

1   **Appendix S1**

2   **Supporting Information for**

3   Optimum growth temperature declines with body size within fish species

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## 54    **Literature search, selection process and criteria**

55    This section is an overview of the literature search approach, and below we present the search  
56    terms for each rate separately (maximum consumption, metabolism and growth). In addition  
57    to search terms, we also applied filters by selecting only the following subjects: ‘marine  
58    freshwater biology’, ‘fisheries’, ‘ecology’, ‘zoology’, ‘biology’, ‘physiology’. For growth  
59    rates, we also included ‘limnology’ and for maximum consumption we included ‘limnology’  
60    and ‘evolutionary biology’. The use of additional subjects for growth and consumption reflects  
61    the lower data availability compared to metabolism. As we suspected that relatively few studies  
62    would have considered both body size- and temperature treatments, our goal was to get an as  
63    extensive as possible list of studies. Therefore, we also evaluated articles cited by articles found  
64    in the search, from published review-type articles and reviews of applications of bioenergetics  
65    models such as the Wisconsin model (Deslauriers *et al.* 2017), and if the study was found in  
66    the literature search for another rate. The source of the article (WoS search or cited in literature)  
67    is indicated in the data sets (Table S1).

68    Articles were filtered out at three levels of the search: title, abstract and full article. The  
69    online repository of this project (<https://github.com/maxlindmark/scaling>) contains .txt files of  
70    the complete list of articles found in the literature search. We removed studies from the lists if  
71    the titles made it clear the articles did not fulfil all of the following conditions: (1) experimental  
72    study, (2) fish as study organism in post-larval life stages, and (3) replicates across both body  
73    size and temperature (factorially). We treat data as individual-level rates (per fish); however,  
74    in some cases they were measured as averages across multiple individuals. In addition to these  
75    general criteria, we also had criteria specific for each rate (see below). When several studies  
76    were found for the same species, we did not include all but instead chose the study with the  
77    largest body size and temperature range (in that order), as there can be large differences in  
78    absolute values of some physiological parameters between studies.

79 For consumption and growth rate, we determined if each data point within species was  
80 below or beyond peak temperature either by using information provided by the authors (e.g. by  
81 deriving a polynomial regression of the rate as a function of temperature to find the temperature  
82 of peak rate), by fitting quadratic models or visually inspecting data for each species separately.  
83 Whether a data point was below or above peak or optimum temperatures is indicated by a  
84 separate column in the data (Table S1).

85

86 ***Maximum consumption rate***

87 We used the following topic terms for maximum consumption rate (three searches in total):  
88 (consumption OR bioenerg\* OR ingestion OR “food-intake”) AND (mass OR weight OR size)  
89 AND (temperature\*), as well as: (feeding-rate OR bio-energ\*) AND (mass OR weight OR  
90 size) AND (temperature\*) and lastly: (“food intake”) AND (mass OR weight OR size) AND  
91 (temperature\*). \* represents any group of characters, including no character. The searches for  
92 maximum consumption rate data resulted in 15259 articles (search date: 18 December 2018),  
93 with 3449 remaining after filtering by subject categories. The second search (search date: 13  
94 March 2019) resulted in 431 additional titles after filtering by subject categories (of which  
95 some where duplicated from the first search) and the third search (search date: 29 June 2020)  
96 yielded 626 but no additional articles as they had either been selected already or did not meet  
97 the criteria. Articles were filtered out at the abstract and whole article stage if the original  
98 reference could not be identified and evaluated, if data were normalized (i.e., using a priori  
99 defined scaling relationships to show corrected data rather than measured values), there was no  
100 acclimation, or if measurements were not maximum consumption rate. As with the growth  
101 data, definitions of ad-libitum feeding may differ between studies – the key for our purpose is  
102 that food rations led to satiation and were not limiting. Consumption rates were converted to  
103 g day<sup>-1</sup>. These data were compiled in the file consumption\_data.xlsx.

