Estimating species interactions from experimental data

Bayesian thinking and Ecology Workshop - Part B project

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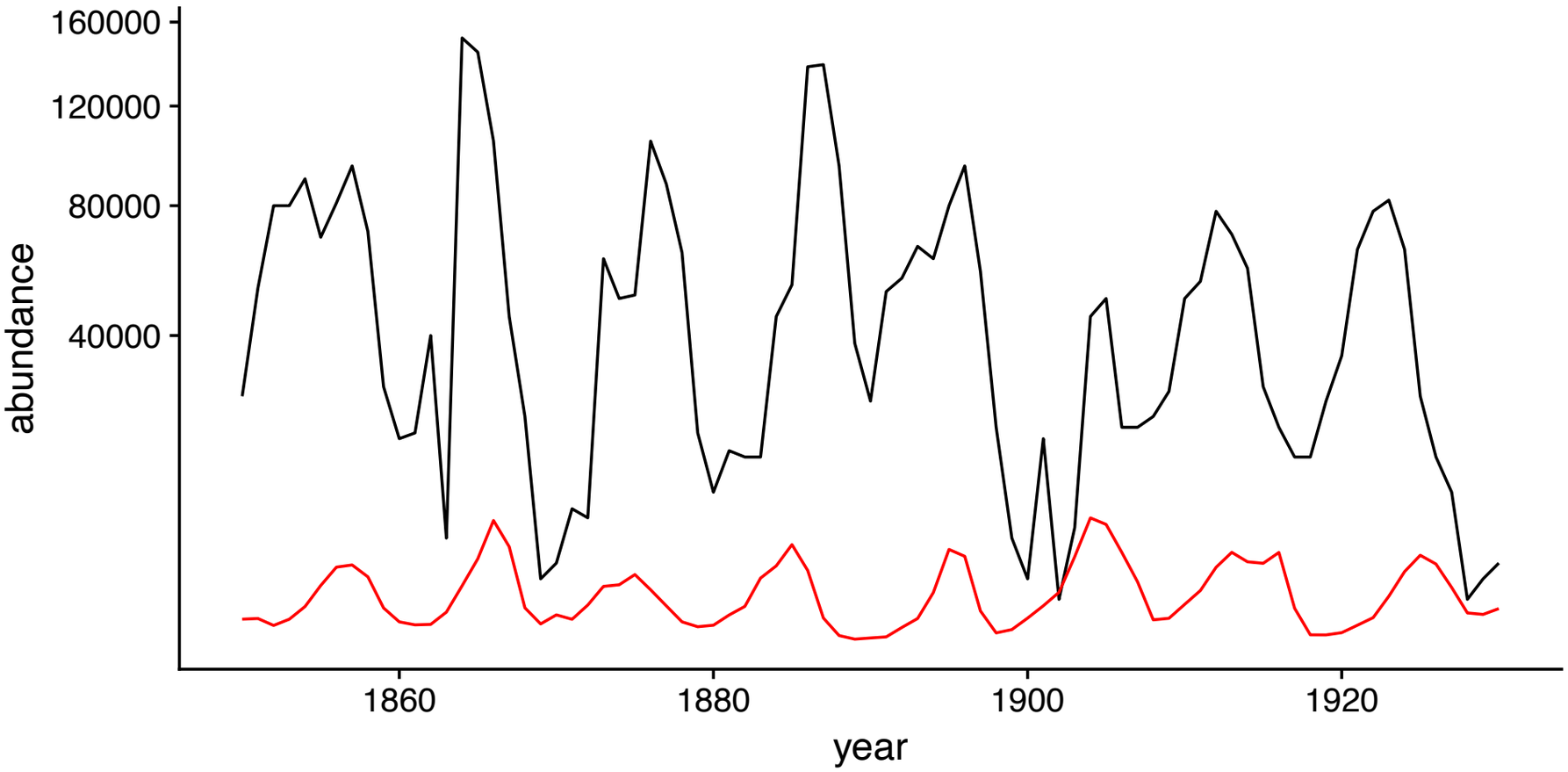
Background

- Species interactions are crucial for the stability of ecological communities
- Example: predator-prey interaction between snowshoe hare and lynx
- Goal: quantify interaction strength



Snowshoe hare

Canadian lynx

Fitting ordinary differential equations to infer parameters

Lotka-Volterra predator-prey model

Change in prey population

$$\frac{d🐭}{dt} = \alpha 🐭 - \beta 🐭 🐈$$

Effect of predator on prey

Change in predator population

$$\frac{d🐈}{dt} = \delta 🐭 🐈 - \gamma 🐈$$

Effect of prey on predator

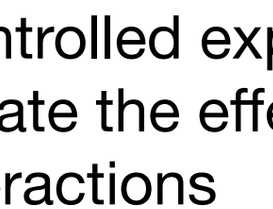
Volterra, V. (1926). Fluctuations in the abundance of a species considered mathematically. Nature, 118(2972), 558-560.

