Trying to understand albatross growth with Dynamic Energy Budget Theory

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Thanks to

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GRS chairs

PLR-1341649 (Leah Johnson PI, Sadie Ryan CoI)
Quantifying how bioenergetics and foraging determine population dynamics in threatened Antarctic albatrosses


9 TIPS FOR LIVING WITH LESS PLASTIC
1
Bring your own shopping bag
2
Carry a reusable water bottle
3
Bring your own cup
4
Pack your lunch in reusable containers
5
Say no to disposable straws & cutlery
6
Skip the plastic produce bags
7
Slow down and dine in
8
Store leftovers in glass jars
9
Share these tips with your friends

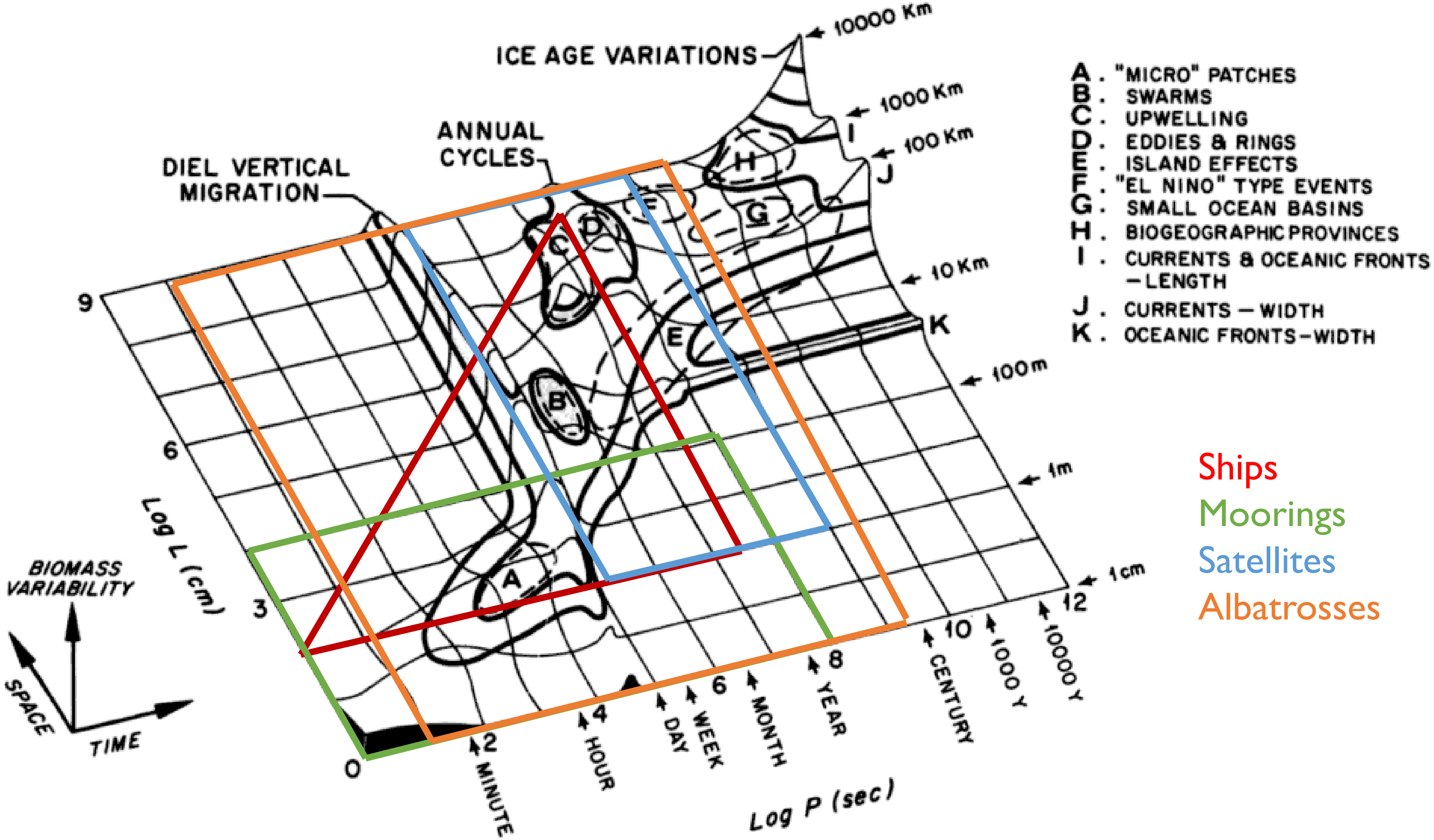
How can we untangle intrinsic and extrinsic drivers of individual growth, reproduction, and survival in a changing environment?

Albatrosses as a model system

- Large, long-lived seabirds
- Efficient fliers, travel very large distances
- 22 species threatened or endangered
- Many populations declining
    - Fisheries bycatch
    - Invasive predators
    - Extreme weather events
    - Climate variation
- We know much about drivers of population dynamics from past demography, but what about the future?

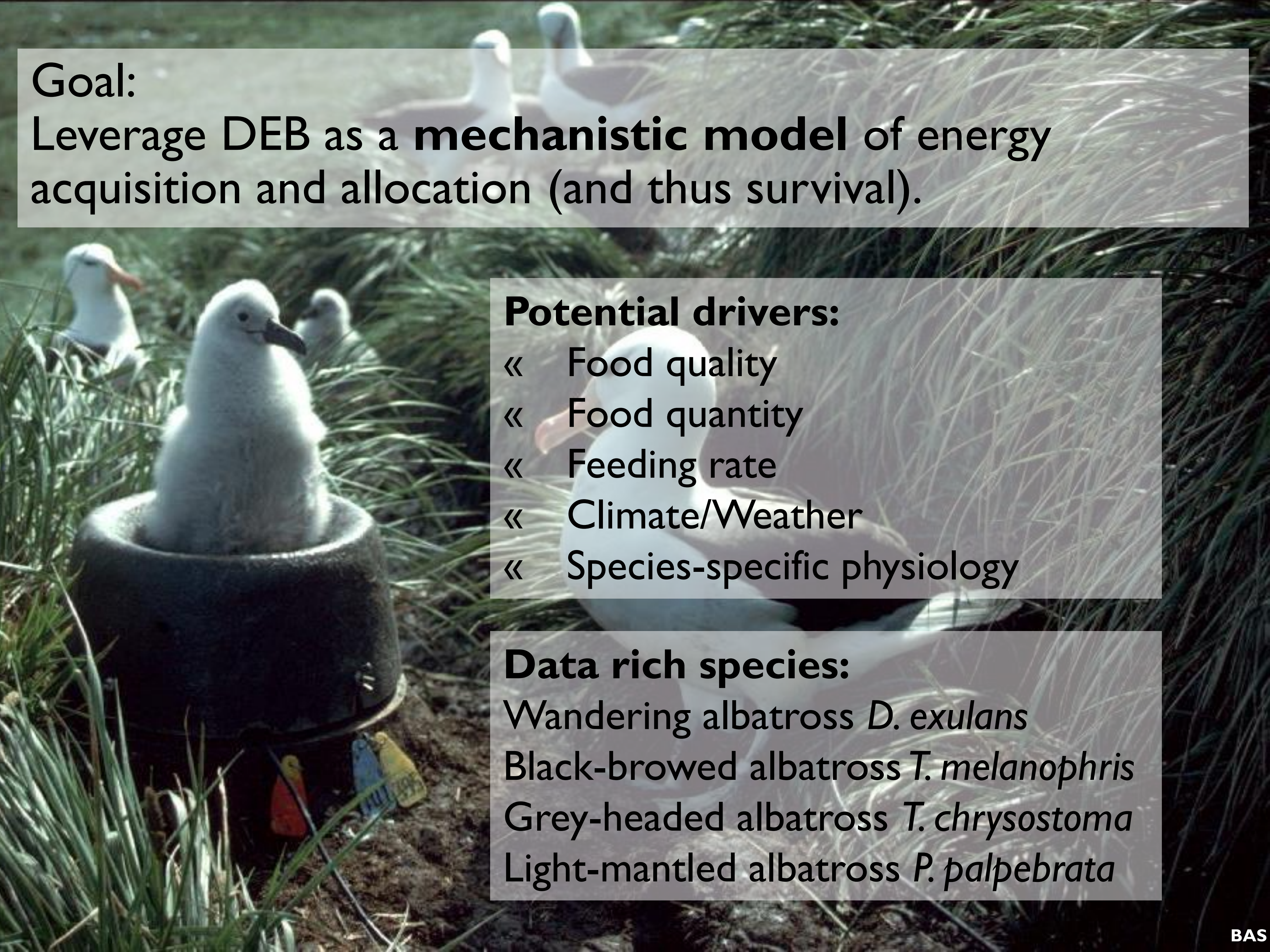
S. Borrelle

Diversion 1: Scales of open ocean ecology



Haury et al 1978, Spatial Pattern in Plankton Communities

Goal:
Leverage DEB as a **mechanistic model** of energy acquisition and allocation (and thus survival).