104

105 ***Metabolic rate***

106 We used the following topic terms for metabolic rate data: (metabolism OR "oxygen-  
107 consumption" OR "oxygen consumption") AND (mass OR weight OR size) AND  
108 (temperature\*). \* represents any group of characters, including no character. The search for  
109 metabolic rate experiments resulted in 8405 articles (search date: 6 June 2019), which was  
110 reduced to 3458 after applying filters for subject categories. Articles were filtered out at the  
111 abstract and whole article stage if the original reference could not be identified and evaluated,  
112 if data were normalized (i.e., using a priori defined scaling relationships to normalize data for  
113 data a given size rather than measured values), if there was no acclimation or if it was not  
114 standard, routine or resting metabolic rate. The latter was defined as oxygen consumption of  
115 an unfed fish at no or little spontaneous activity. Metabolic rates were converted to mg O<sub>2</sub> h<sup>-1</sup>,  
116 because it was the most common unit in the data set. These data were compiled in the file  
117 metabolism\_data.xlsx.

118

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

120 Growth rates were taken from data found in the literature search for optimum growth  
121 temperatures. Therefore, articles in which growth rates were measured at sub-optimum  
122 temperatures only were not included (note this is in contrast to consumption data where  
123 "optimum" was not included in the search terms). We used the following topic terms for growth  
124 rate data: (growth) AND (mass OR weight OR size) AND (temperature\*) AND (optimum), as  
125 well as: (growth) AND (mass OR weight OR size) AND (temperature\*) AND (optim\*). \*  
126 represents any group of characters, including no character. The two searches for growth rates  
127 resulted in 3313 articles (search date: 22 March 2019), and 3747 articles (search date: 5 May  
128 2019), respectively. After applying additional filters by subject category, we acquired 566 and

129 893 studies, respectively (of which some are duplicates due to similar search-strings). We  
130 removed studies at the abstract and whole article stage where the original reference could not  
131 be identified and evaluated, if we could not extract actual growth rates, if there was not a  
132 controlled temperature for each growth trial, or if there were not multiple defined size-classes.  
133 We used only one observation (data point) per size class and temperature treatment, and in  
134 cases where there were two, we used the mean value. In addition, we ensured that no other  
135 treatment (e.g., food limitation) confounded the response variable and thus only used data from  
136 experiments with satiating food levels. Body mass is either the geometric mean of the initial  
137 and final mass of the growth trial or the size class, depending on data availability (see Table  
138 S1). It is important to control for feeding rations as it affects the temperature optimum for  
139 growth (Brett *et al.* 1969). This was achieved in different ways in the different experimental  
140 studies, but commonly involved excess feeding rations once or several times per day. The key  
141 description we looked for in the study was that food was not limiting. We treat data as  
142 individual-level growth (per fish); however, these were commonly measured as averages for  
143 multiple individuals. In the case growth was length-based, we converted it to mass using  
144 weight-length relationships from FishBase (Froese *et al.* 2014; Froese & Pauly 2019). We  
145 compiled two separate data sets: raw growth rates (growth\_data.xlsx) and temperature at  
146 optimum growth (growth\_data\_Topt.xlsx). In the latter, we defined optimum temperature for  
147 growth as the fitted optimum temperature by size-class (usually estimated in the original study).  
148 Therefore, the optimum temperature may not always correspond to an actual experimental  
149 temperature but could be an estimation. If the optimum temperature (by size group) was not  
150 estimated in the original study, we used the temperature where growth rate was maximized.  
151 All growth rates were expressed in unit % day<sup>-1</sup>.  
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154 **Table S1** Explanation of data columns (G=growth data,  $T_{opt}$ =optimum growth temperature  
 155 data, C=maximum consumption data, M=metabolism data).