Experimental data to infer interaction coefficients

- Controlled experiments to isolate the effect of species interactions

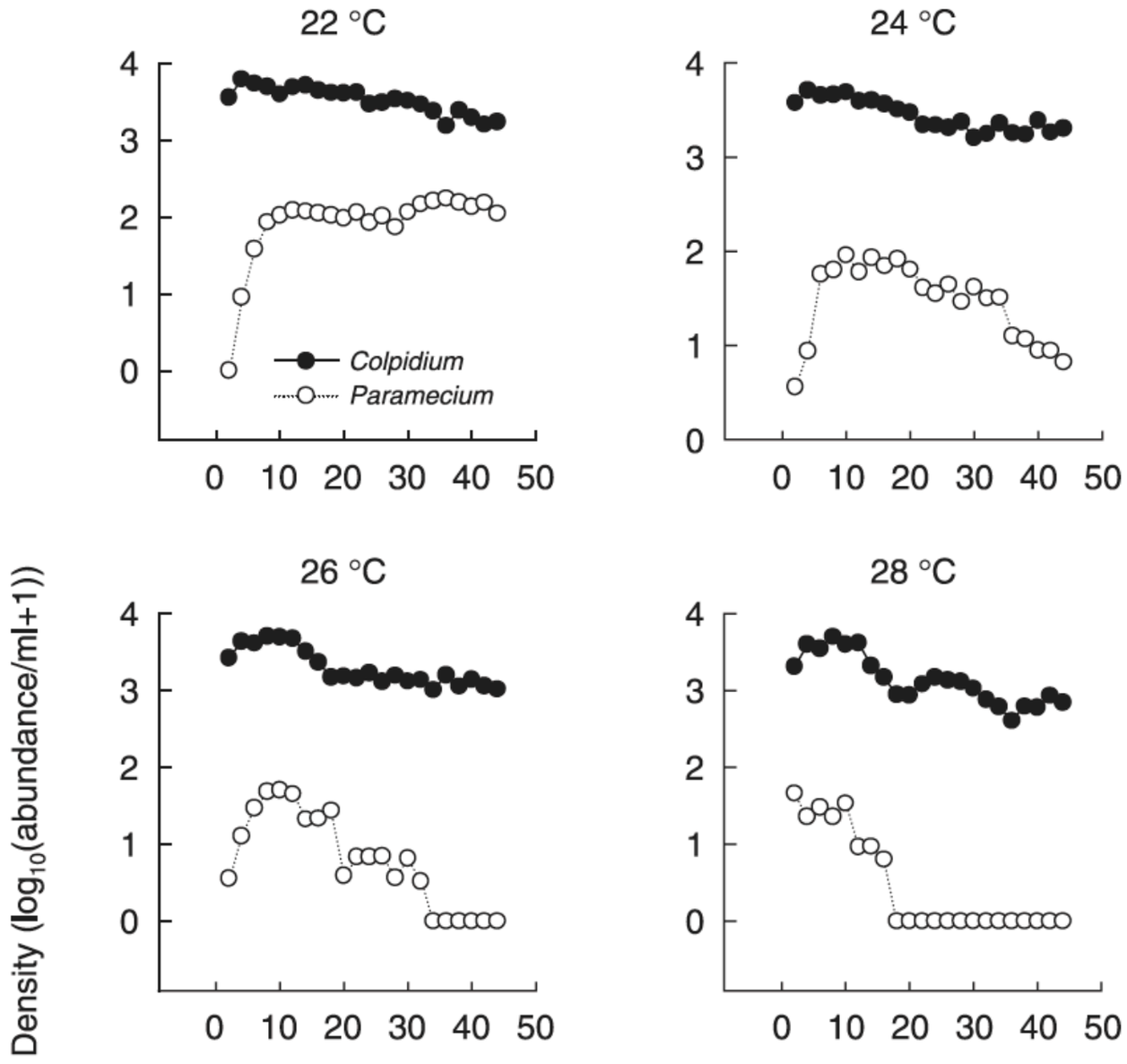
- Example: competition between *Colpidium* and *Paramecium* across temperature

- Replication and treatments available that can provide additional information



Paramecium caudatum

Colpidium striatum



Jiang, L., Morin, P.J., 2004. Temperature-dependent interactions explain unexpected responses to environmental warming in communities of competitors. Journal of Animal Ecology 73, 569–576.

