Bayesian thinking and Ecology Workshop - Part B

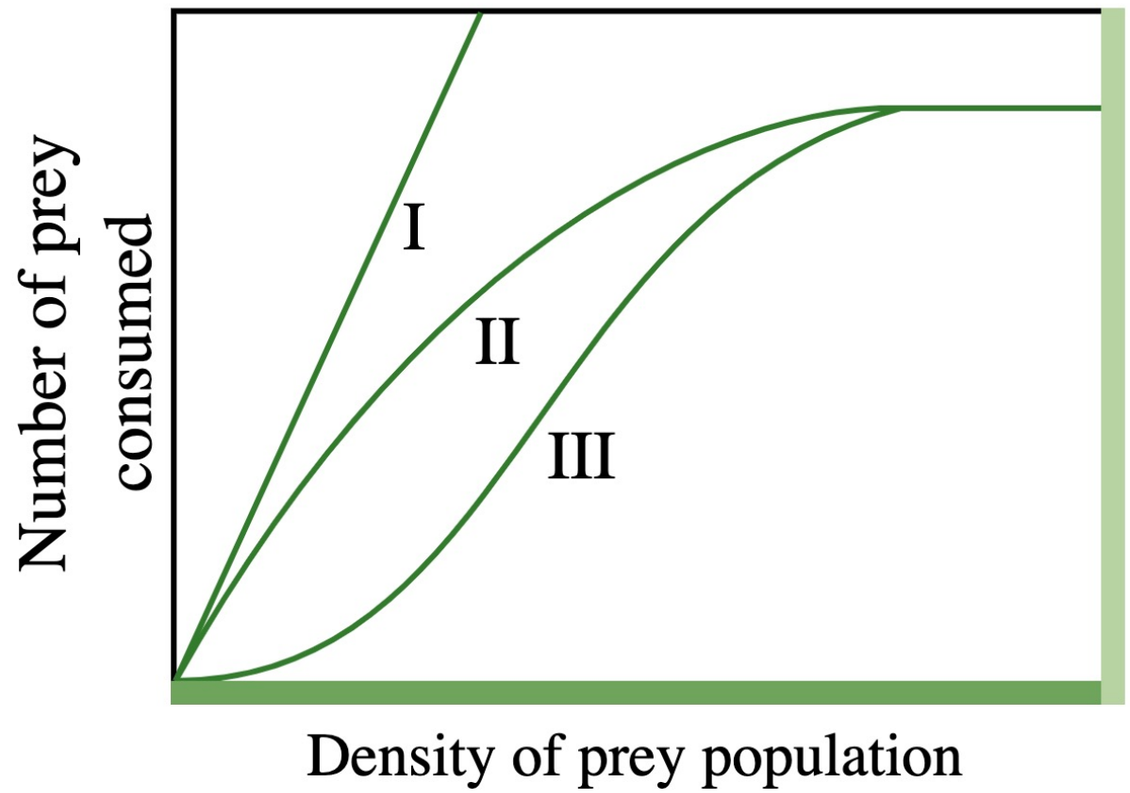
Estimating species interactions from experimental data using Bayesian ODEs (Ordinary differential equations)

Instructors: Florian Hartig & Frank Pennekamp

Participants: Lukas Heiland, Nico Neureiter, Mikaela Tillman, Pengjuan Zu

Species interactions

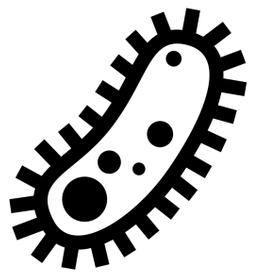
- Species interactions are crucial for the stability of ecological communities
- Predator-prey
- Functional responses:
  - Type I
  - Type II
  - Type III



Temperature effects on predator-prey interactions

Interaction strength

Spathidium sp.

