**Appendix S1**

**Supporting Information for**

*Intraspecific scaling of individual growth, consumption and metabolism with temperature and body mass across fishes*

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# Literature search, selection process and criteria

Prior to starting the actual literature review, we conducted several test-searches with alternative search strings on Web of Science Core Collection, basic search. This was done in order to find a manageable number of articles to review and to have a reasonable ratio article titles that passed the first screening, given our pre-defined criteria for when to choose a study. As we suspected that relatively few studies would have considered both size- and temperature treatments (combined factorially), our goal was to get an as extensive as possible list of studies. Therefore, we also evaluated articles cited by articles in the literature list, and from published review-type articles and reviews of applications of bioenergetics models such as the Wisconsin model (Deslauriers *et al.* 2017).

The search terms and subject categories are presented in the main text. We filtered out articles at three levels of the search: title, abstract and full article. The online repository of this project (<https://github.com/maxlindmark/scaling>) contains .txt files of the complete list of articles found in the literature search. We also used studies that did not appear in the literature search but that we found by following cited literature when reading the full article. The source of the article (WoS search or cited in literature) is indicated in the data sets. We removed studies from the lists if the titles made it clear the articles did not fulfil all of the following conditions: (1) experimental study, (2) fish as study organism in life stages older than larval, and (3) replicates across both size and temperature. In addition to these general criteria, we also had criteria specific for each rate (see below). When several studies were found for the same species, we did not include both but instead chose the study with the largest size and temperature range (in that order), as there can be large differences in absolute values of some physiological parameters between studies. While this reduces the number of data points, it avoids additional observation error due to different experimental setups and experimenters.

## *Growth rates & optimum temperature for growth over body mass*

Growth rates were taken from data found in the literature search for optimum growth temperatures. Therefore, articles in which growth rates were measured at sub-optimum temperatures only were not included (note this is in contrast to consumption data where “optimum” was not included in the search terms). The two searches for growth rates described in the main text resulted in 3313 articles (search date: 2019.03.22), and 3747 articles (search date: 2019.08.05), respectively. After applying additional filters by subject category, we acquired 566 and 893 studies, respectively (of which some are duplicates due to similar search-strings). We removed studies at the abstract and whole-article stage where the original reference could not be identified and evaluated, if we could not extract actual growth rates, if there was not a controlled temperature for each growth trial, or if there were not multiple defined size-classes. In addition, we ensured that no other treatment (e.g. food limitation) confounded the response variable and thus only used data from experiments with satiating food levels. It is important to control for feeding rations as it affects the temperature optimum for growth (Brett *et al.* 1969). This was achieved in different ways in the different experimental studies, but normally involved excess feeding rations once or several times per day. The key description we looked for in the study was that food should not be limiting, or that “reduced” rations provided. In the case growth was length-based, we converted it to mass using weight-length-relationships from FishBase (Froese *et al.* 2014; Froese & Pauly 2016). We compiled two separate data sets: raw growth rates (growth\_data.xlsx) and temperature at optimum growth (growth\_data\_Topt.xlsx). In the latter, we defined optimum temperature for growth as the fitted optimum temperature by size-class (usually estimated in the original study). Therefore, the optimum temperature may not always correspond to an actual measured temperature. If the optimum temperature (by size group) was not estimated in the original study, we used the temperature where growth rate was maximized. All growth rates were expressed in unit .

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## *Maximum consumption rate*

The two searches for maximum consumption rates described in the main text resulted in 15259 articles (search date: 2018.12.18), with 3449 remaining after filtering by subject categories. The second search (search date: 2019.03.13) resulted in 431 additional titles after filtering by subject categories (of which some where duplicated from the first search). Articles where filtered out at the abstract and whole-article stage if the original reference could not be identified and evaluated, if data were normalized (i.e. using a priori defined scaling relationships to show corrected data rather than measured values), there was no acclimation, or if it was not maximum consumption rate. As with the growth data, definitions of ad-libitum feeding may differ between studies – the key for our purpose is that food rations should lead to satiation and not be limiting. Consumption rates were converted (but note we fitted models to mass-specific rates, ). These data where compiled in the file consumption\_data.xlsx.

