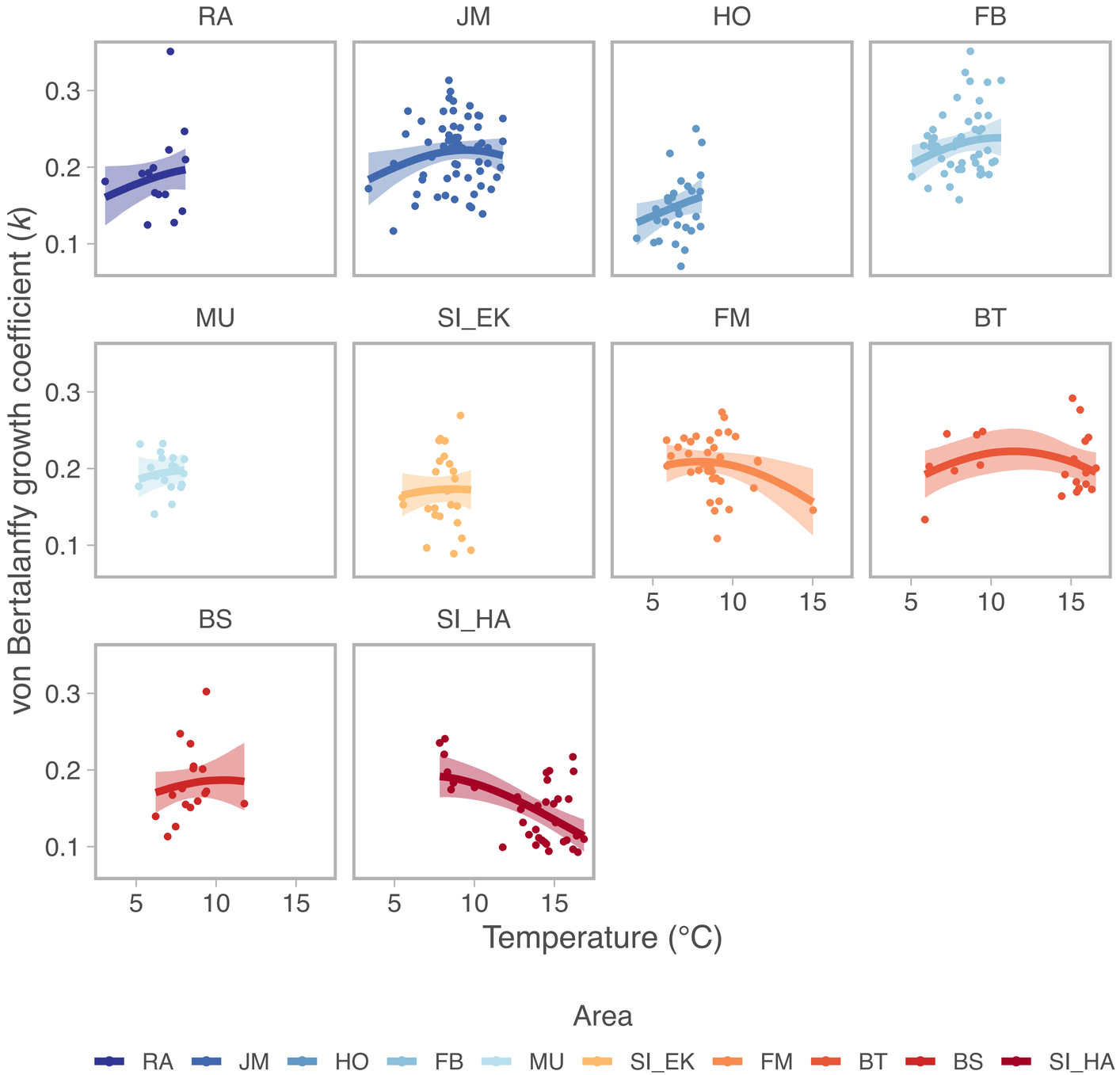
$$\mu = \frac{b(T_c)e^{E(\frac{1}{kT_c} - \frac{1}{kT})}}{1 + e^{E_h(\frac{1}{kT_h} - \frac{1}{kT})}}$$