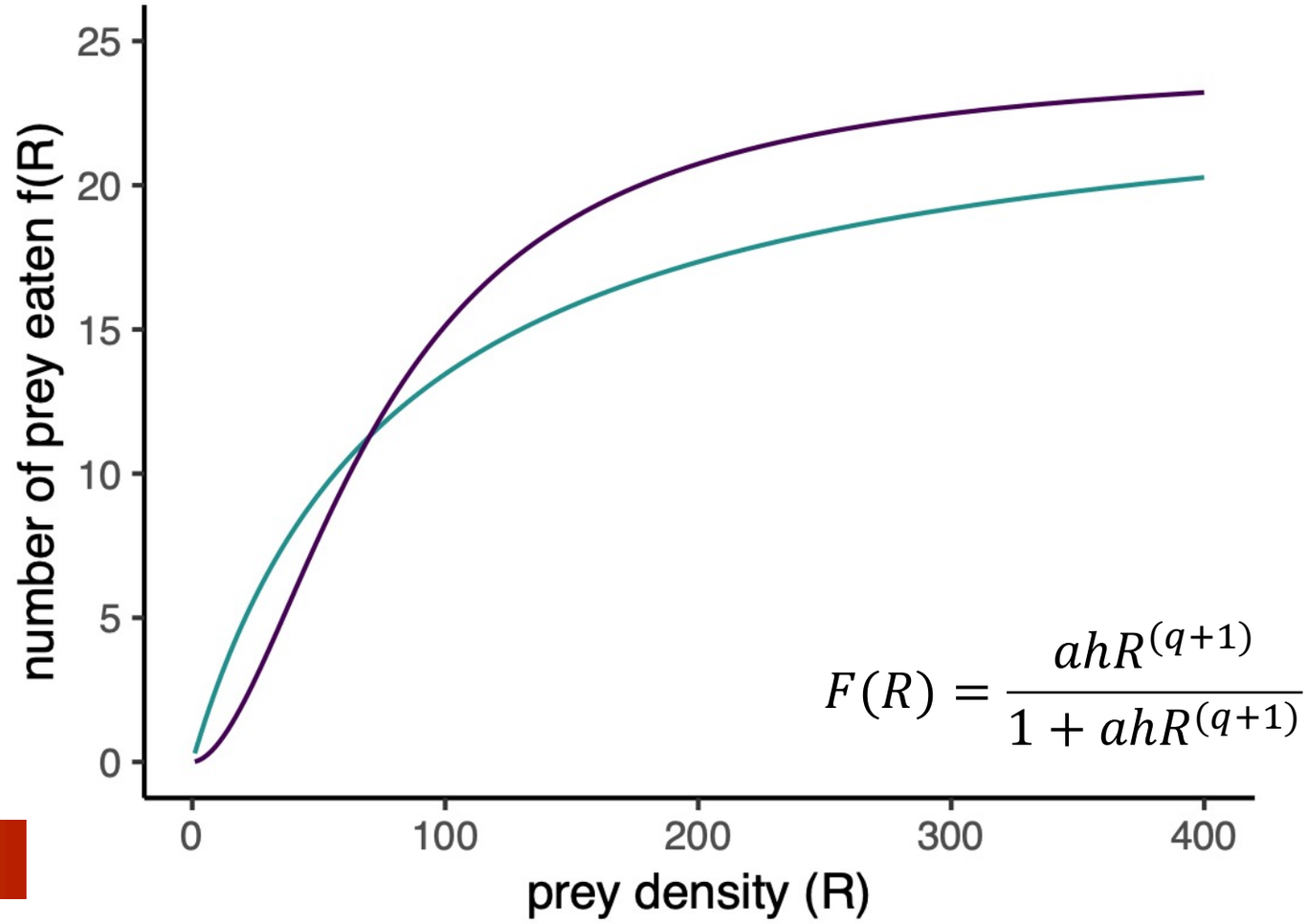


Dexiostoma

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.