## *Metabolic rate*

The search for metabolic rate experiments described in the main text resulted in 8405 articles (search date: 2019.06.06), which was reduced to 3458 after applying filters for subject categories. Articles where filtered out at the abstract and whole-article stage if the original reference could not be identified and evaluated, if data were normalized (i.e. using a priori defined scaling relationships to normalize data for data a given size rather than measured values), if there was no acclimation or if it was not standard, routine or resting metabolic rate. The latter was defined as oxygen consumption of an unfed fish at no or little spontaneous activity, in line with common convention. Metabolic rates were converted to , because it was the most common unit in the data set (but not models where fitted to mass-specific rates, ). These data where compiled in the file metabolism\_data.xlsx.

EXPLANATORY TABLE HERE

* + If percentage per day (same as g/g/d), multiply by mass and divide by 100 to get g/day. Write this in the appendix
  + Basically write down things I will forget in appendix, e.g. conversion from length to mass, pref\_temp etc etc. See notes in the excel files. If env temp, take median. If not, take median of range of preferred temperature. If that columns value is not from FB, write in notes. I.e. in most cases that column is from FB. In some cases that comes from another paper or the same paper. See notes. Unless stated in notes, it's from FB. Check all the notes when I fill in the explanatory table, in case I forgot some edit I made. Go through all notes in the spreadsheet, see they are publishable
  + Some species have continuous data, others don’t, for both rates. Explain why
  + Authors use different definitions. If oxygen con of resting fish = routine. If actively trying to get lowest values, e.g. Percentile or extrapolation, standard. Irrespective, they all starve. this means we can't be 100% sure that species effects are not also author effects
  + Write in methods temp is a hugely important metric when mixing species. We used midpoint, because range depends on what type of metric is used and cite appendix table on temperature.
  + Put the temperature-stuff I showed to Jan and Anna (as well as the double paper stuff) in Appendix so that I know where I have everything.
  + Do the same with the “double” species document I prepared for the same meeting
  + The optimum growth and consumption temperatures were also compared to the minimum, mid-point and maximum of the ranges in experienced environmental temperatures (also taken from FishBase). In the growth data, this information was not available on FishBase for marbled sole (*Pseudopleuronectes yokohamae*),

hence 3-24 (mid-point 13.5) was used (Joh *et al.* 2013; Mitamura *et al.* 2020).

# Data exploration

## *Growth rate*

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Fig. S1. Taxonomic representation (top) (order and family, the latter indicated by colour) and the lifestyle (indicated by colour) and habitat (bottom) of species represented in the growth data sets.

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Fig. S2. Biogeography of species (top) and range of rescaled masses (mass/mass at maturation) of species represented in the growth data sets.

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Fig. S3. Trophic level (top) and mass at maturation (bottom) of species represented in the growth data sets.

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Fig. S4. Experimental and environmental (min, median and max) temperatures (indicated by colours) in the growth data sets.

## *Maximum consumption & metabolic rate*

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Fig. S5. Taxonomic information (order and family, latter indicated by colour) of species represented in the consumption (left) and metabolism (right) data sets.

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Fig. S6. Lifestyle and habitat (indicated by colour) of species represented in the consumption (left) and metabolism (right) data sets.

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Fig. S7. Biogeography of species represented in the consumption (left) metabolism (right) data sets.

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Description automatically generatedFig. S8. Distribution of maximum body masses of species represented in the consumption (left) and metabolism (right) data sets.

A screenshot of a social media post

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Fig. S9. Distribution of body masses of species represented in the consumption (top) and metabolism (bottom) data sets, expressed as relative to maximum mass of the species. Colours indicate species (legend not shown).

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Fig. S10. Trophic level of species represented in the consumption (left) and metabolism (right) data sets.

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Fig. S11. Experimental and environmental (min, median and max) temperatures (indicated by colours) of species represented in the consumption (left) and metabolism (right) data sets.

# Supplementary analysis

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Fig. S12. Posterior distributions of the global intraspecific mass-specific mass exponents () and temperature coefficients () for metabolic rate (top) and maximum consumption rate (bottom). For metabolism, the global interaction coefficient () is also shown (estimated and presented on an Arrhenius temperature scale), but for consumption this term was not included in the model. Numbers in the top left corner correspond to the posterior median. The axes are the same for each parameter for comparison between the two rates.