Why Bayes?

- Get richer inference about parameters
- Hierarchical model:
    - leverage information from multiple replicates and treatments when estimating coefficients
- Potential to consider different error sources: observation vs process error in experimental data

Temperature effects on the functional response

Interaction strength

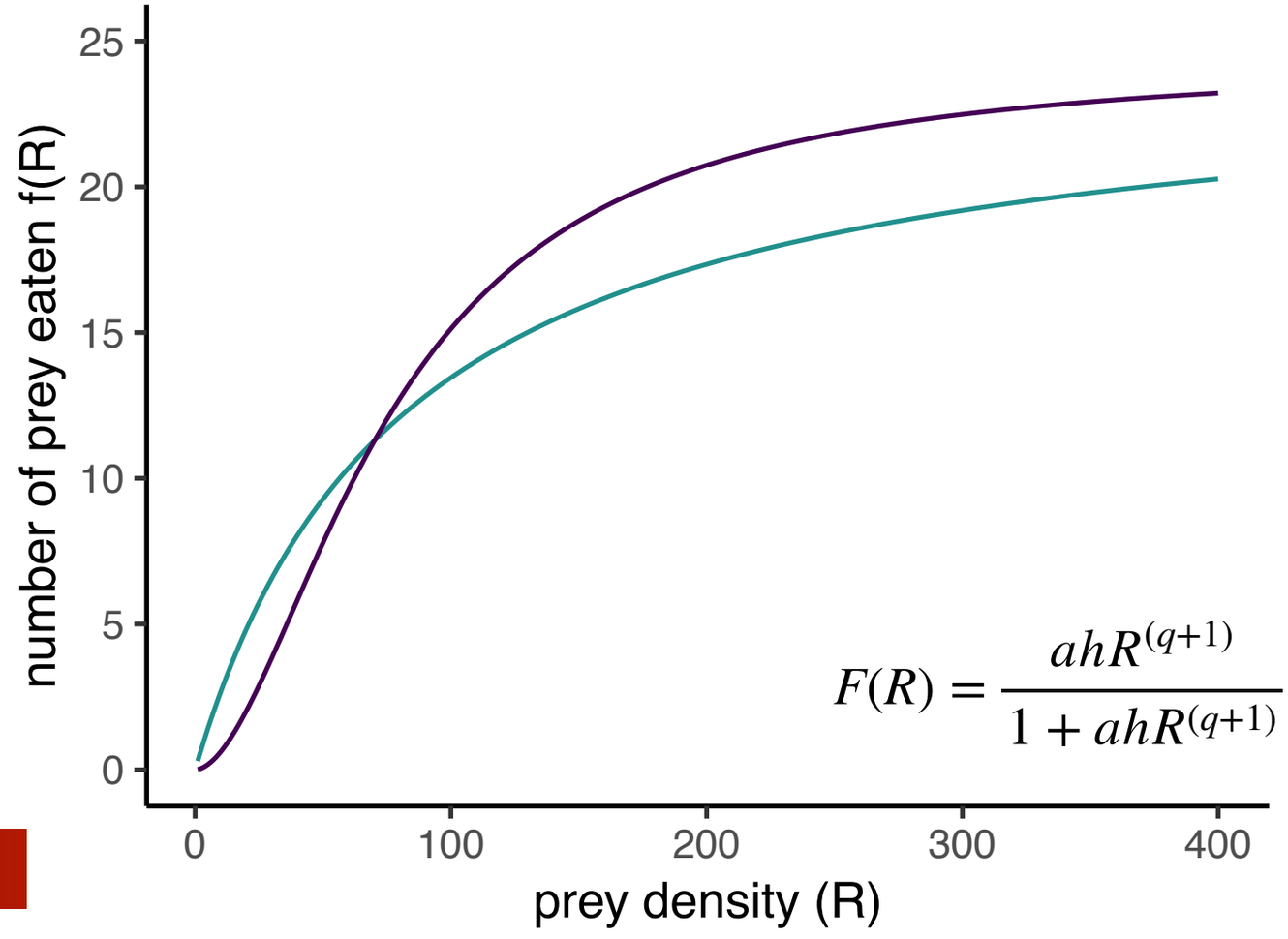
***Spathidium* sp.**

Dexiostoma

15 ° C — **25 ° C**

Functional response

***per capita* prey consumption by predator**



Daugaard, U., Petchey, O. L., & Pennekamp, F. (2019). Warming can destabilize predator–prey interactions by shifting the functional response from Type III to Type II. *Journal of Animal Ecology*, *88*(10), 1575–1586.