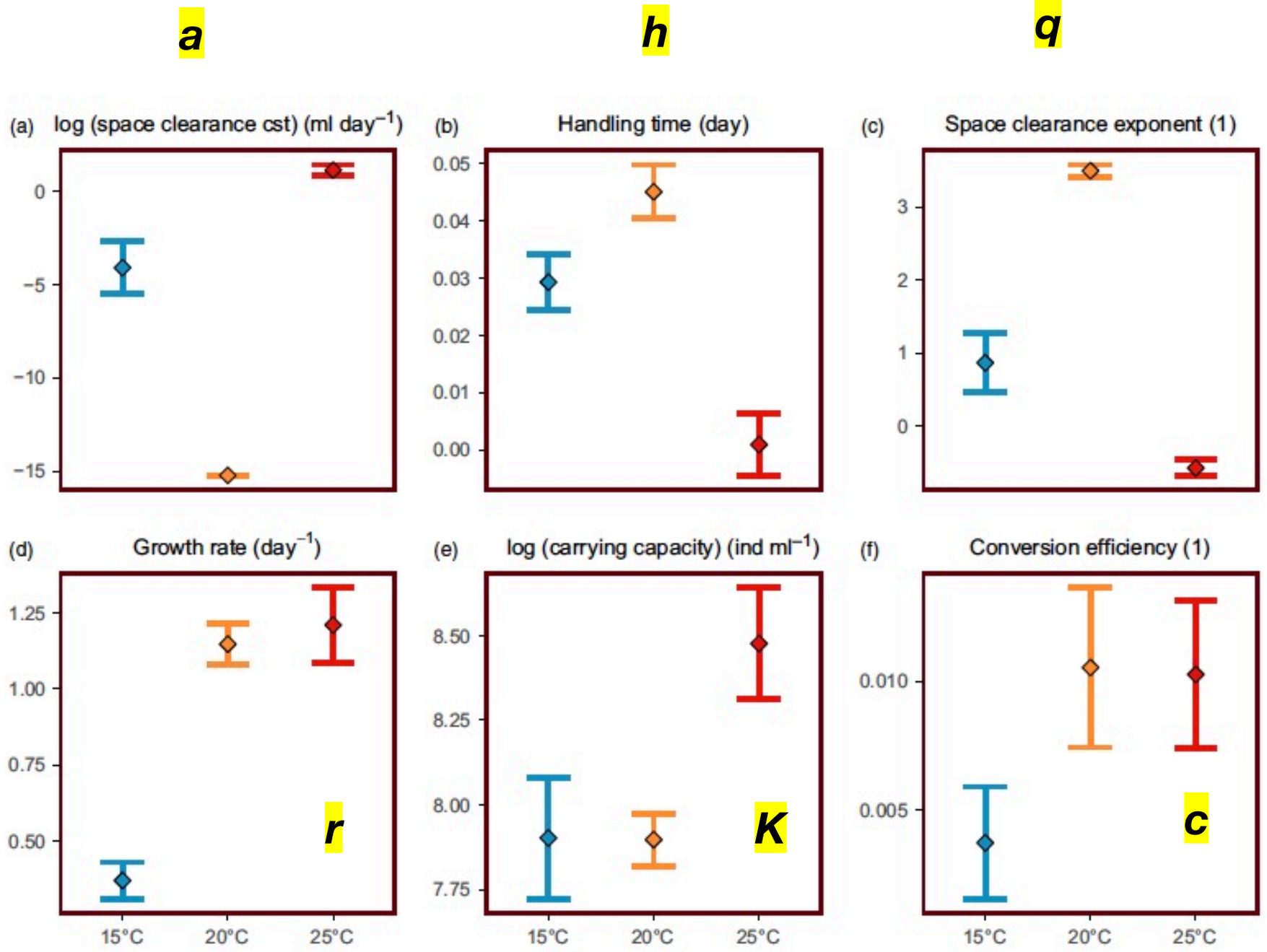
Model parameters

Predator-prey model

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

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

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



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.

Project goals

- Compare three models where the functional response parameters b, h and q are functions of temperature, while all other parameters are fitted hierarchically

- The three parameters of interest will be treated differently:

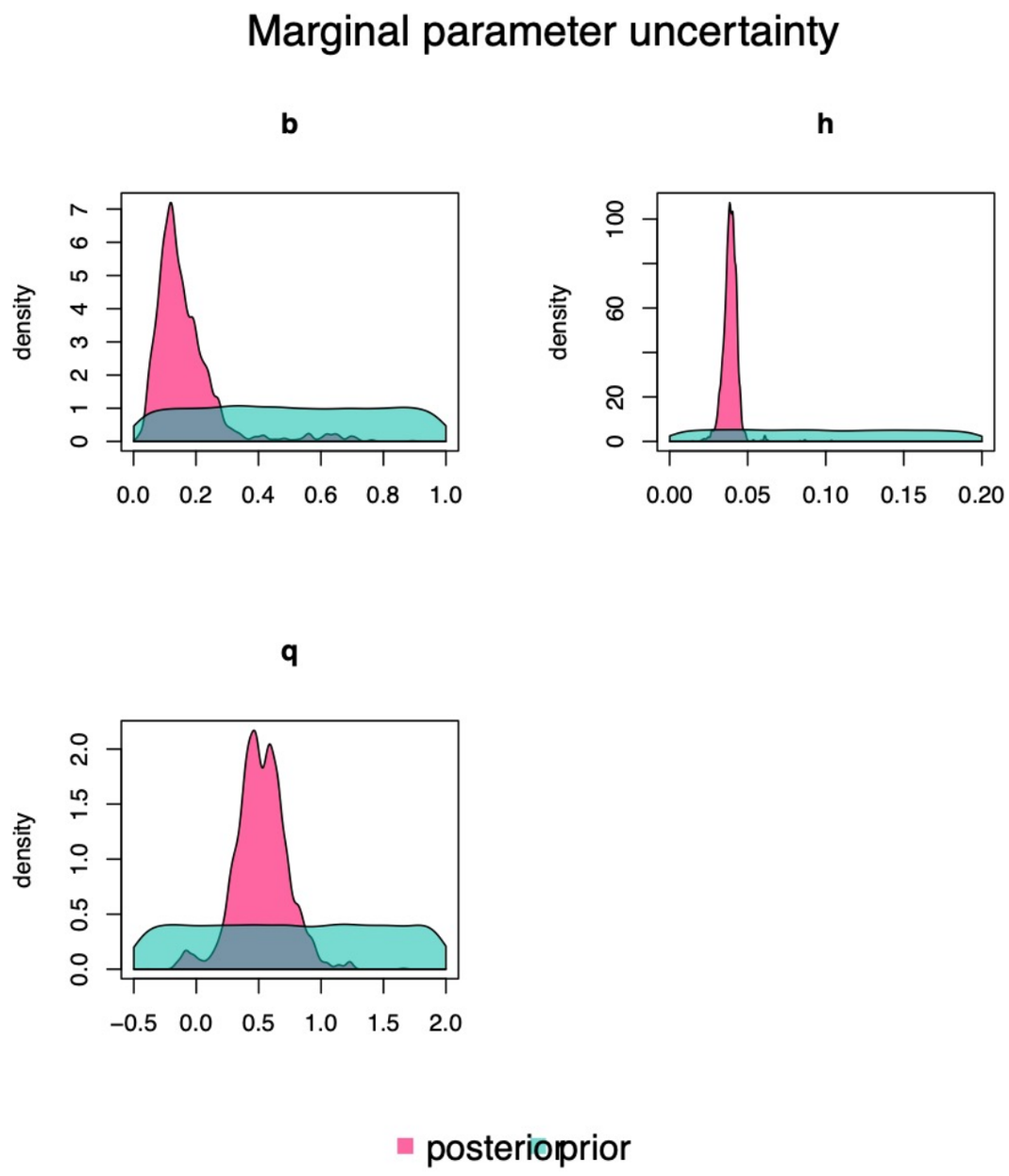
  1) Fitted as independent fixed effects

  2) Fitted as random effects (hierarchical)

  3) Fitted as linear temperature effect (not conducted)

Estimating model parameters with BayesianTools package

- Original estimation based on Maximum Likelihood
- Refitted parameters with BayesianTools package
- ODE solving based on odeintr package (pre-compiled ODEs in C++)
- Working solution in Stan