Potential drivers:

- Food quality
- Food quantity
- Feeding rate
- Climate/Weather
- Species-specific physiology

Data rich species:

Wandering albatross *D. exulans*
Black-browed albatross *T. melanophris*
Grey-headed albatross *T. chrysostoma*
Light-mantled albatross *P. palpebrata*

BAS

Current state in (sea)bird ecology

- Asymptotic growth models with varying degrees of mechanism:
  - logistic curve fitting Starck & Ricklefs (1998)
    - Gompertz (1825)
    - von Bertanlanffy (1934)

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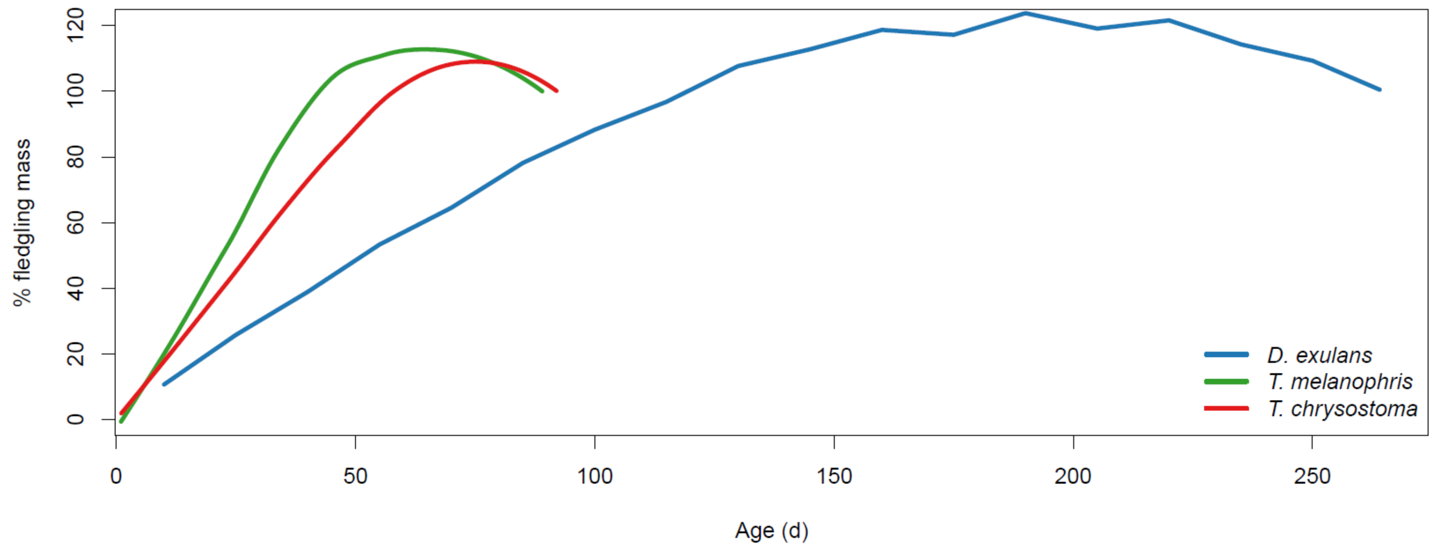
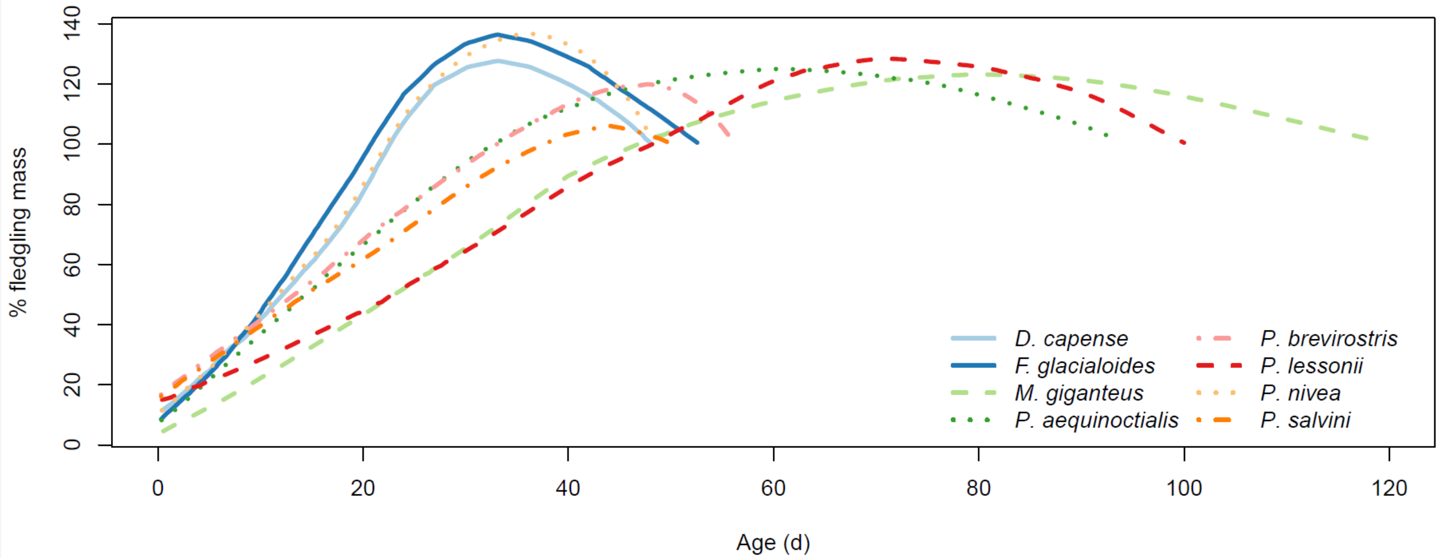
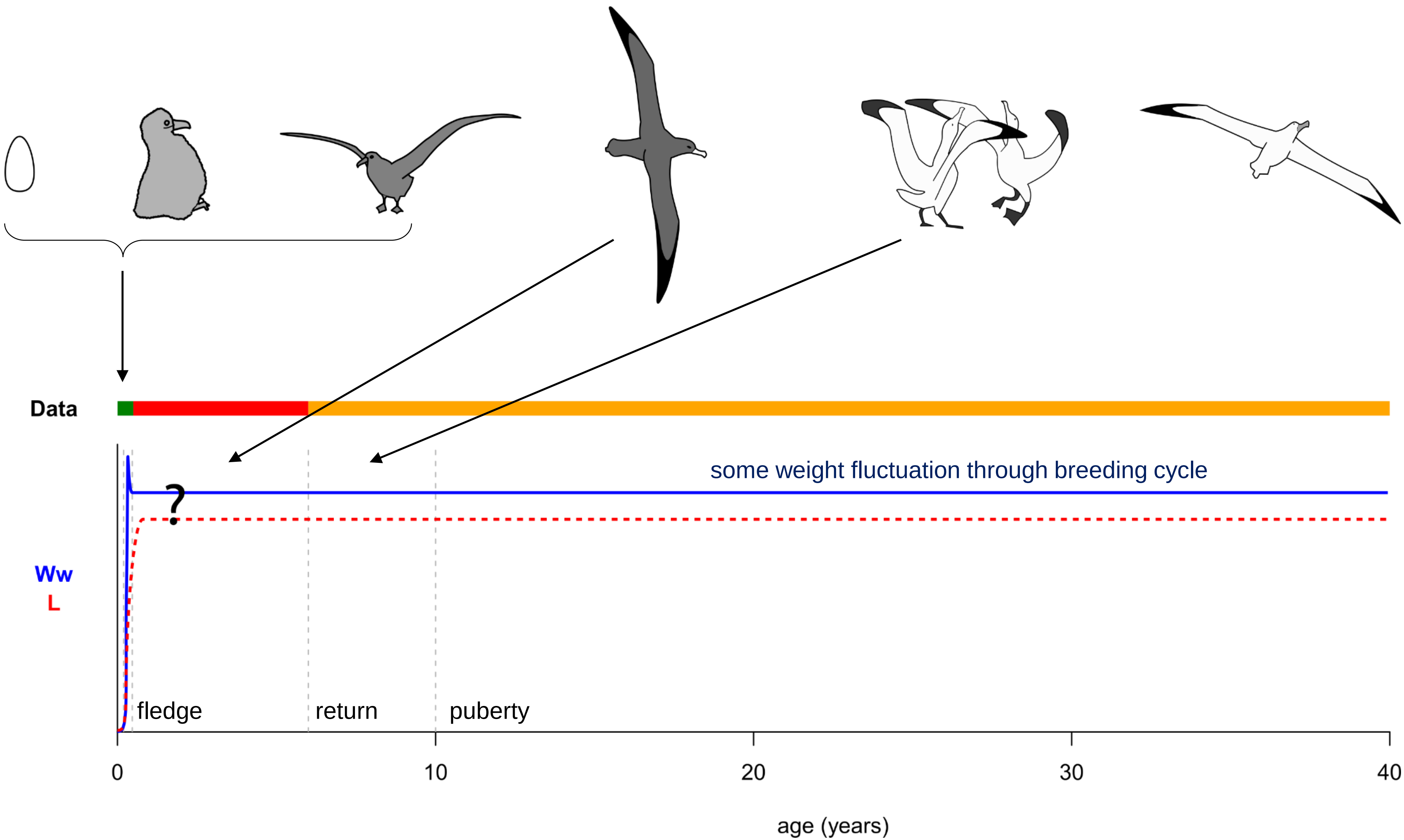
Seabird mass ontogenies do not follow logistic growth





Data sources: BAS, unpublished; Mabille et al. 2004, Ibis 146:85; Mougin 1975, MNHN

Why do we care about this?