- Area random effect for all parameters OR global model

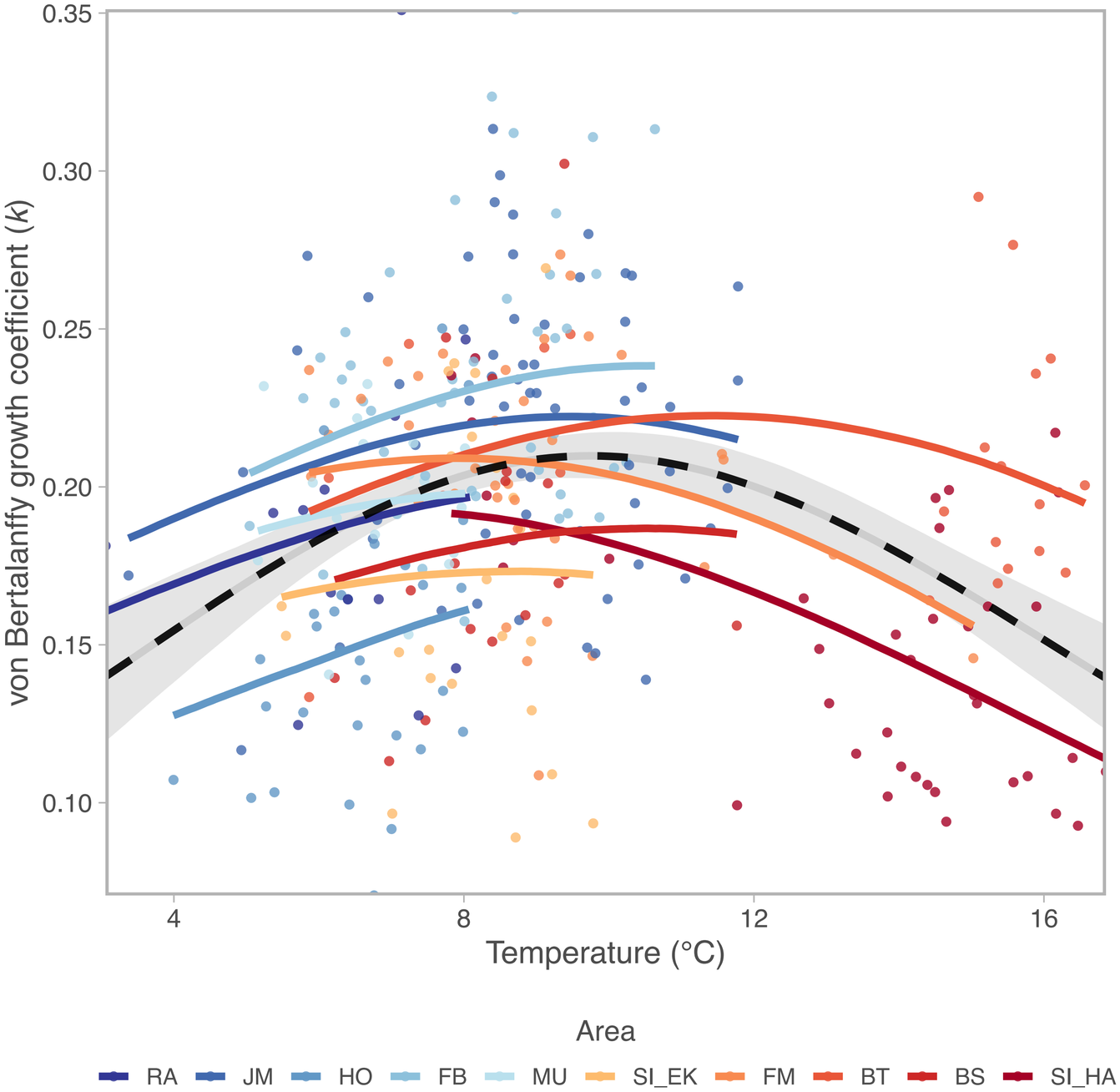
- Informative priors

'brms' (Bürkner 2017) JSS; Schoolfield & Magnuson (1981) J. Theor. Bio.;Padfield et al., (2020) ISME