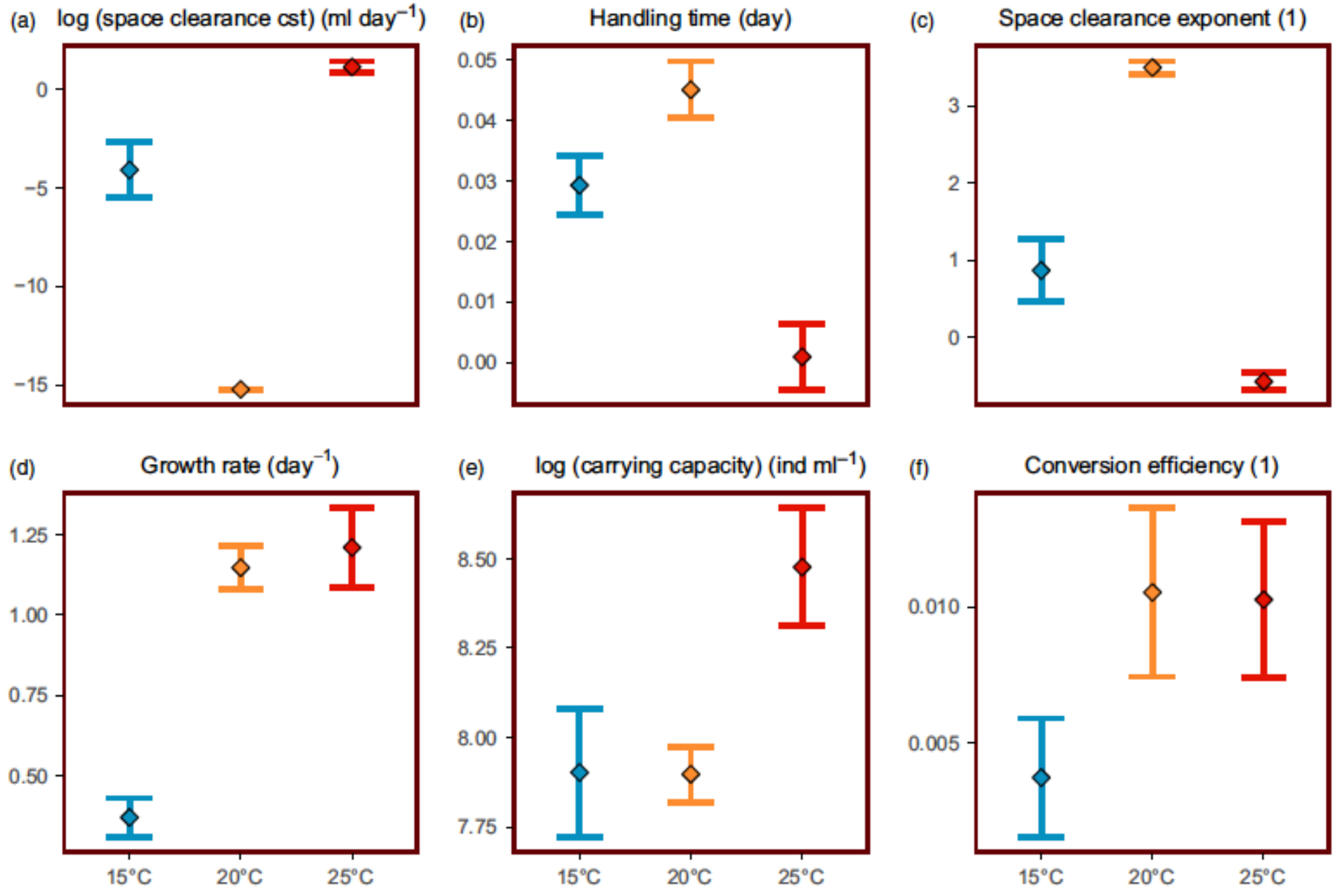
Estimated model parameters

Predator-prey model

$$\frac{dR}{dt} = -F(R)P + rR(1 - \frac{R}{K})$$

$$\frac{dP}{dt} = -cF(R)P$$

$$F(R) = \frac{ahR^{(q+1)}}{1 + ahR^{(q+1)}}$$



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Predator-prey dynamics across temperature