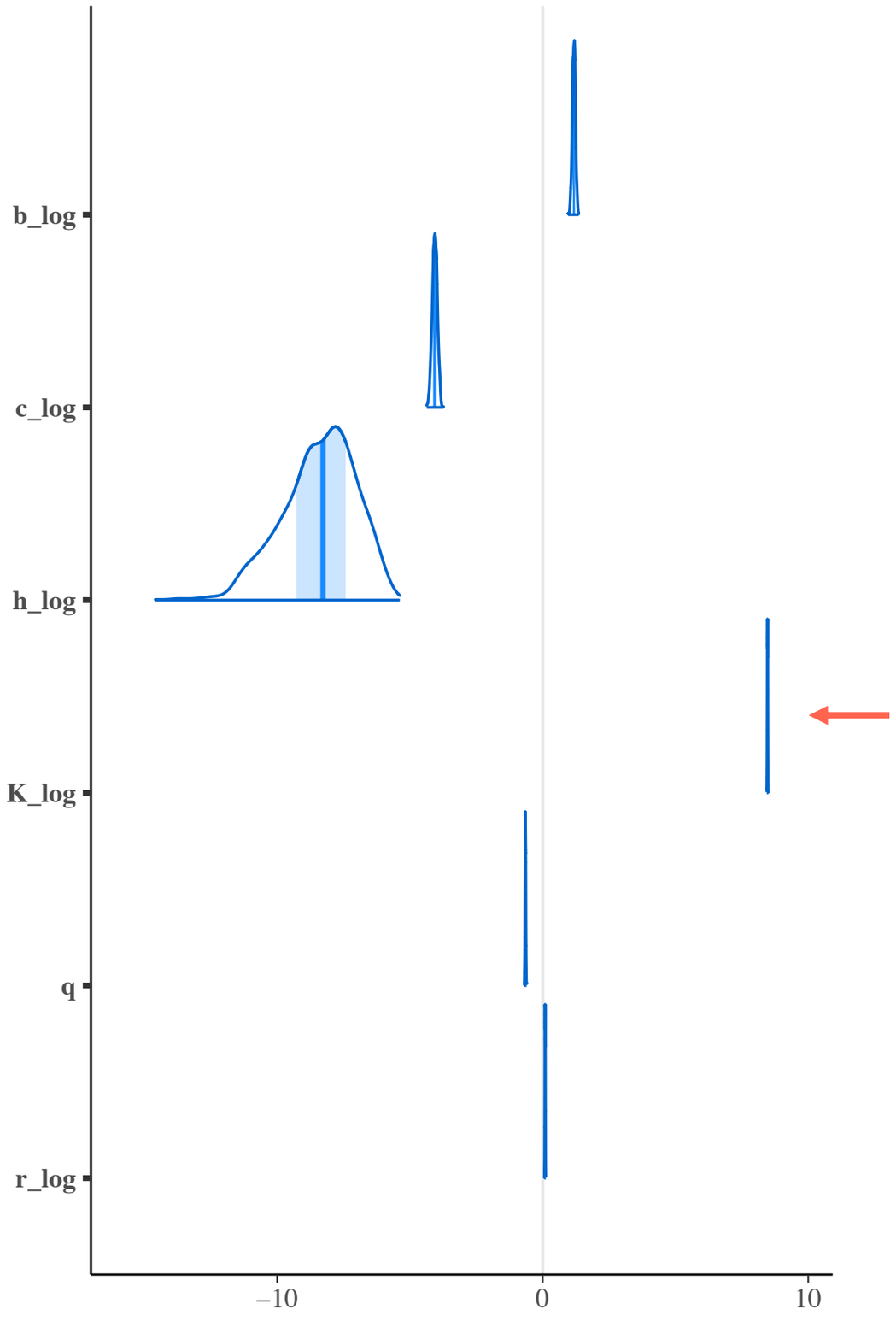


Goals achieved

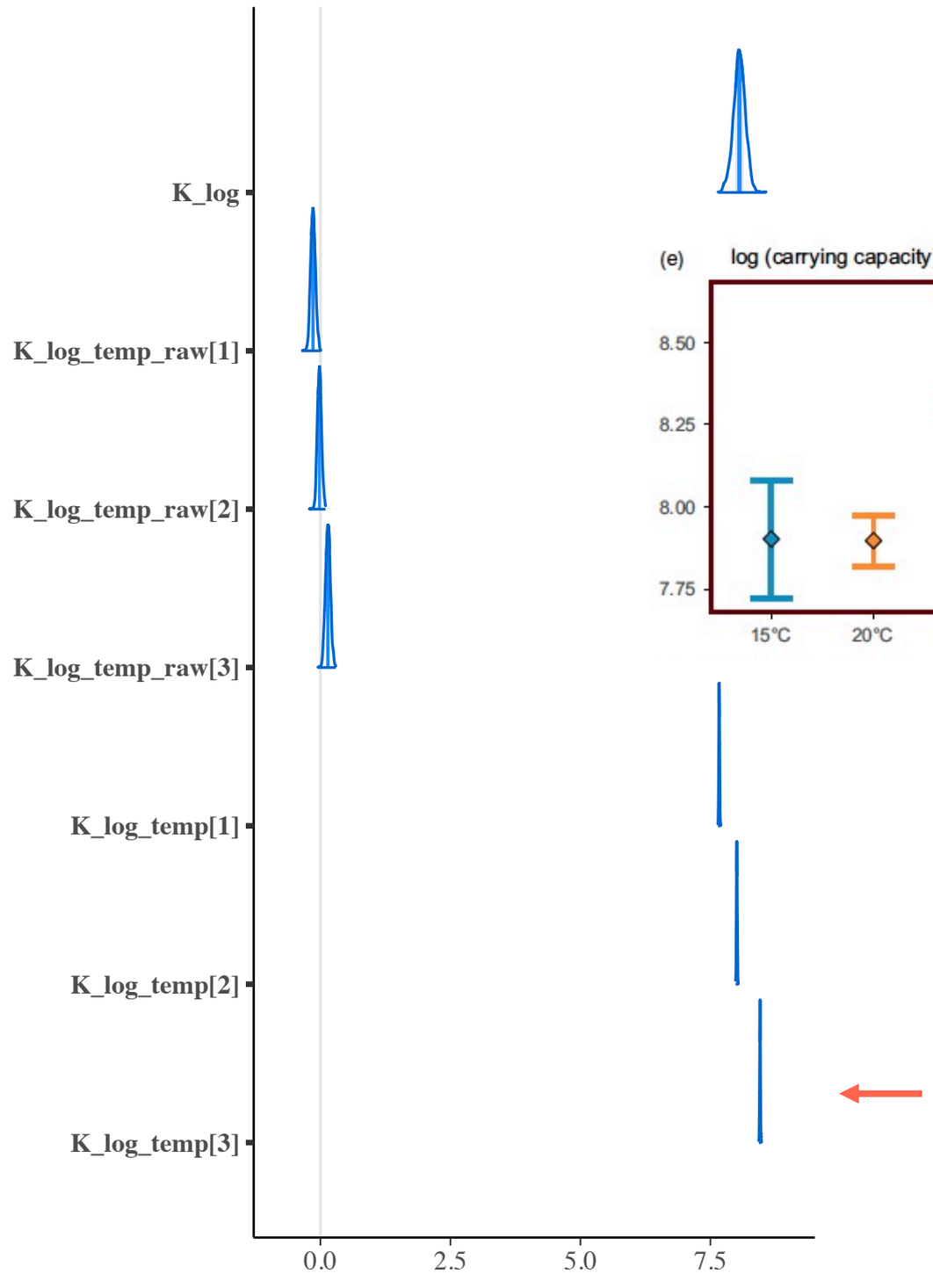
✓ Fit models in Stan

✓ Recover parameters