A close up of a map

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Fig. S13. Maximum consumption rates expressed as relative to maximum consumption rates (done by species) for species with data above peak temperatures plotted against temperature, expressed as the difference between the experimental temperature and the median environmental temperature (also by species species). Lines show fits from polynomial model using the posterior medians and the global prediction, grey bands show 95% and 80% credible intervals.

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*Fig. S14. Experimental temperatures (grey) overlap environmental temperatures (green), and optimum growth temperatures (orange) are typically at the upper end or above the environmental range. Horizontal green lines show the minimum and maximum environmental temperature based on either temperature in distribution range (triangles) or modelled distribution maps (circles), both taken from FishBase. The optimum growth temperatures are depicted for all size-classes per species, where the circle size is proportional to number of observations at that temperature.*

# Model validation and fit

Figures showing convergence of species-level parameters can be found on: <https://github.com/maxlindmark/scaling>, in this section only global parameters are visualized.

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## *Growth rate*

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Fig. S15. Posterior densities and trace plots for evaluation of chain convergence (by chain, indicated by colour), for the global-level parameters for the growth rate model at temperatures below optimum temperatures.

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Fig. S16. Potential scale reduction factor () for the growth rate model. This factor is based on the comparison of between and within-chain variation for the same parameter. A value close to one implies chains converged to the same distribution. The index of the parameter corresponds to species.