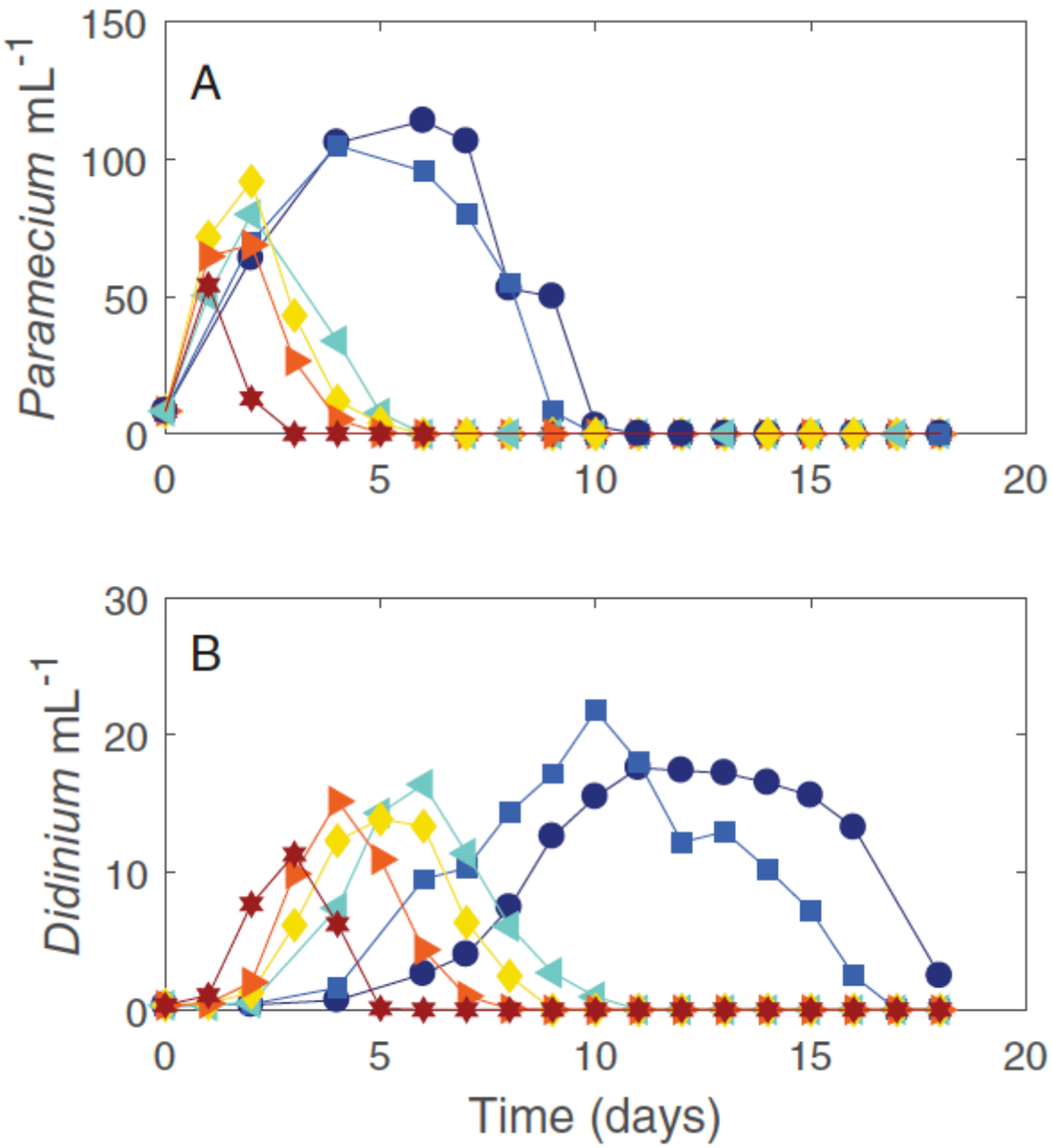
- Predator-prey dynamics across six temperatures (17 - 31C)