Column	Explanation	Datasets
<i>growth_rate_%/day</i>	Main response variable.	G, $T_{opt}$
<i>opt_temp_c</i>	Main response variable.	$T_{opt}$
<i>initial_mass_g</i>	Body mass [g] at the onset of the growth trial.	G, $T_{opt}$
<i>final_mass_g</i>	Body mass [g] at the end of the growth trial.	G, $T_{opt}$
<i>geom_mean_mass_g</i>	Geometric mean mass in $t_1$ and $t_2$ of the growth trial.	G, $T_{opt}$
<i>size_group</i>	Representative body mass of size group in the growth trial, in case initial, final or geometric body mass could not be retrieved.	G, $T_{opt}$
<i>consumption</i>	Main response variable.	C
<i>metabolic_rate</i>	Main response variable.	M
<i>type</i>	Type of respiration measurement (resting, routine, standard).	M
<i>unit</i>	Unit of response variable.	C, M
<i>original_unit</i>	Original unit of response variable. If different from “ <i>unit</i> ”, see “ <i>notes</i> ” column for information on conversion.	C, M
<i>mass_g</i>	Body mass in experiment [g]. Some studies report body masses before and some after the feeding trials. See “ <i>notes</i> ”.	C, M
<i>temp_c</i>	Experimental temperature [ $^{\circ}\text{C}$ ].	G, C, M
<i>above_peak_temp</i>	Is the experiment conducted at temperature above peak temperature for the given size group? Y/N.	G, C, M
<i>common_name</i>	Common name of species.	G, $T_{opt}$ , C, M
<i>species</i>	Scientific name of species.	G, $T_{opt}$ , C, M
<i>genus</i>	Genus of species.	G, $T_{opt}$ , C, M
<i>family</i>	Family of species.	G, $T_{opt}$ , C, M
<i>order</i>	Order of species.	G, $T_{opt}$ , C, M
<i>habitat</i>	Species natural habitat, taken from FishBase (Froese & Pauly 2019).	G, $T_{opt}$ , C, M
<i>lifestyle</i>	Lifestyle of species, taken from FishBase (Froese & Pauly 2019).	G, $T_{opt}$ , C, M
<i>biogeography</i>	Biogeography of species, taken from FishBase (Froese & Pauly 2019).	G, $T_{opt}$ , C, M
<i>trophic_level</i>	Trophic level of species, taken from FishBase	G, $T_{opt}$ , C, M

	(Froese & Pauly 2019).	
<i>w_maturity_g</i>	Body mass [g] at maturation taken from FishBase (Froese & Pauly 2019). If not available, weight was estimated from length using species-specific allometric weight-length, else taken from alternative sources (see " <b>notes</b> "). Used to estimate relative body size across species in the data and to normalized optimum growth temperatures across species.	G, T <sub>opt</sub>
<i>w_max_published_g</i>	Max. published weight [g] taken from FishBase (Froese & Pauly 2019). If not available, weight was estimated from length using species-specific allometric weight-length, else taken from alternative sources (see " <b>notes</b> "). Used to estimate relative body size across species in the data.	G, T <sub>opt</sub> , C, M
<i>env_temp_min</i>	Min. environmental temperature [°C], taken from FishBase (Froese & Pauly 2019). If not available on FishBase, data were taken from alternative sources (see " <b>notes</b> "). Used to compare experimental temperatures to common temperatures for species.	G, T <sub>opt</sub> , C, M
<i>env_temp_max</i>	Max. environmental temperature [°C], taken from FishBase (Froese & Pauly 2019). If not available on FishBase, data were taken from alternative sources (see " <b>notes</b> "). Used to compare experimental temperatures to common temperatures for species.	G, T <sub>opt</sub> , C, M
<i>env_temp_mid</i>	Median of environmental temperature [°C], taken from FishBase (Froese & Pauly 2019). If not available on FishBase, data were taken from alternative sources (see " <b>notes</b> "). Used to compare experimental temperatures to common temperatures for species.	G, T <sub>opt</sub> , C, M
<i>pref_temp_mid</i>	Median of preferred temperature [°C], taken from FishBase (Froese & Pauly 2019). If not available on FishBase, data were taken from alternative sources (see " <b>notes</b> "). Used to compare experimental temperatures to common temperatures for species.	G, T <sub>opt</sub> , C, M
<i>notes</i>	This column contains additional information, including if data were sent by authors, if any column above has data that is not from the main source (i.e. FishBase), how certain metrics were calculated, alternative common names, comments on the experimental protocol, information on conversion to standard " <b>unit</b> ", source of the data (literature search or cited in paper from literature search)	G, T <sub>opt</sub> , C, M
<i>reference</i>	Source (See Table S2).	G, T <sub>opt</sub> , C, M