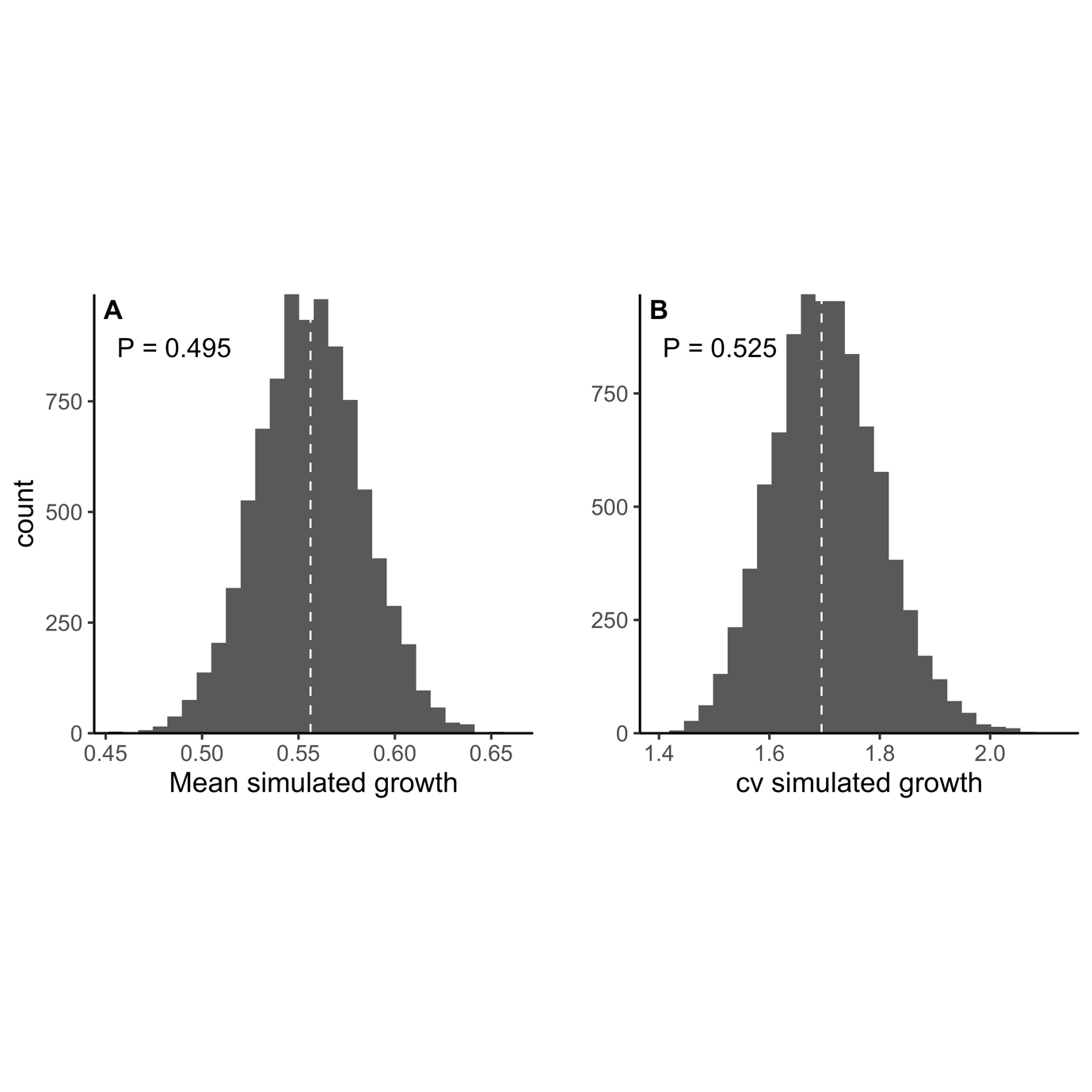


Fig. S17. Model fit (A=mean and B=coefficient of variation) for model of growth at temperatures below temperature optima. Vertical lines correspond to mean in data and histogram depicts each posterior mean. Fit is evaluated by simulating data from the likelihood (at each iteration of the MCMC chain), and each simulated data is assigned a 0 or 1 if it is below or above the mean data point. The number in the plot corresponds to the mean of the vector of 0’s and 1’s.

A close up of a map

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Fig. S18. Posterior (black) and prior distribution for the global parameters in the model for growth rate, including their % overlap, effective sample size and (rounded).

## *Maximum consumption rate*

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Fig. S20. Posterior densities and trace plots for evaluation of chain convergence (by chain, indicated by colour), for the global-level parameters for the maximum consumption rate model at temperatures below optimum temperatures.

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Fig. S21. Potential scale reduction factor () for the maximum consumption rate model. This factor is based on the comparison of between and within-chain variation for the same parameter. A value close to one implies chains converged to the same distribution. The index of the parameter corresponds to species.

A close up of a map

Description automatically generated

Fig. S22. Model fit (A=mean and B=coefficient of variation) for model of maximum consumption rate at temperatures below temperature optima. Vertical lines correspond to mean in data and histogram depicts each posterior mean. Fit is evaluated by simulating data from the likelihood (at each iteration of the MCMC chain), and each simulated data is assigned a 0 or 1 if it is below or above the mean data point. The number in the plot corresponds to the mean of the vector of 0’s and 1’s.

A close up of a map

Description automatically generated

Fig. S23. Posterior (black) and prior distribution for the global parameters in the model for maximum consumption rate, including their % overlap, effective sample size and (rounded).

## *Metabolic rate*

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Fig. S24. Posterior densities and trace plots for evaluation of chain convergence (by chain, indicated by colour), for the global-level parameters for the metabolic rate model at temperatures below optimum temperatures.

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Fig. S25. Potential scale reduction factor () for the metabolic rate model. This factor is based on the comparison of between and within-chain variation for the same parameter. A value close to one implies chains converged to the same distribution. The index of the parameter corresponds to species.

A close up of a logo

Description automatically generated

Fig. S26. Model fit (A=mean and B=coefficient of variation) for model of metabolic rate at temperatures below temperature optima. Vertical lines correspond to mean in data and histogram depicts each posterior mean. Fit is evaluated by simulating data from the likelihood (at each iteration of the MCMC chain), and each simulated data is assigned a 0 or 1 if it is below or above the mean data point. The number in the plot corresponds to the mean of the vector of 0’s and 1’s.

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Fig. S27. Posterior (black) and prior distribution for the global parameters in the model for metabolic rate, including their % overlap, effective sample size and (rounded).