- Predator-prey model fitted to time-series to estimate

Predator-prey model

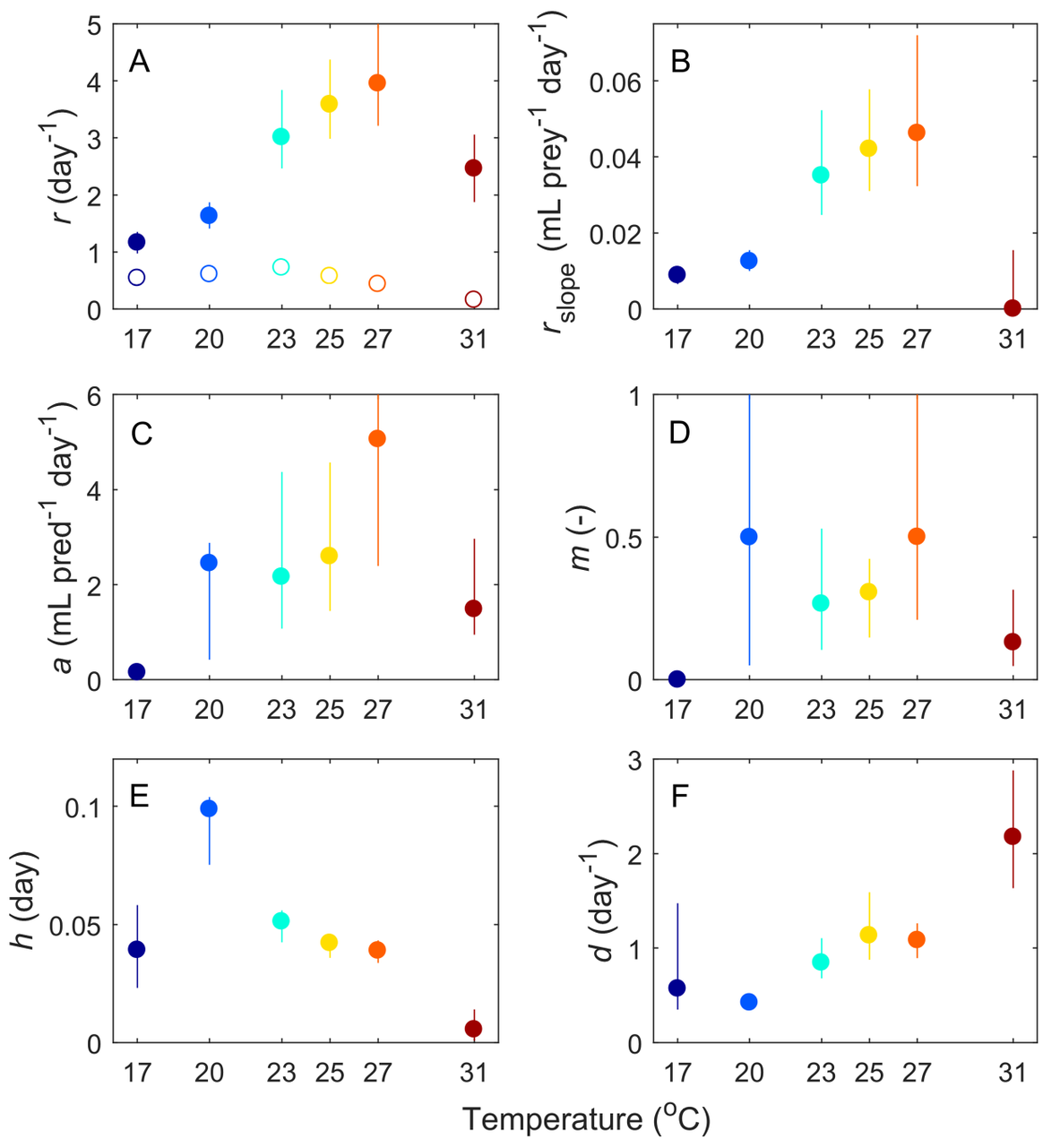
$$\frac{dR}{dt} = (r - r_{\text{slope}}R)R - \frac{aRC}{1 + ahR + m(C - 0.167)}$$

$$\frac{dC}{dt} = e\frac{aRC}{1 + ahR + m(C - 0.167)} - C(de^{-RC_d})$$



DeLong, J. P., & Lyon, S. (2020). Temperature alters the shape of predator–prey cycles through effects on underlying mechanisms. *PeerJ*, *8*, e9377.

Estimated model parameters



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Project goals

- Fitting ODEs to experimental data to estimate species interaction coefficients

- Build hierarchical models that take information from treatments / replicates into account

- Implementation in Stan