Non-linear growth~temperature by area



Area-specific predictions align with the global prediction



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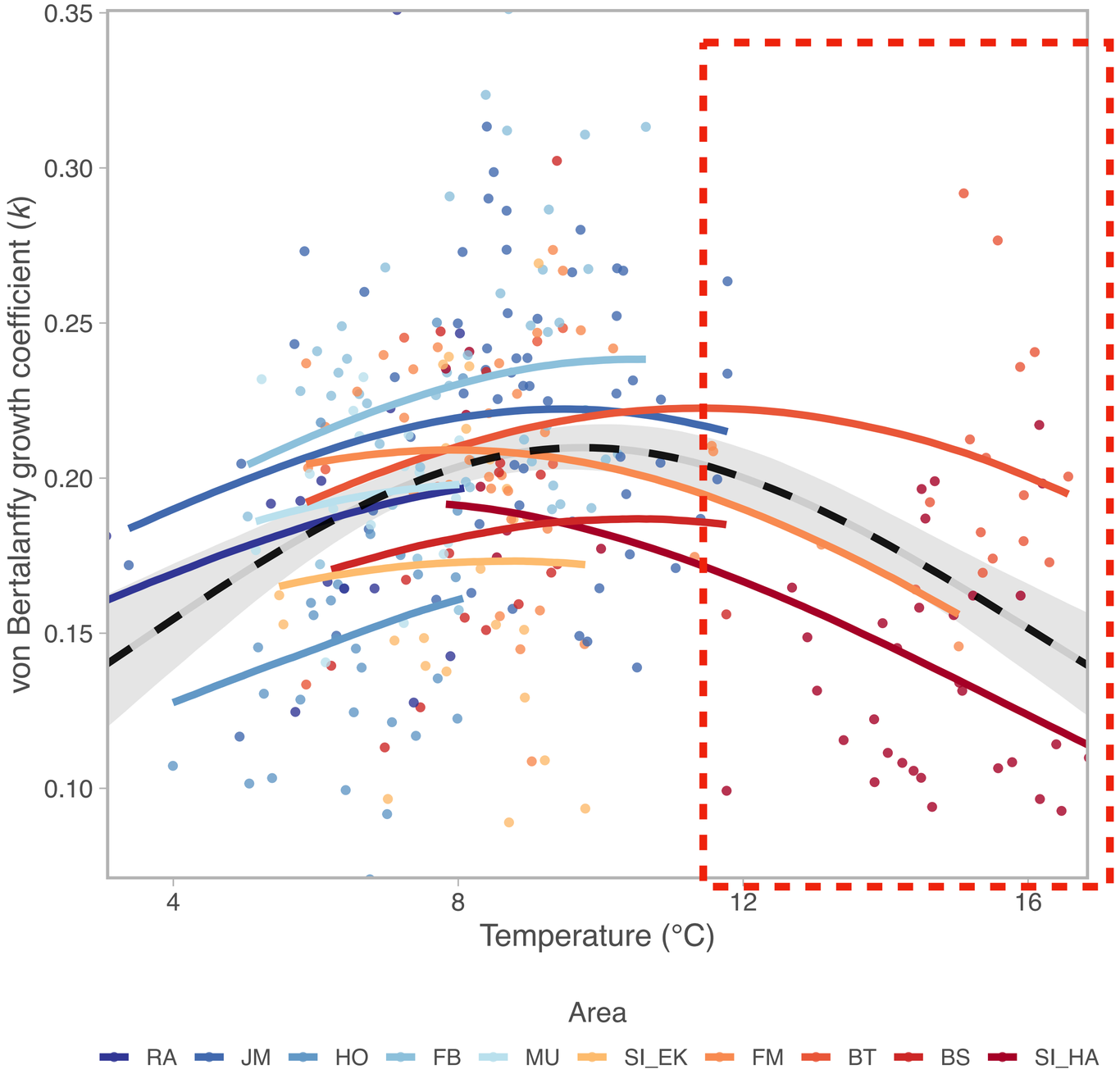
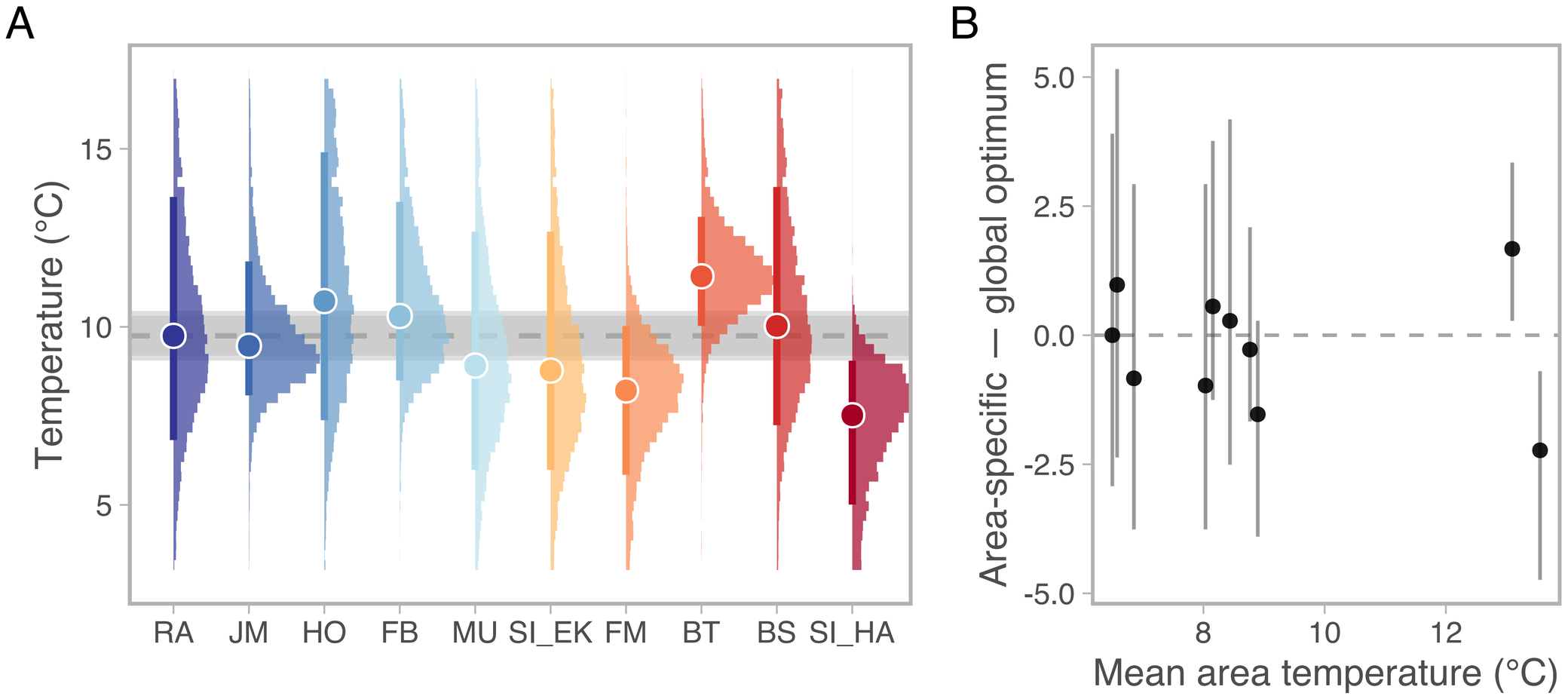