## *Optimum growth temperature*

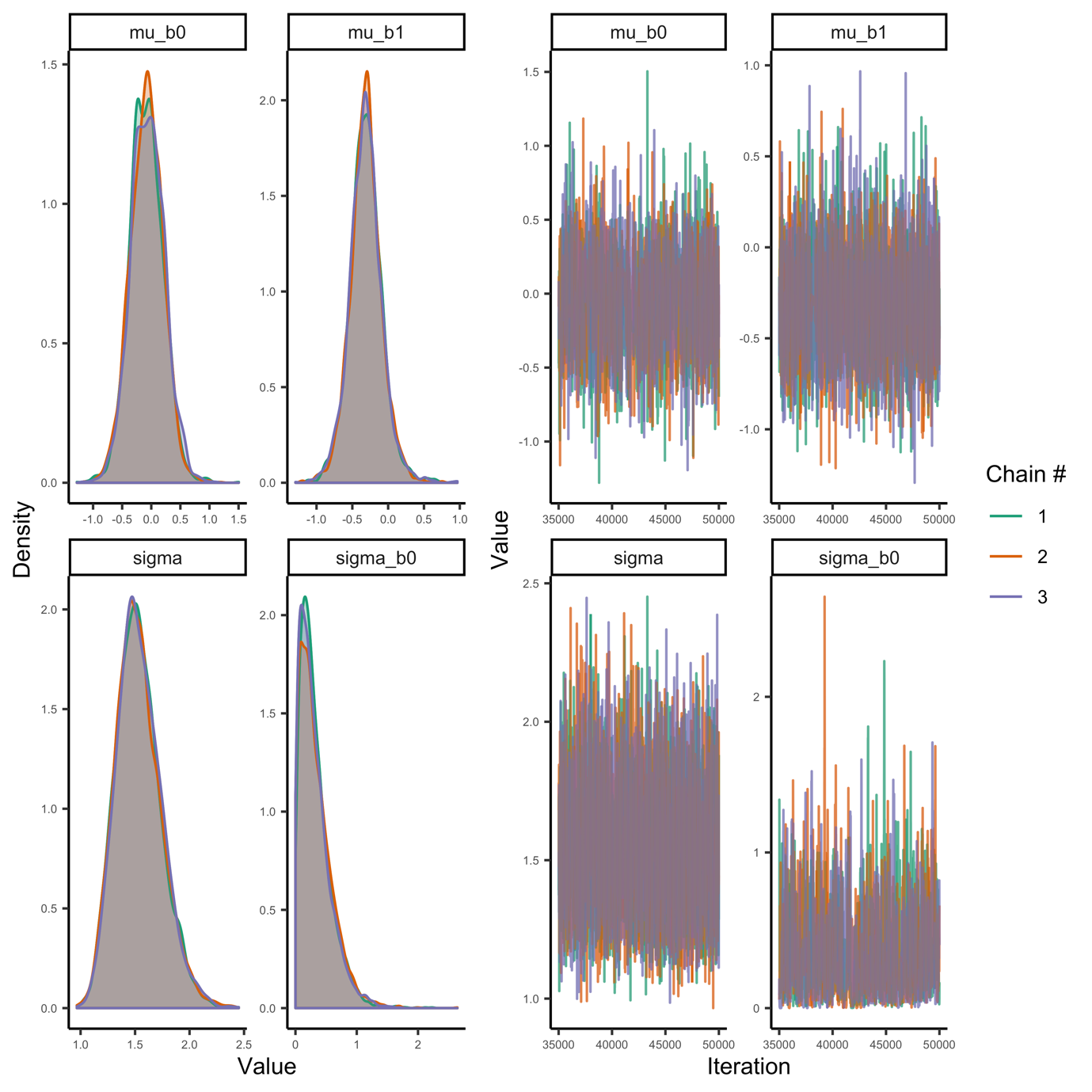


Fig. S28. Posterior densities and trace plots for evaluation of chain convergence (by chain, indicated by colour), for the global-level parameters for the model.

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Fig. S29. Potential scale reduction factor () for the model. This factor is based on the comparison of between and within-chain variation for the same parameter. A value close to one implies chains converged to the same distribution. The index of the parameter corresponds to species.

A screenshot of a cell phone

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Fig. S30. Model fit (mean) for -model. Vertical line corresponds to mean in data and histogram depicts each posterior mean. Fit is evaluated by simulating data from the likelihood (at each iteration of the MCMC chain), and each simulated data is assigned a 0 or 1 if it is below or above the mean data point. The number in the plot corresponds to the mean of the vector of 0’s and 1’s.

A picture containing text, map

Description automatically generated

Fig. S31. Posterior (black) and prior distribution for the global parameters in the model for , including their % overlap, effective sample size and (rounded).

# References

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