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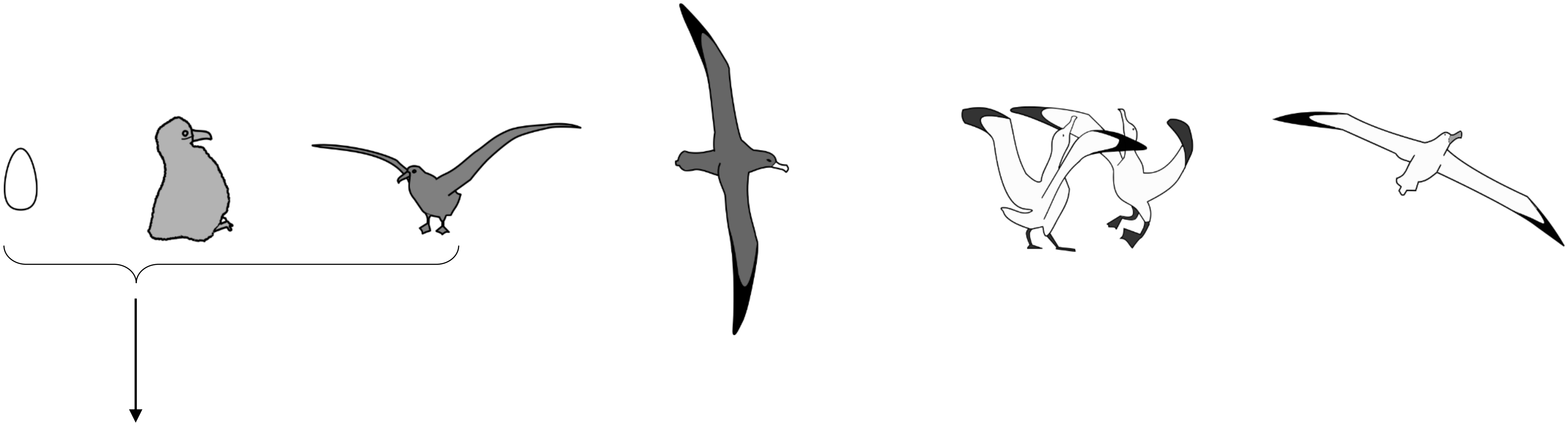
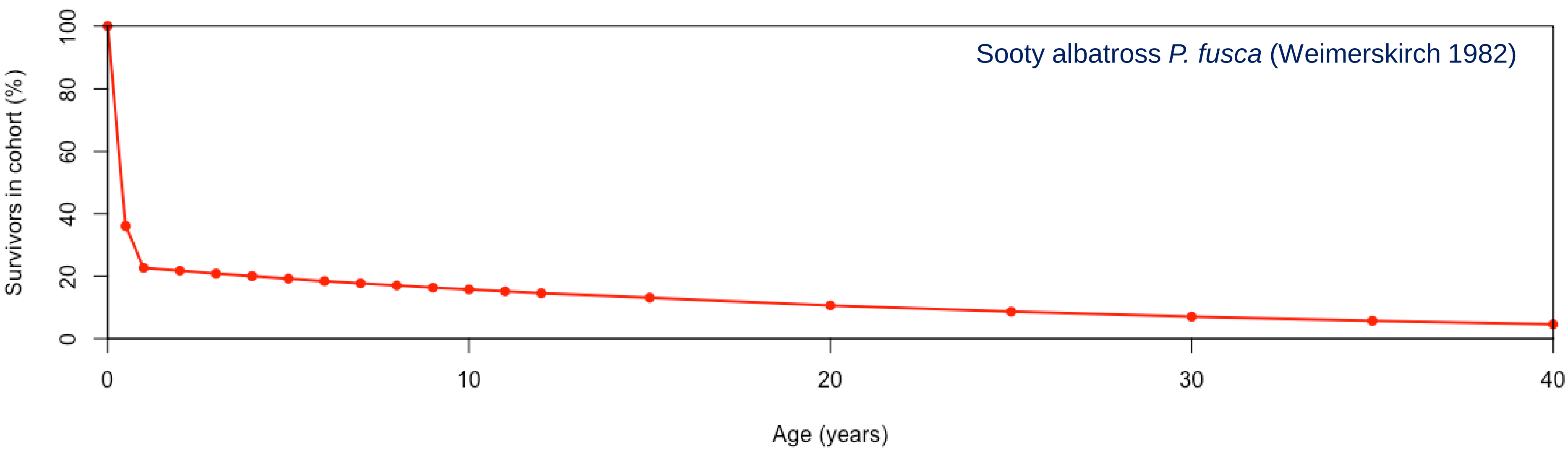
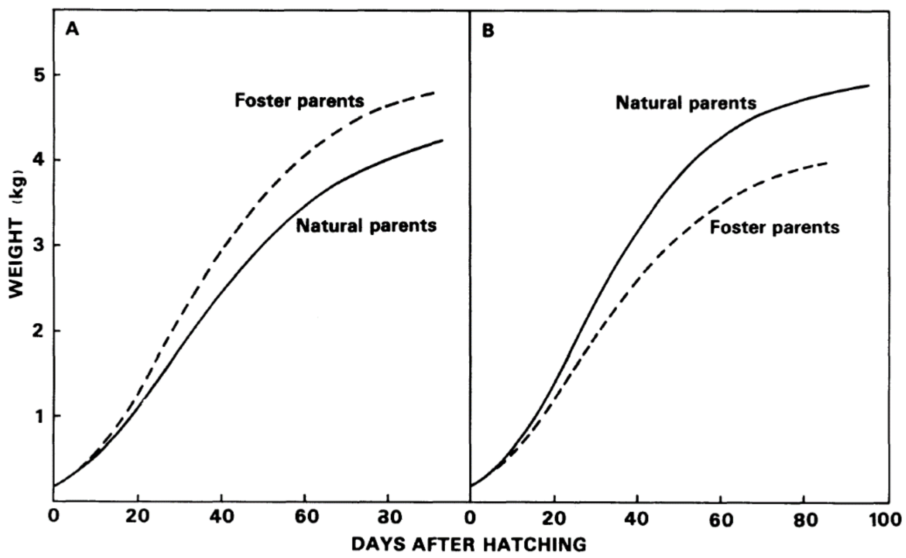
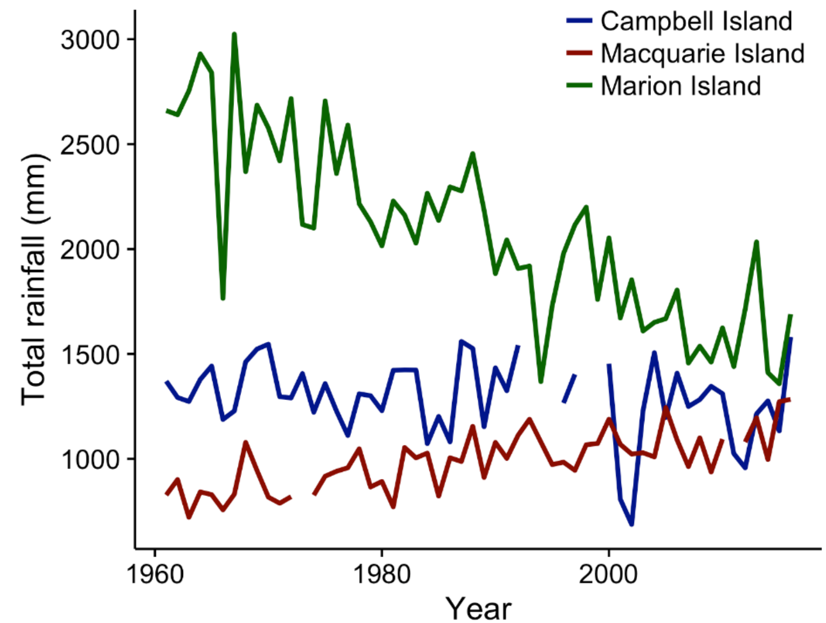