No systematic deviation in area-specific optimum from global optimum



Summary & Outlook

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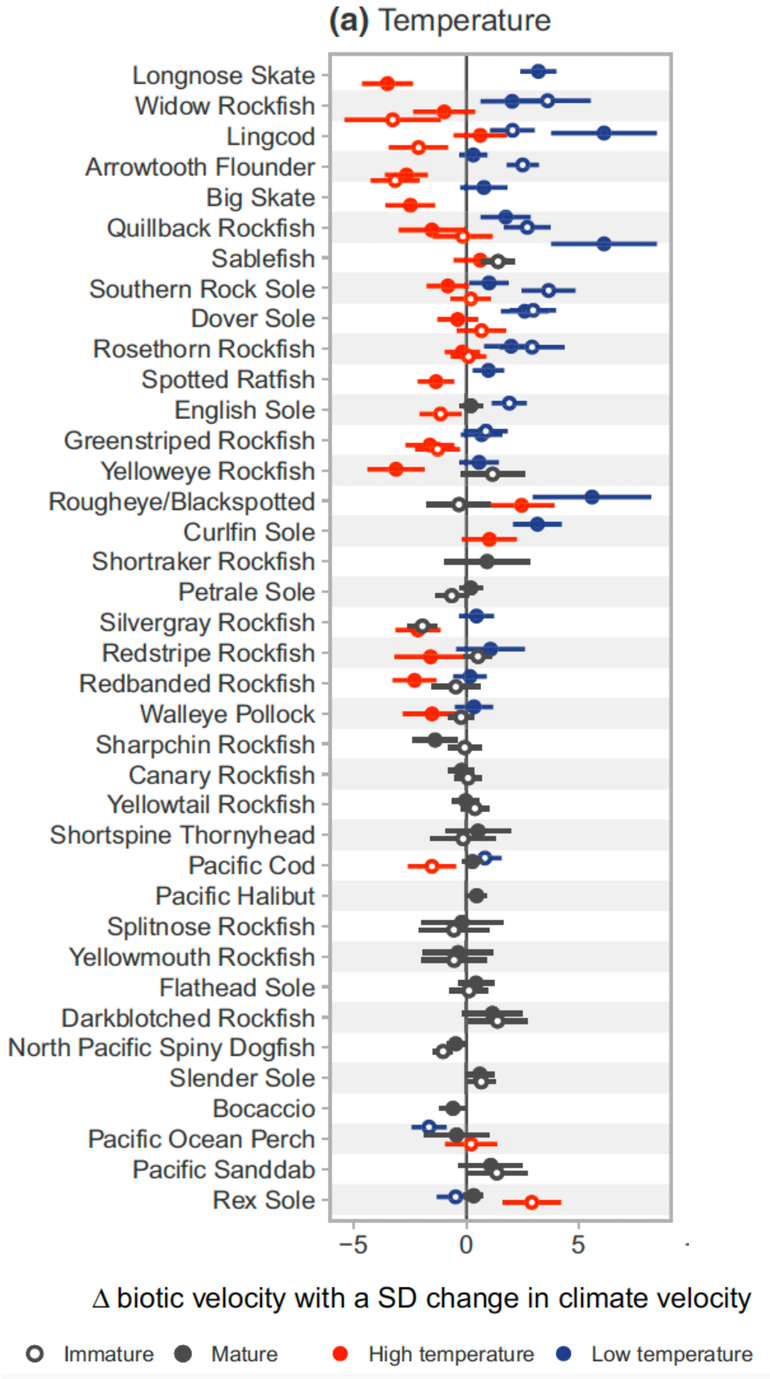