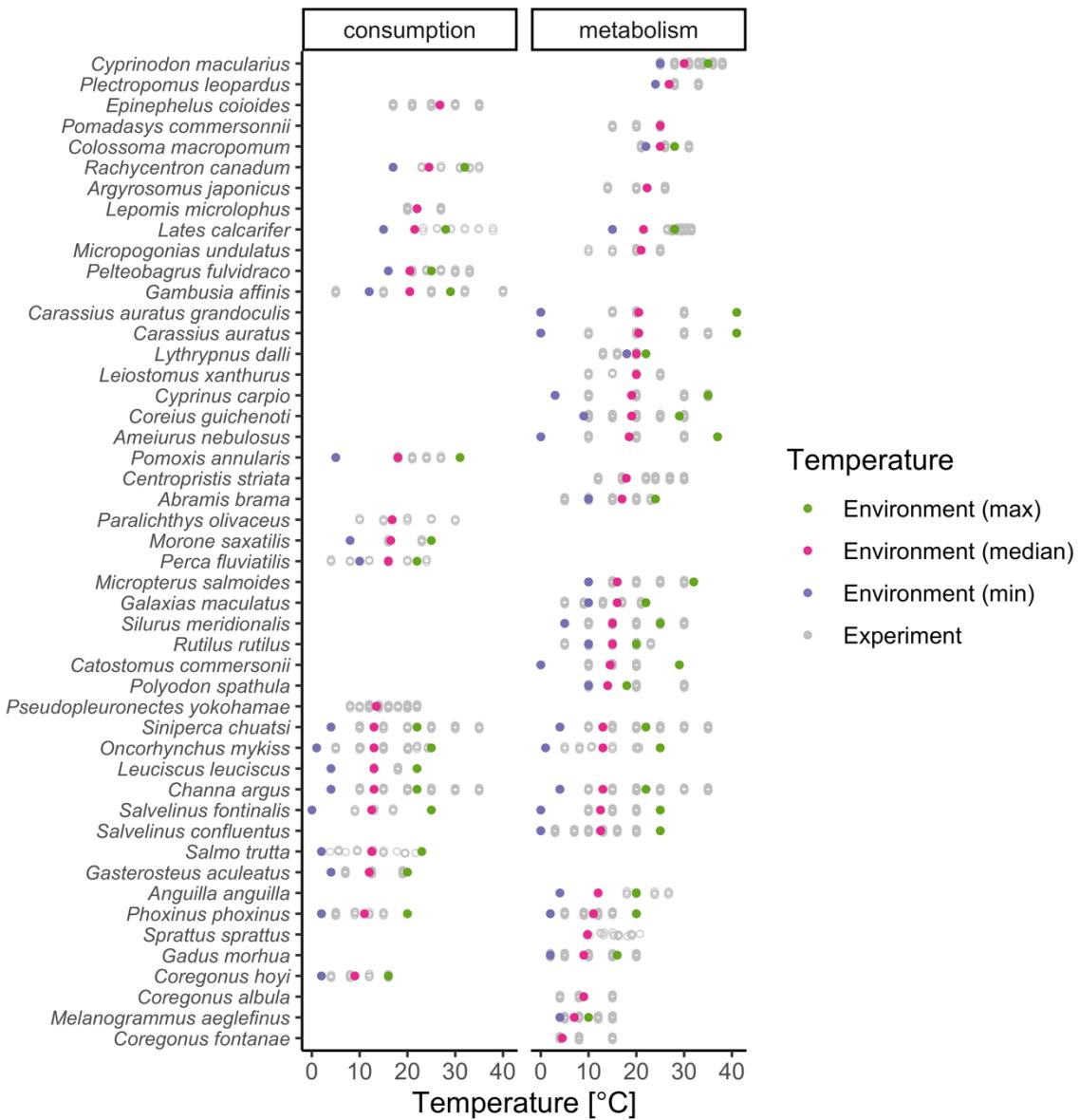
157 **Table S2** Species, common name, the data set(s) in which they appear and the sources  
 158 (G=growth data,  $T_{opt}$ =optimum growth temperature data, C=maximum consumption data,  
 159 M=metabolism data). If more than one data and source, the sources are in order (1 study per  
 160 species and rate).