Early life survival is crucial for population dynamics

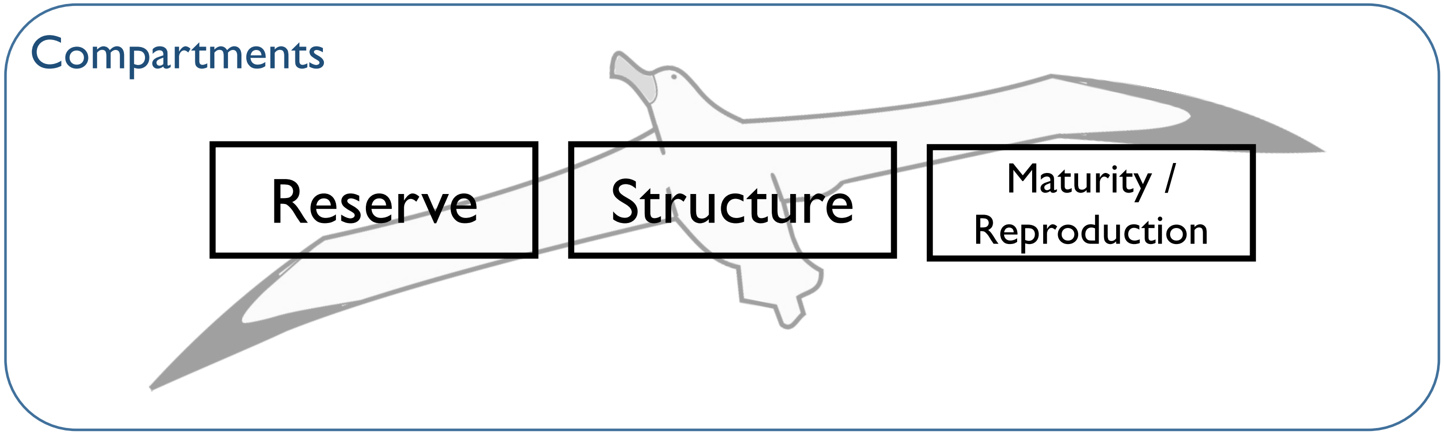
Relevant simulation scenarios

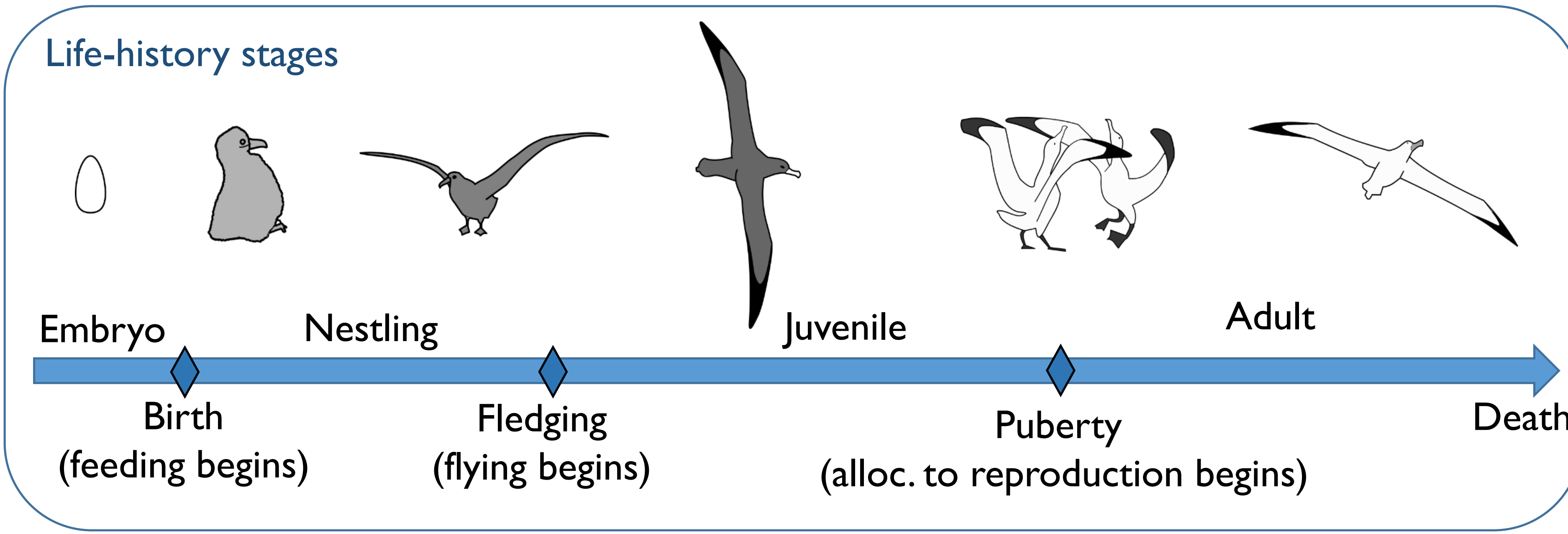




- Re-analysis of cross fostering experiments of sister-species (Prince 1981)
- weather related nestling survival under climate change
  - Rainfall inpacts nestling survival (Wheeler et al 2013, GHA Marion Island)
  - Changing precipitation on subantarctic islands (Adams et al 2009)

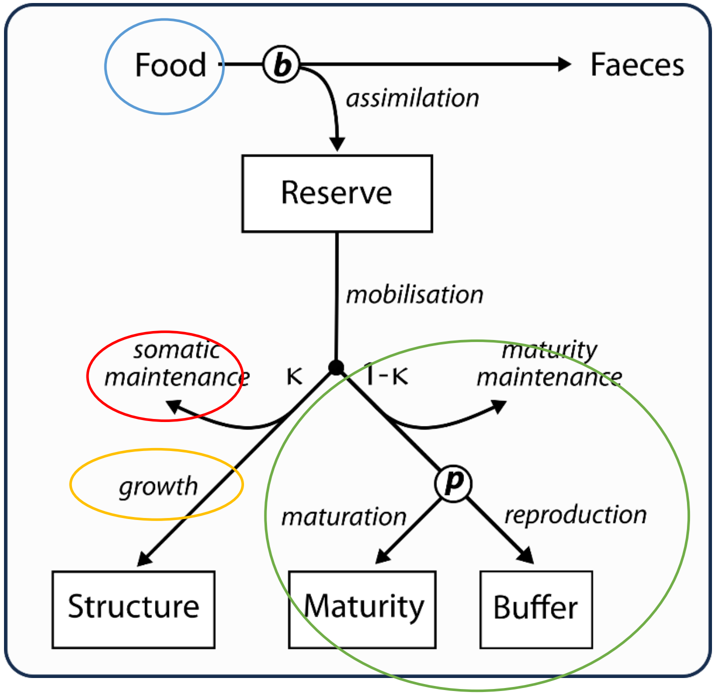
Wandering albatross DEB model (Teixeira et al. 2014)



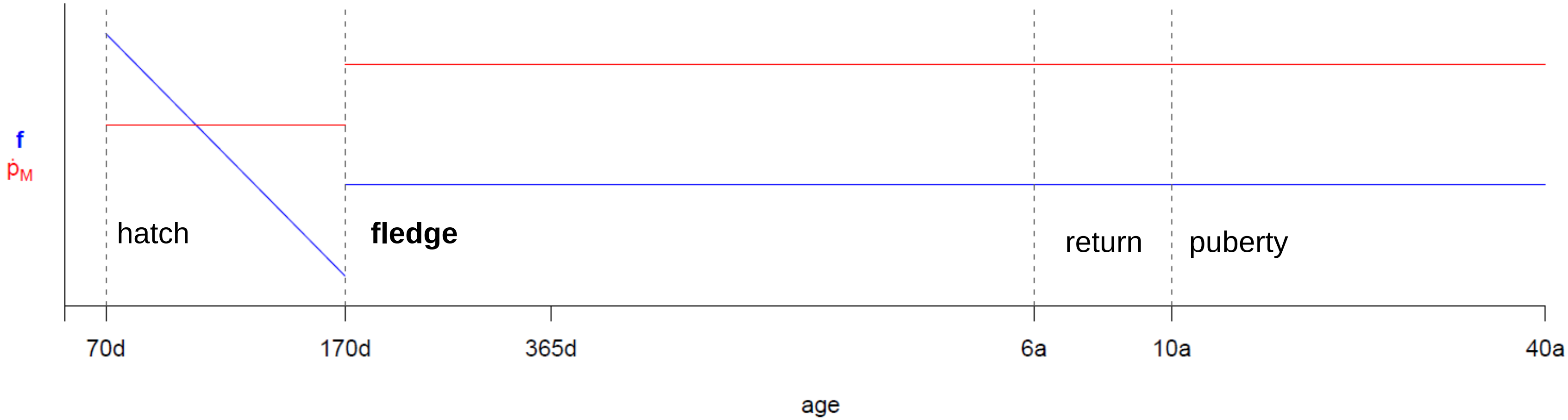


Teixeira et al. 2014, J Sea Res 94:117

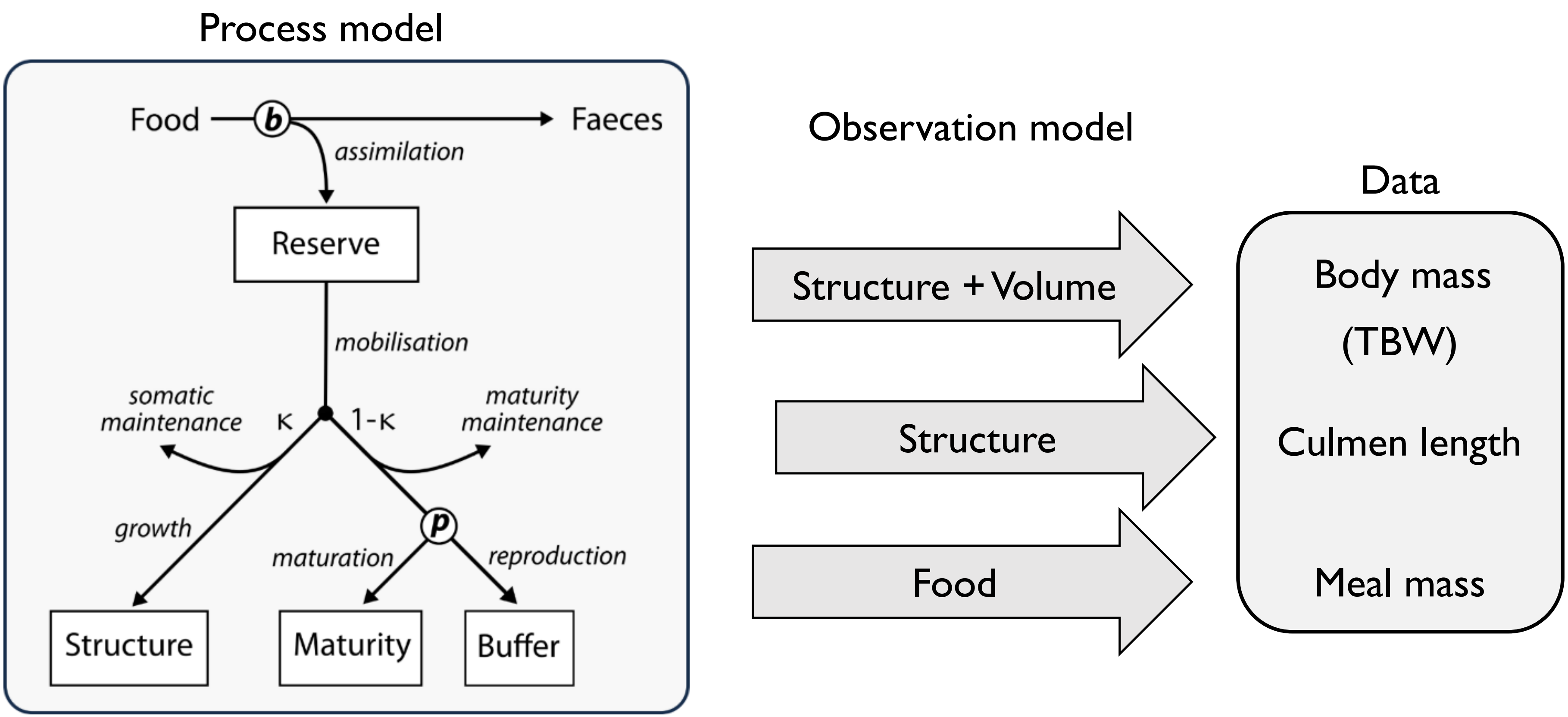
Wandering albatross DEB model (Teixeira et al. 2014)



- food composition constant
- functional response declines linearly until fledging
- *constant f = 0.8 post-fledging*
- stepwise constant
- pre- < post-fledging
- poorly constrained by data
- humped body mass trajectory
- slightly humped structural growth
- total body water content drops