English et al., (2022) Fish and Fisheries

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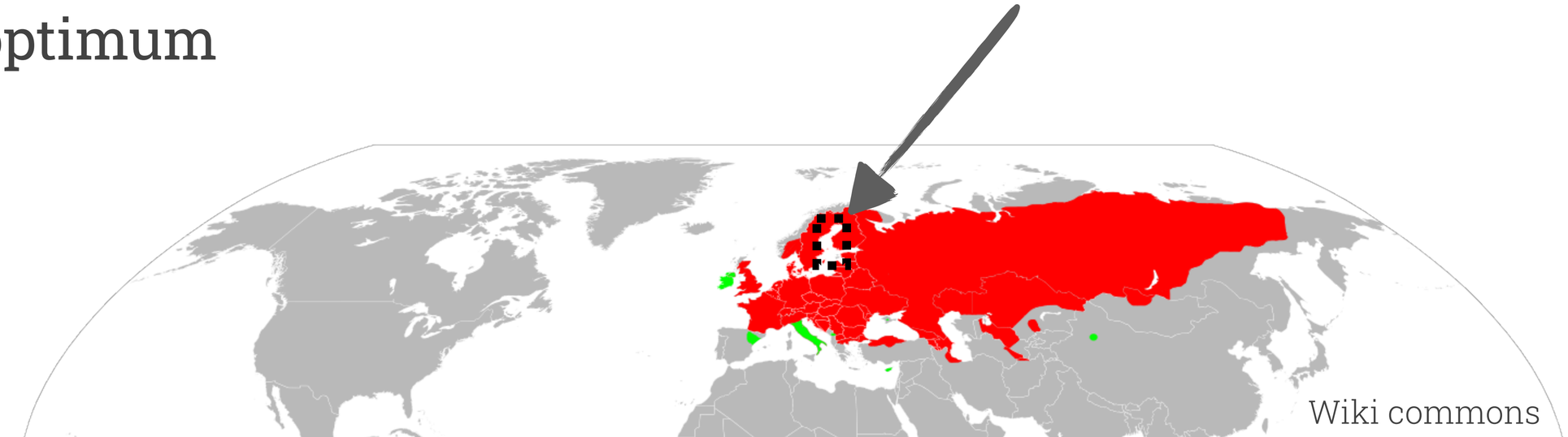

Wiki commons

Summary & Outlook

- Important to account for non-linear temperature effects & species distributions in relation to those

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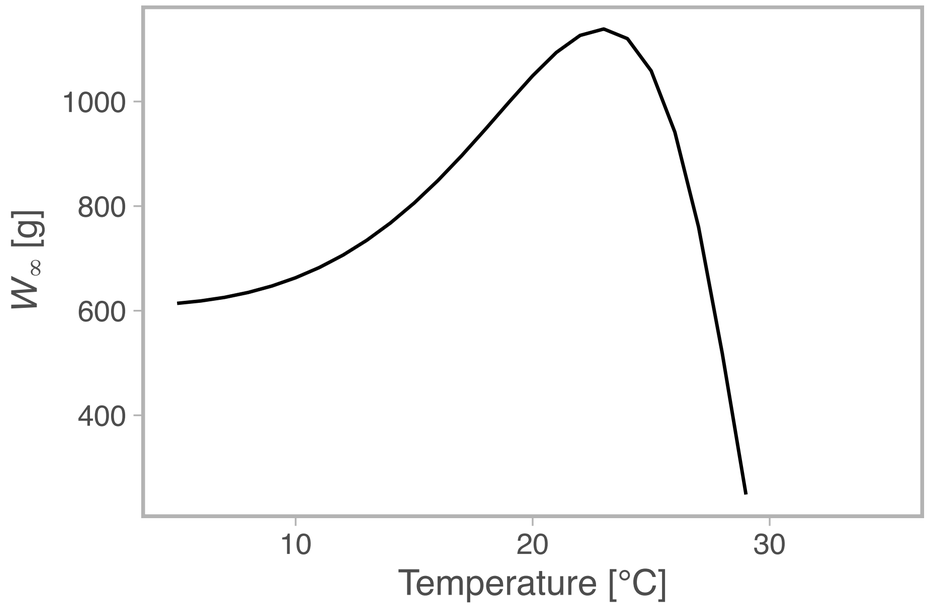
$$\frac{dW}{dt} = a(T)W^y - b(T)W^z$$

$$W_\infty = (a/b)^{1/(z-y)}$$



Thank you for listening!

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