estimated with ML approach

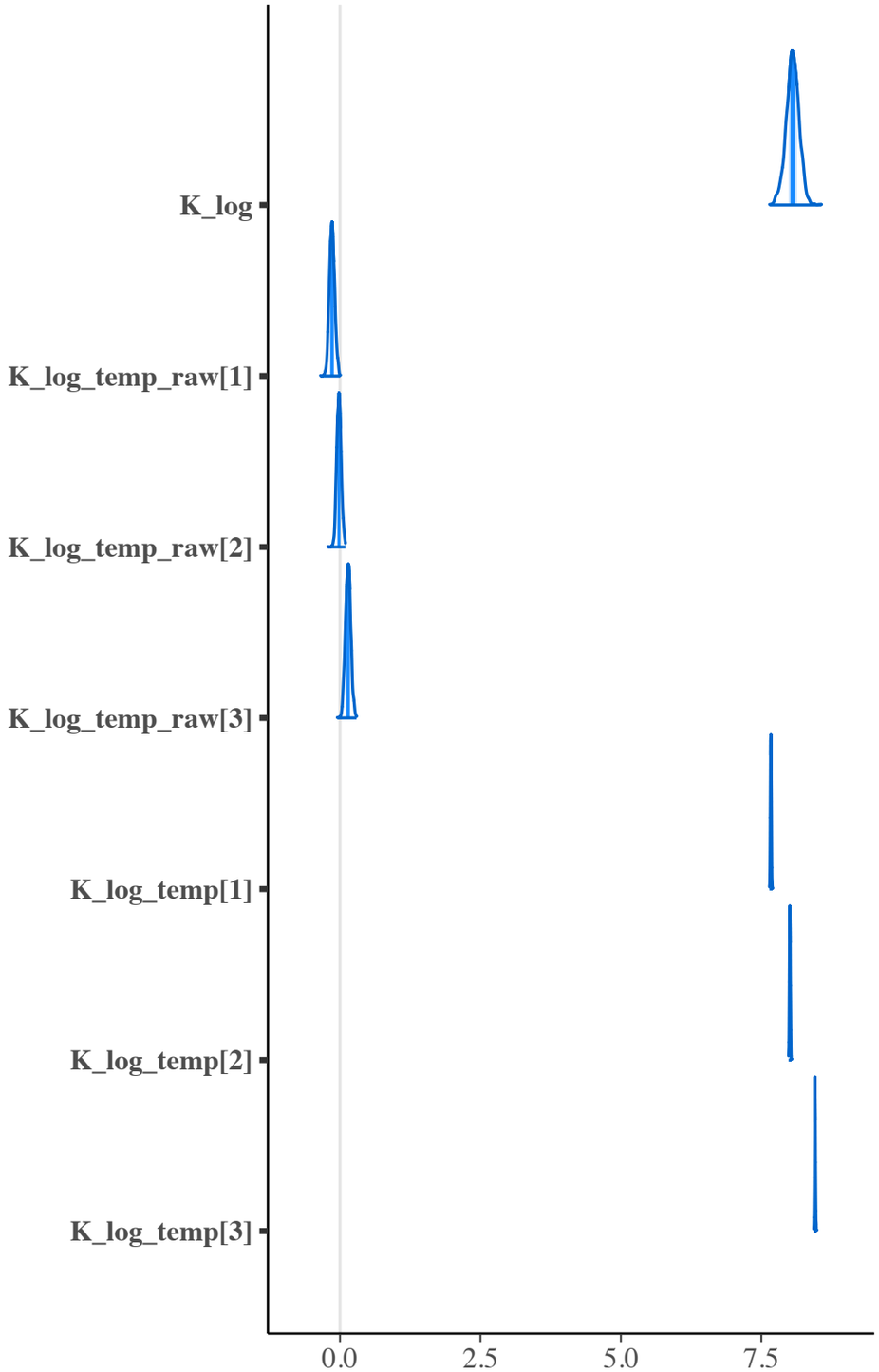
✓ Fit models in hierarchical fashion with all parameters as random effects