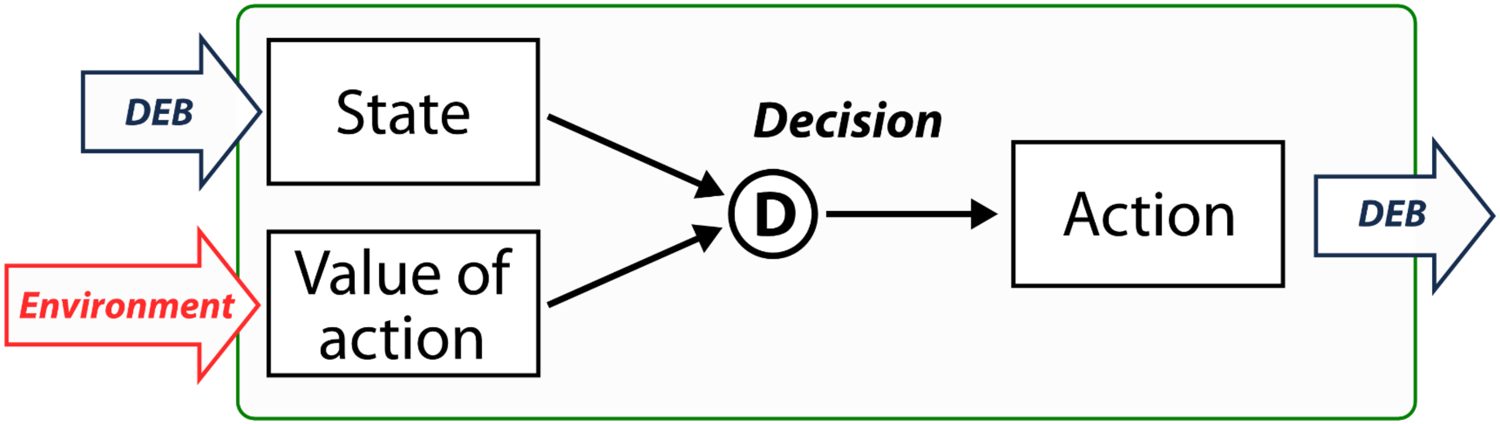
Confronting the model with data



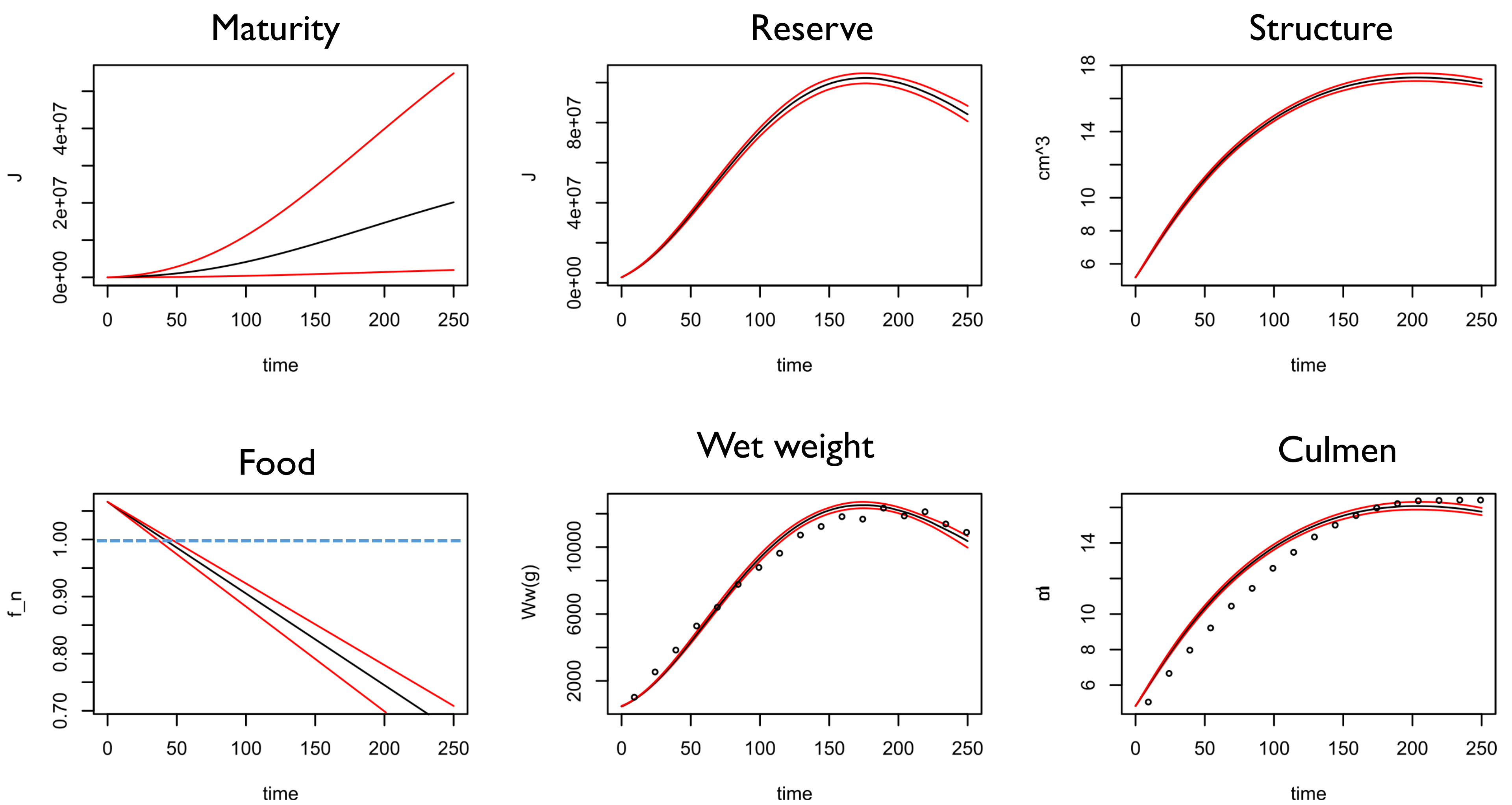
Fitting can be achieved with the "covariation method", a weighted least-squares approach.
We propose a Bayesian approach to better handle uncertainty.

Johnson et al. 2013, Ecology 94:882

- Individual heterogeneity is important in albatross populations
  - Ultimately we want to understand population distributions of DEB parameters
- Exploit scaling relationships from DEB theory to propagate parameters from data-rich to data poor species
- Propagate parameter uncertainty into coupled models
  - e.g. state-space foraging models



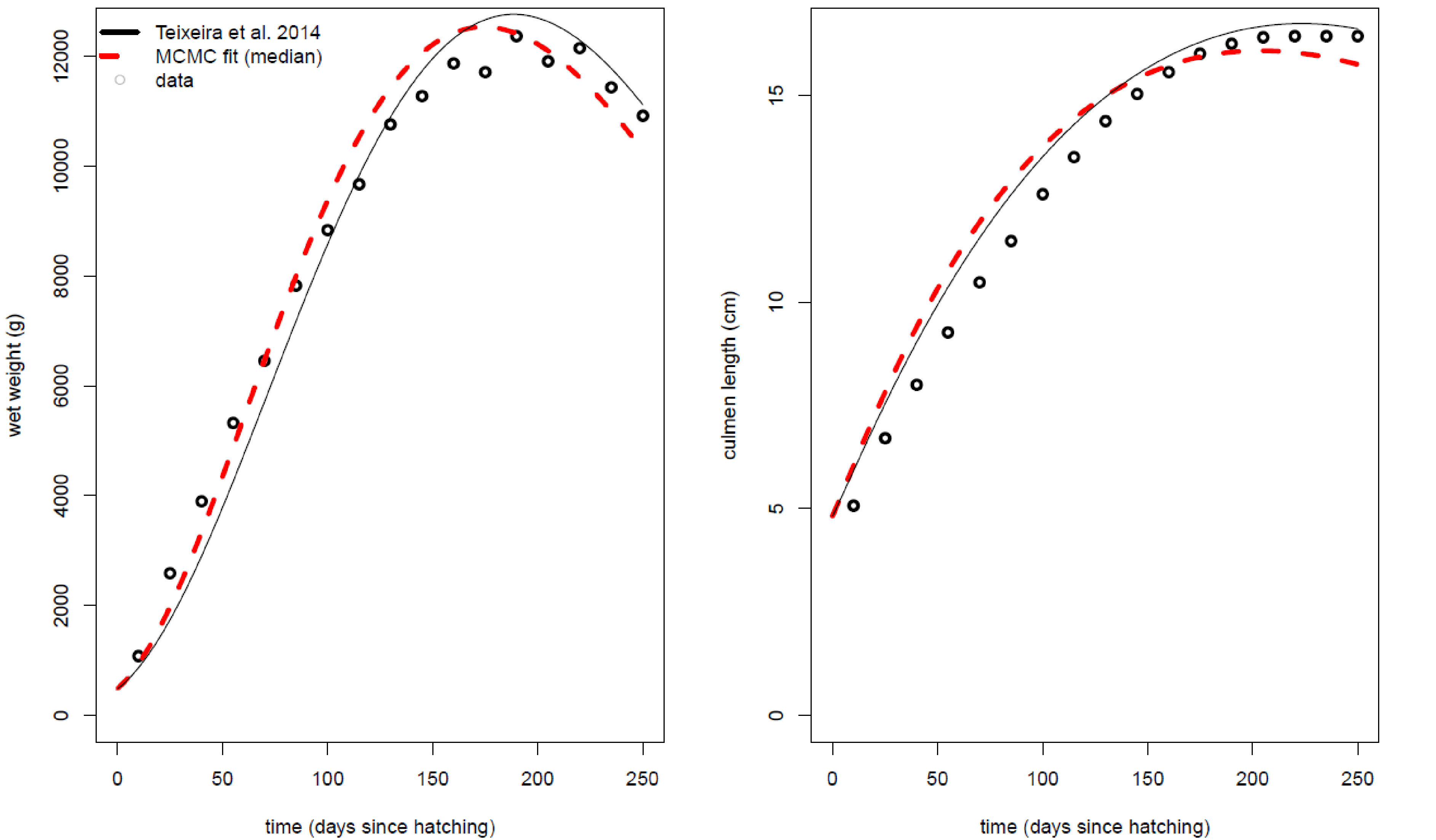
Model fits: Wandering Albatross (strong priors)



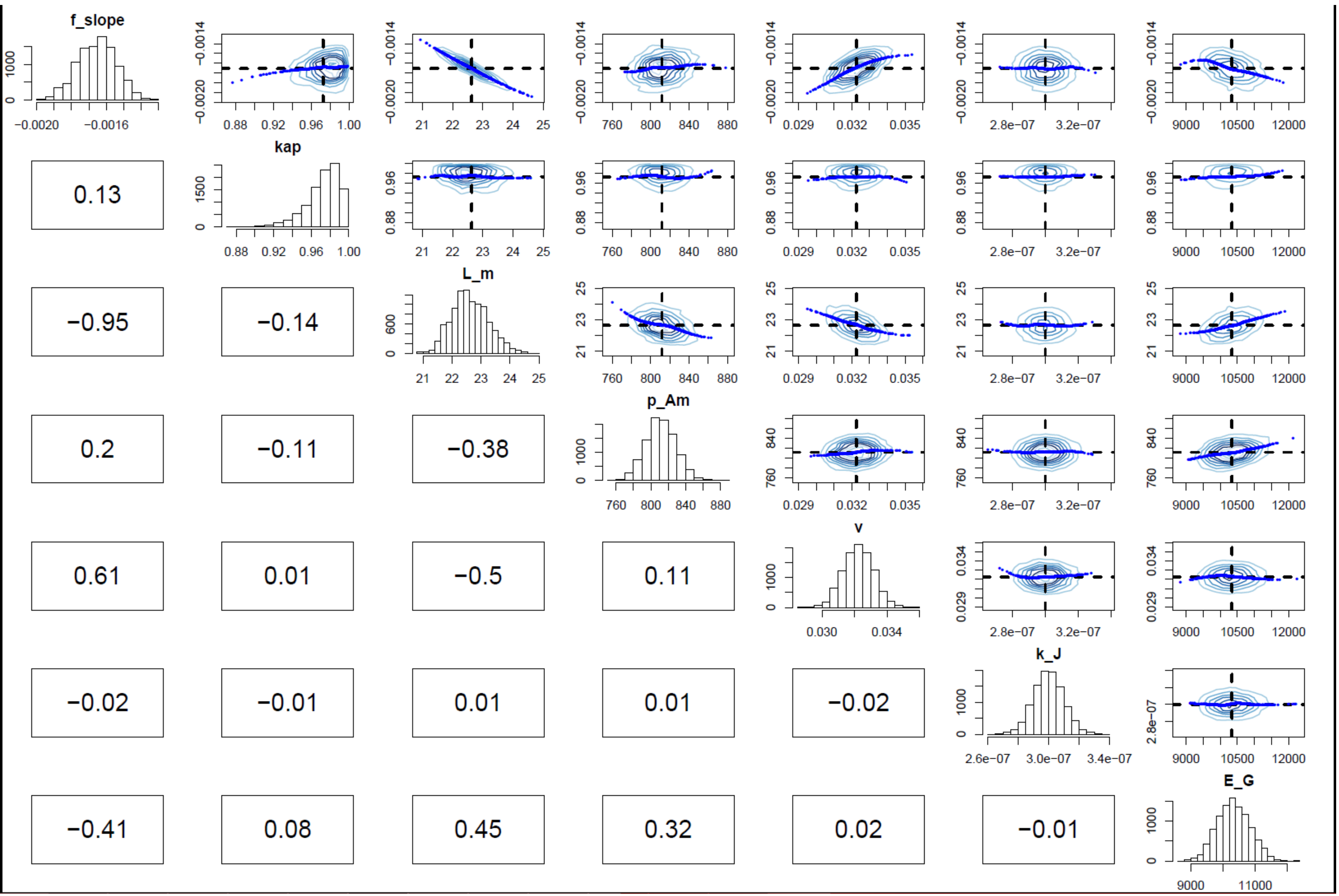
Early overfeeding → rapid build-up of reserve

Declining food input towards fledging → draw-down of reserve

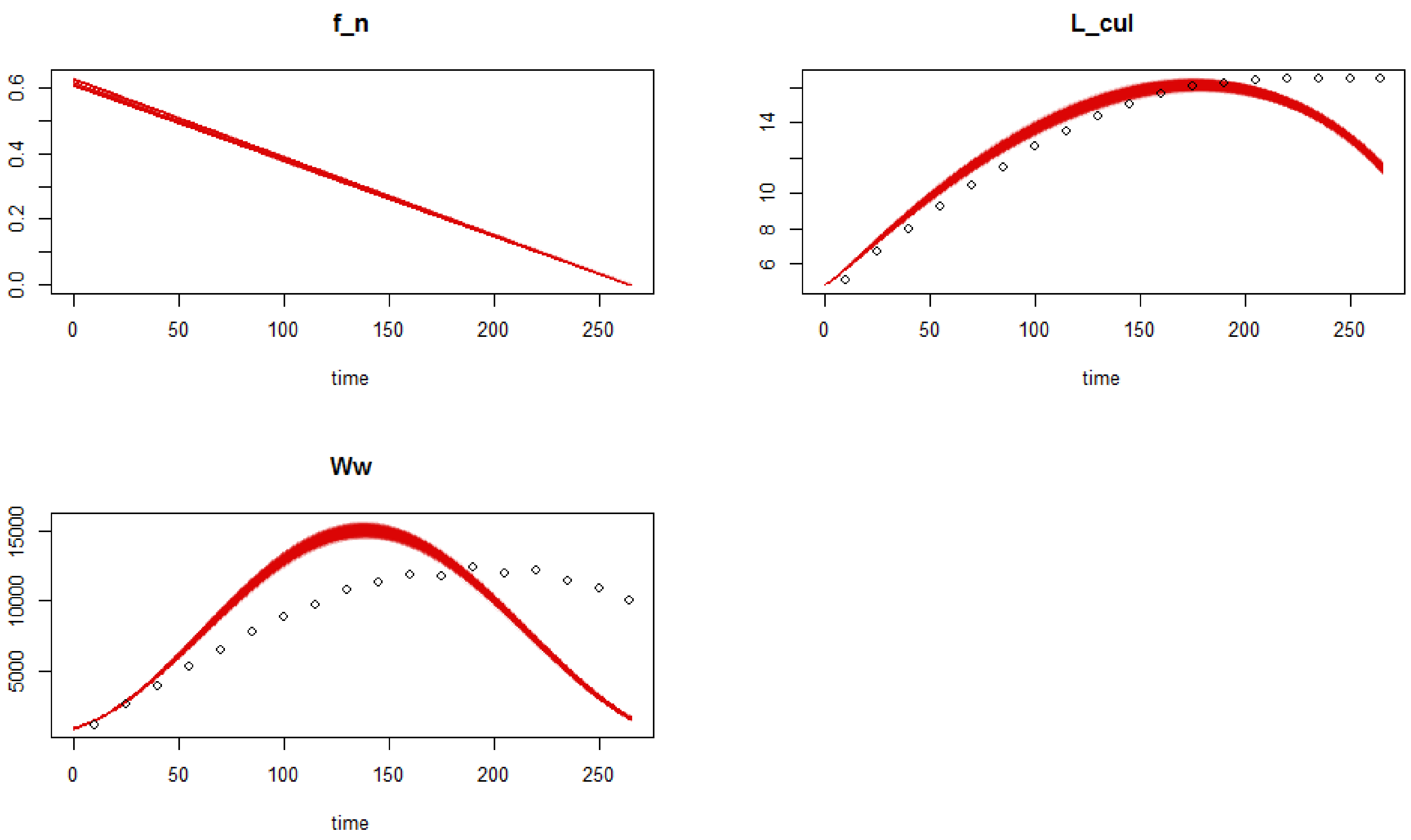
Model fits: Wandering Albatross



Parameter estimation results



Parameter estimation results (weak priors)