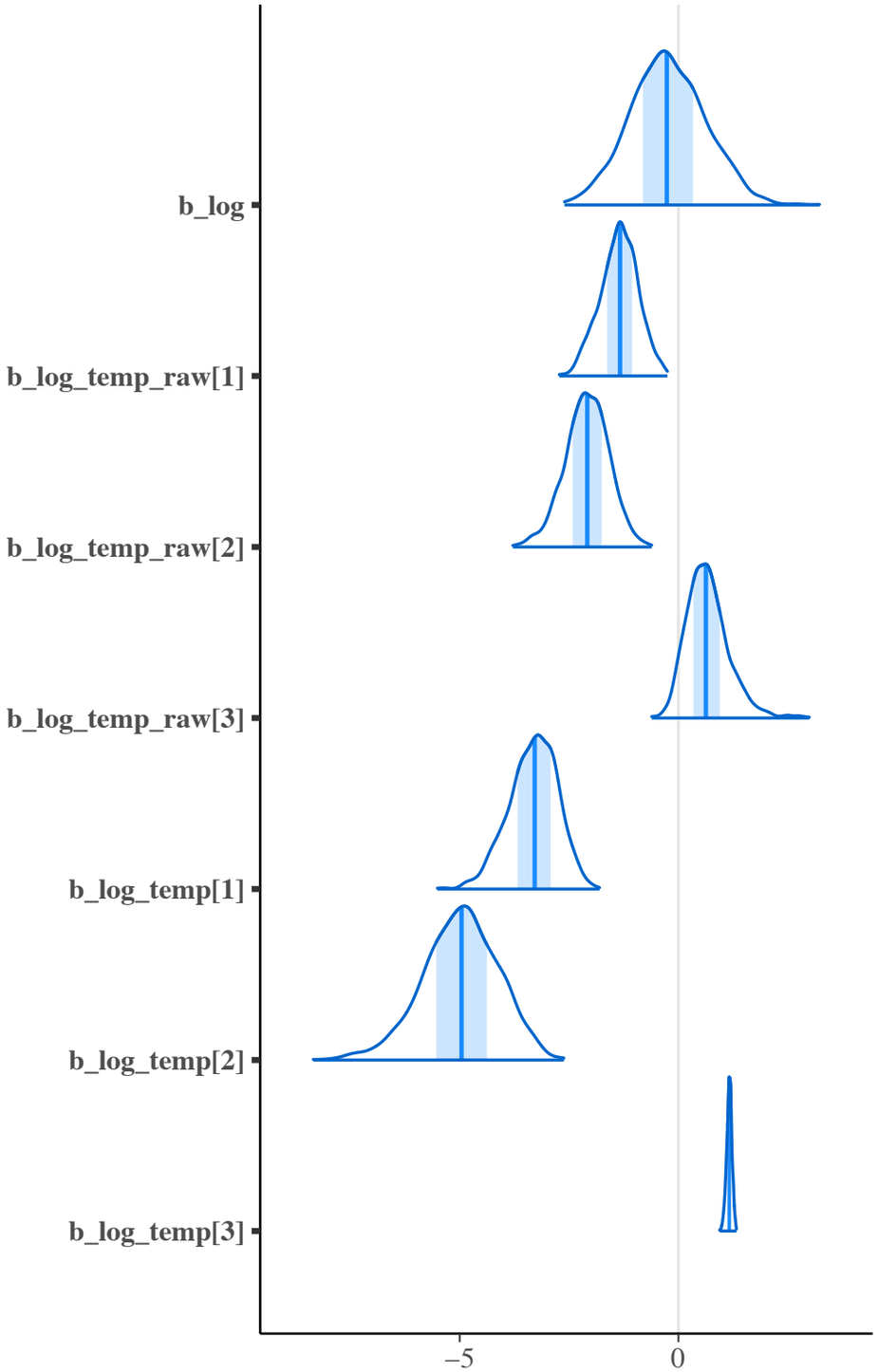


25 C only

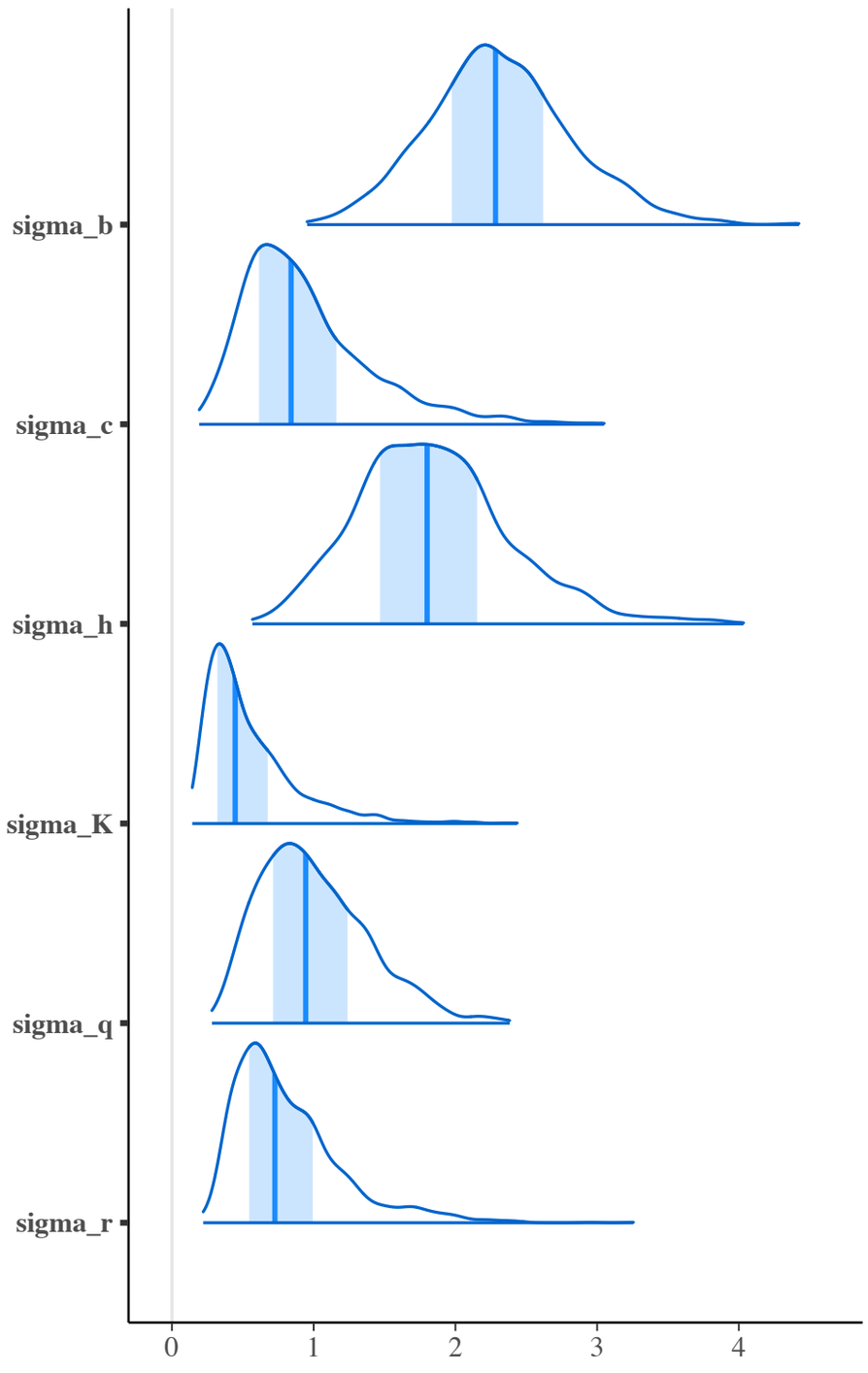


All temperatures


K_log
K_log_temp_raw[1]
K_log_temp_raw[2]
K_log_temp_raw[3]
K_log_temp[1]
K_log_temp[2]
K_log_temp[3]
0.0
2.5
5.0
7.5


b_log
b_log_temp_raw[1]
b_log_temp_raw[2]
b_log_temp_raw[3]
b_log_temp[1]
b_log_temp[2]
b_log_temp[3]
−5
0

Temperature dependency



Lessons learned

- Deeper understanding of inner workings of hierarchical models
- Familiar with Bayesian analysis