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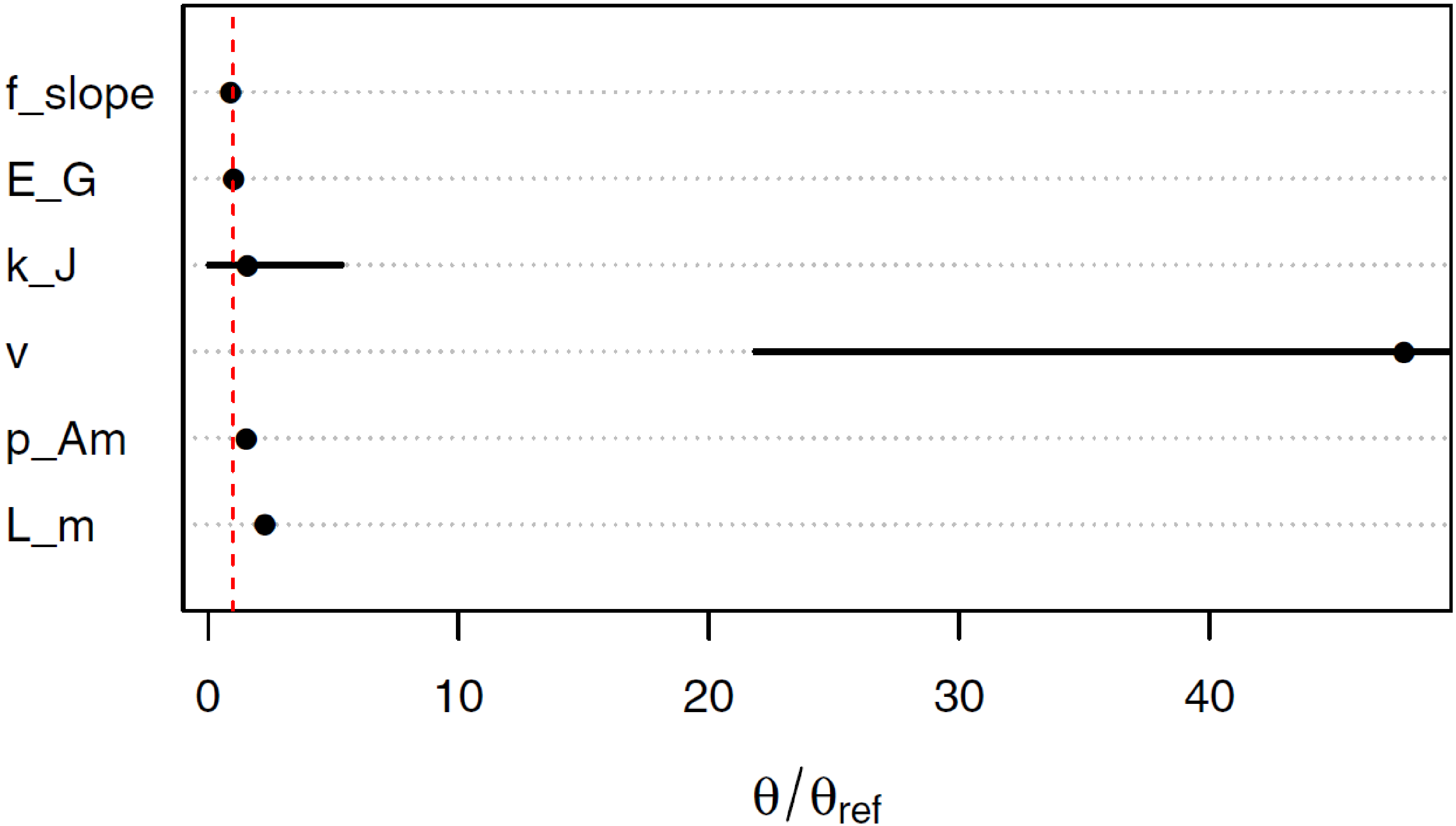
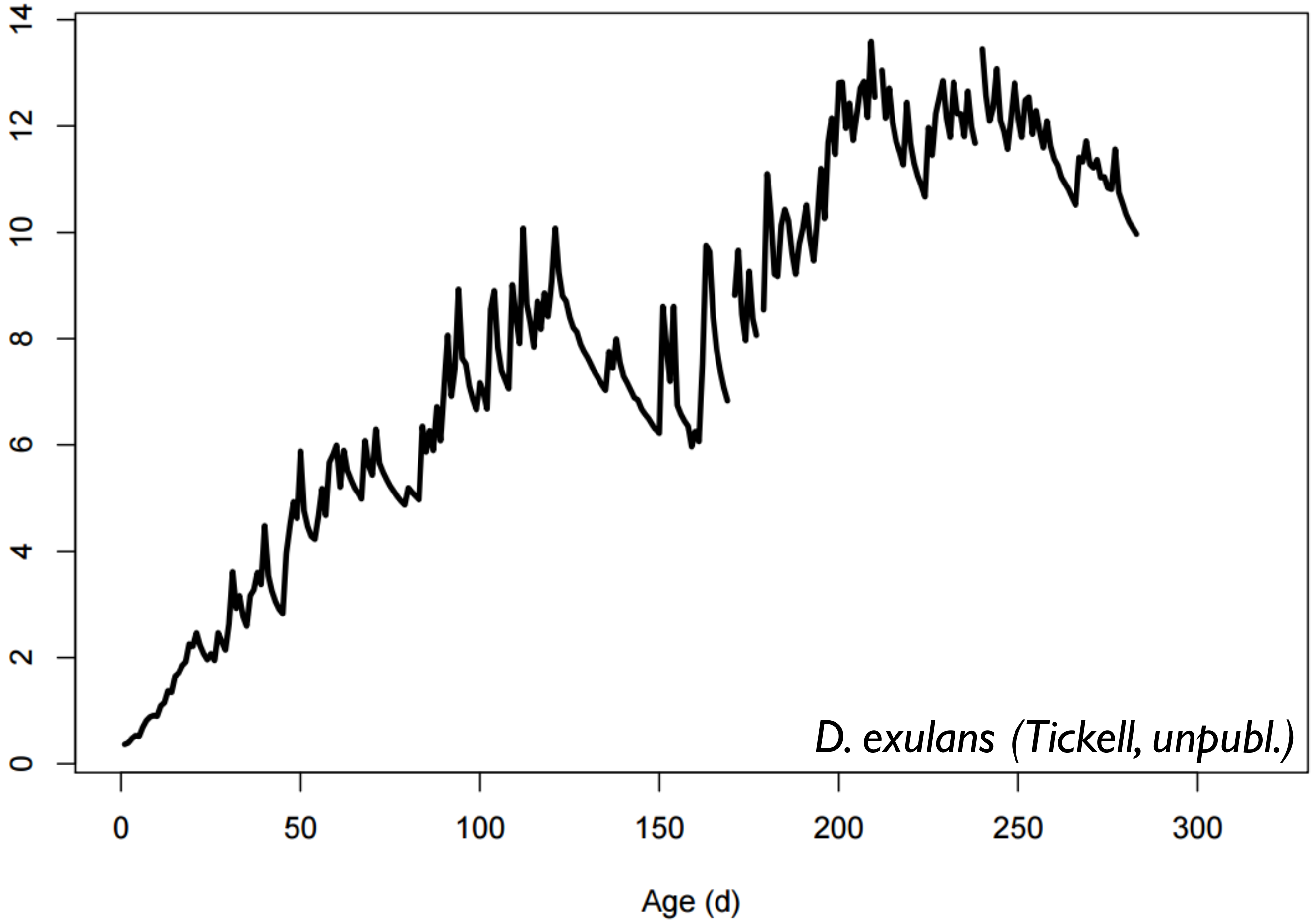
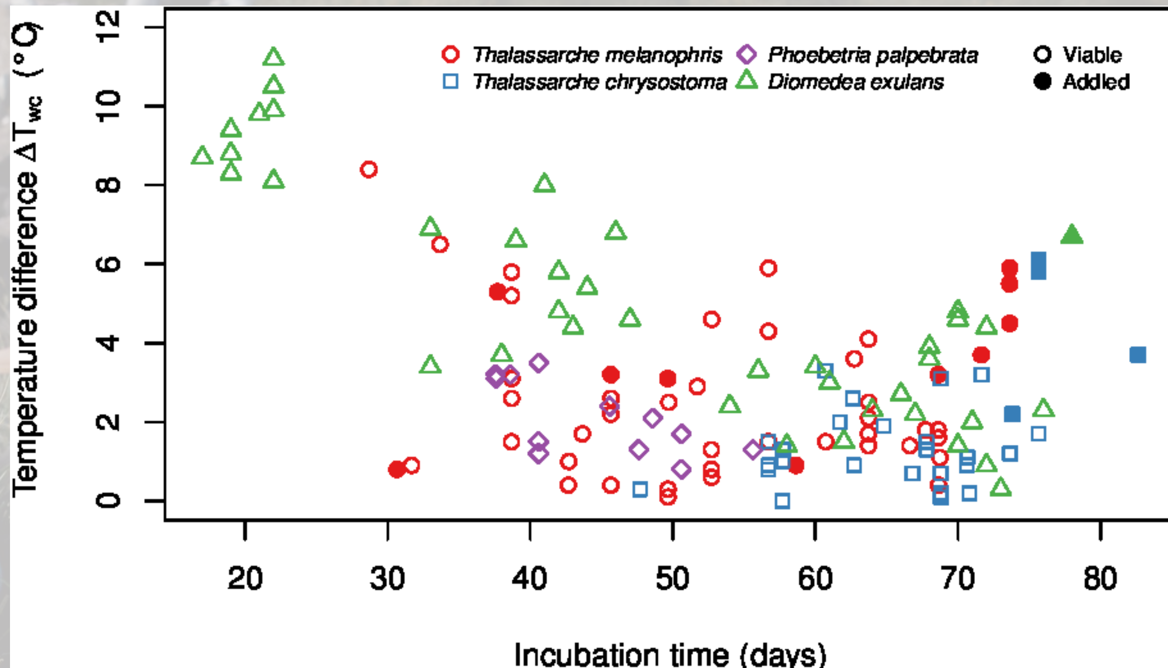


Albatross mass ontogenies are not smooth



Albatross are not born as endotherms



Boersch-Supan, Johnson et al., submitted

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Conclusions

- DEB provides a quantitative framework to investigate the effects of multiple drivers on individual growth, reproduction, and survival
- The Teixeira model provides a mechanistic explanation of humped mass ontogenies
- Bayesian parameter estimation has potential to link the model to data, incorporating parameter uncertainties and covariances
- More (smarter?) data is needed for model identifiability
  - Better constrained feeding model
  - Respiration and temperature data in egg phase

Thank you for listening!

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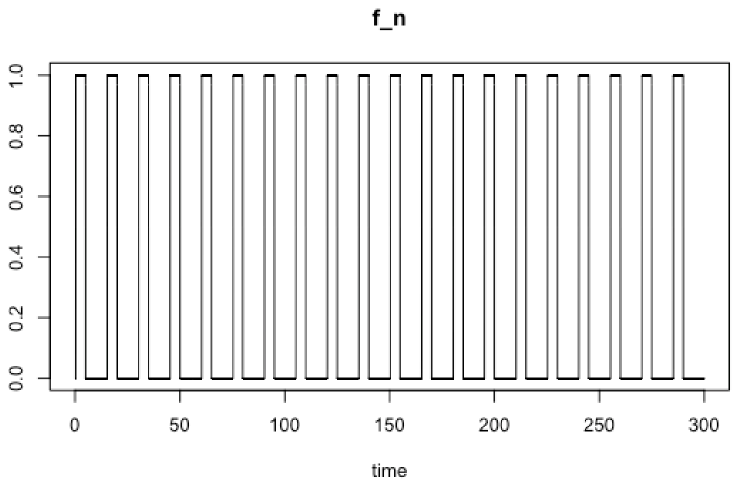
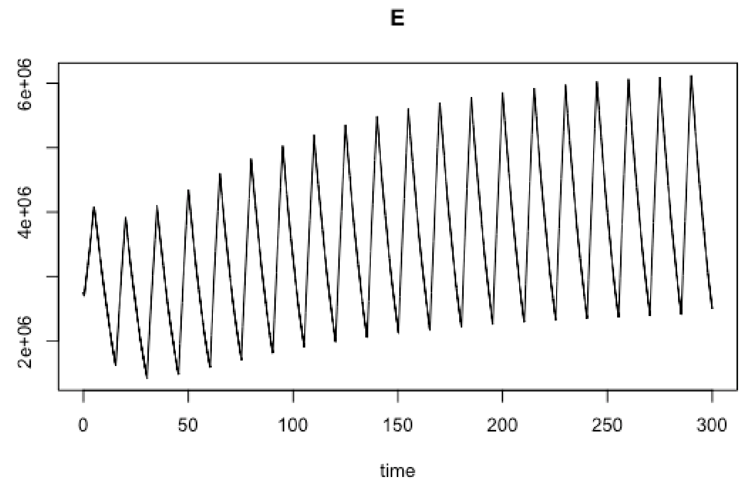
github.com/pboesu/seabirdeb

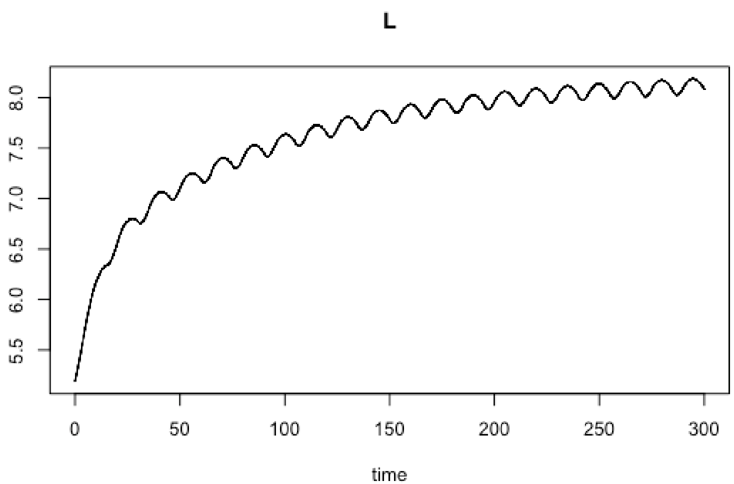
Model dynamics with pulsed food

food

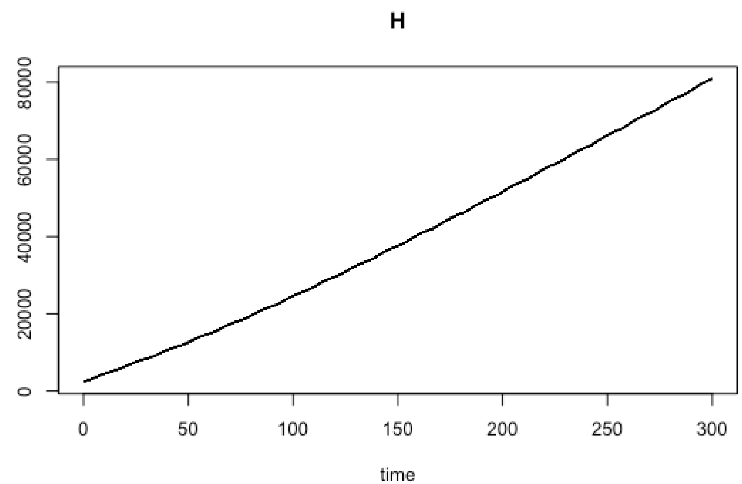


reserve density





structure

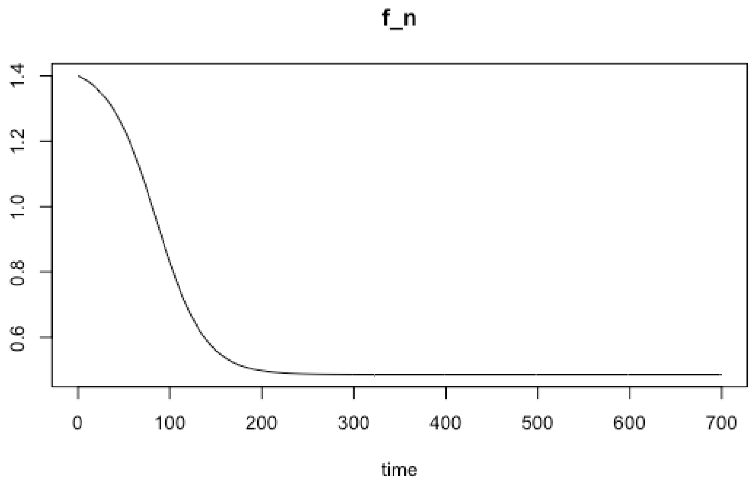


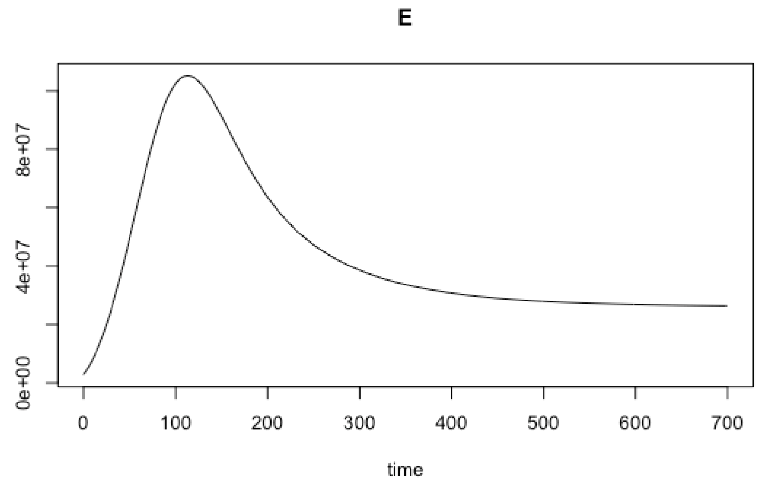
maturity

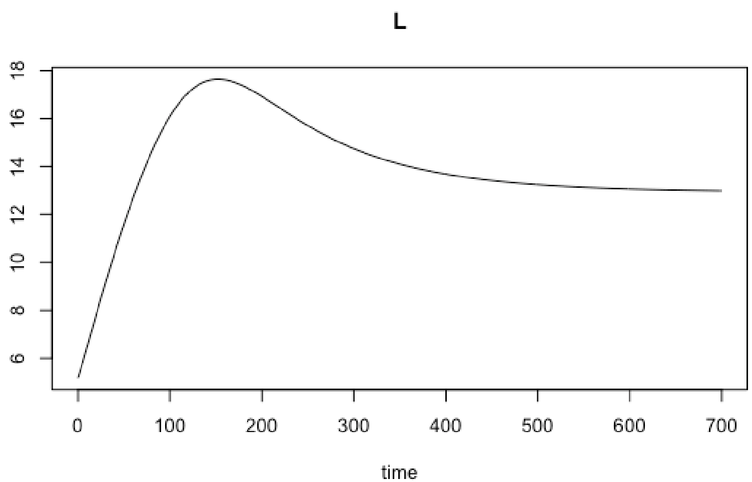
Model dynamics with logistic food

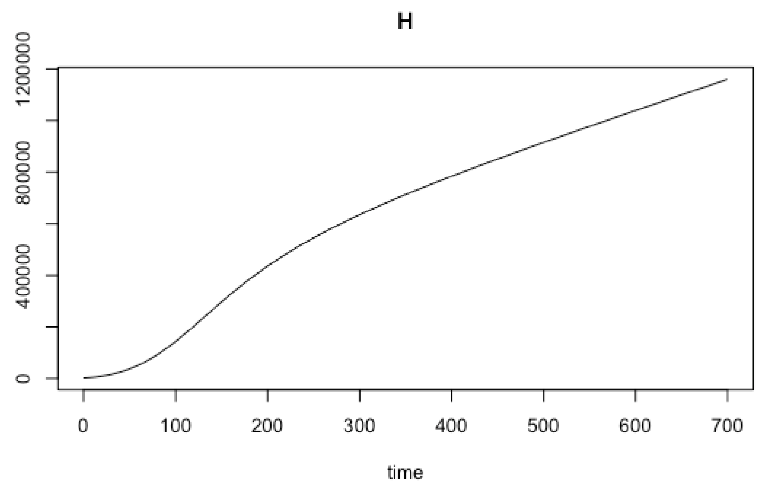
food

reserve density









structure

maturity

deBInfer provides templates for:

1. the (D)DE model
2. the observation model and likelihood
3. the prior distributions of the parameters.

Additionally, the user must specify/input:

- Data
- Proposal variances

ODE Equations

$$\frac{dL}{dt} = \frac{\dot{r}L}{3}$$
$$\frac{dE}{dt} = \{\dot{p}_{Am}\}fL^2 - \dot{p}_C$$
$$\frac{dE_H}{dt} = (1-\kappa)\dot{p}_C - \dot{k}_J E_H$$
$$\frac{df}{dt} = f_{slope}$$

Observation Equations

$$W_w = L^3\left(1 + f\frac{\{\dot{p}_{Am}\}w_E}{\dot{v}d_V\mu_E}\right)d_V\delta_{wd}$$
$$L_{cul} = \delta_M L$$

$$\mathcal{L}(\mathcal{Y}|\boldsymbol{\theta}) = \prod_t \frac{1}{\tilde{L}_t\sigma_L\sqrt{2\pi}}\exp\left(-\frac{(\ln\tilde{L}_t - \ln L_t)^2}{2\sigma_L^2}\right) \times \frac{1}{\tilde{W}_{wt}\sigma_W\sqrt{2\pi}}\exp\left(-\frac{(\ln\tilde{W}_{wt} - \ln W_{wt})^2}{2\sigma_W^2}\right)$$

Once these are specified, we use a standard Metropolis within Gibbs MCMC algorithm to obtain draws from the posterior distribution.