Species	Common name	Datasets	Source
<i>Pseudopleuronectes yokohamae</i>	Marbled flounder	G, $T_{opt}$ , C	(Tomiyama <i>et al.</i> 2018)
<i>Cyclopterus lumpus</i>	Lumpfish	G, $T_{opt}$	(Nytrø <i>et al.</i> 2014)
<i>Paralichthys olivaceus</i>	Japanese flounder (alt. bastard halibut, Japanese halibut or Olive flounder)	G, $T_{opt}$ , C	(Iwata <i>et al.</i> 1994)
<i>Salvelinus alpinus</i>	Arctic char	G, $T_{opt}$	(Siikavuopio <i>et al.</i> 2013)
<i>Salmo salar</i>	Atlantic salmon	G, $T_{opt}$	(Handeland <i>et al.</i> 2008)
<i>Lates calcarifer</i>	Barramundi	G, $T_{opt}$ , C, M	(Bermudes <i>et al.</i> 2010) (Bermudes <i>et al.</i> 2010) (Bermudes <i>et al.</i> 2010) (Glencross & Felsing 2006)
<i>Gadus morhua</i>	Atlantic cod	G, $T_{opt}$ , M	(Björnsson <i>et al.</i> 2007)(Tirsgaard <i>et al.</i> 2015)
<i>Hippoglossus hippoglossus</i>	Atlantic halibut	G, $T_{opt}$	(Björnsson & Tryggvadóttir 1996)
<i>Scophthalmus maximus</i>	Turbot	G, $T_{opt}$	(Árnason <i>et al.</i> 2009)
<i>Boreogadus saida</i>	Arctic cod	G, $T_{opt}$	(Laurel <i>et al.</i> 2017)
<i>Rachycentron canadum</i>	Cobia	G, $T_{opt}$ , C	(Sun & Chen 2014)
<i>Pelteobagrus fulvidraco</i>	Yellow catfish	G, $T_{opt}$ , C	(Zhang <i>et al.</i> 2017)
<i>Anarhichas minor</i>	Spotted wolffish	G, $T_{opt}$	(Imsland <i>et al.</i> 2006)
<i>Oncorhynchus mykiss</i>	Rainbow trout	C, M	(From & Rasmussen 1984)
<i>Perca fluviatilis</i>	Eurasian perch	C	(Lessmark 1983)
<i>Phoxinus phoxinus</i>	Eurasian minnow	C, M	(Cui & Wootton 1988)
<i>Coregonus hoyi</i>	Bloater	C	(Binkowski & Rudstam 1994)
<i>Pomoxis annularis</i>	White crappie	C	(Hayward & Arnold 1996)
<i>Gambusia affinis</i>	Western mosquitofish	C	(Chipps & Wahl 2004)
<i>Morone saxatilis</i>	Striped bass	C	(Duston <i>et al.</i> 2004)
<i>Salvelinus fontinalis</i>	Brook trout	C, M	(Baldwin 1957) (Beamish 1964)
<i>Leuciscus leuciscus</i>	Dace	C	(Marmulla & Rosch 1990)
<i>Lepomis microlophus</i>	Redear sunfish	C	(Wang <i>et al.</i> 2003)

<i>Channa argus</i>	Chinese snakehead (alt. Northern snakehead or Snakehead)	C, M	(Liu <i>et al.</i> 1998) (Liu <i>et al.</i> 2000)
<i>Siniperca chuatsi</i>	Mandarin fish	C, M	(Liu <i>et al.</i> 1998) (Liu <i>et al.</i> 2000)
<i>Gasterosteus aculeatus</i>	Three-spined stickleback	C	(Wootton <i>et al.</i> 1980)
<i>Salmo trutta</i>	Brown trout	C	(Elliott 1976)
<i>Epinephelus coioides</i>	Orange-spotted grouper	C	(Lin <i>et al.</i> 2008)
<i>Coregonus albula</i>	Vendace	M	(Ohlberger <i>et al.</i> 2012)
<i>Coregonus fontanae</i>	Stechlin cisco	M	(Ohlberger <i>et al.</i> 2012)
<i>Abramis brama</i>	Common bream	M	(Ohlberger <i>et al.</i> 2012)
<i>Rutilus rutilus</i>	Common roach	M	(Ohlberger <i>et al.</i> 2012)
<i>Salvelinus confluentus</i>	Bull trout	M	(Mesa <i>et al.</i> 2013)
<i>Catostomus commersonii</i>	White sucker	M	(Beamish 1964)
<i>Cyprinus carpio</i>	Common carp	M	(Beamish 1964)
<i>Ameiurus nebulosus</i>	Brown bullhead	M	(Beamish 1964)
<i>Silurus meridionalis</i>	Southern catfish	M	(Xie & Sun 1990)
<i>Carassius auratus</i>	Goldfish	M	(Beamish & Mookherjee 1964)
<i>Pomadasys commersonii</i>	Spotted grunter	M	(Du Perez <i>et al.</i> 1986)
<i>Melanogrammus aeglefinus</i>	Haddock	M	(Peck <i>et al.</i> 2005)
<i>Centropristes striata</i>	Black sea bass	M	(Slesinger <i>et al.</i> 2019)
<i>Anguilla anguilla</i>	European eel	M	(Degani <i>et al.</i> 1989)
<i>Micropterus salmoides</i>	Largemouth bass	M	(Glover <i>et al.</i> 2012)
<i>Cyprinodon macularius</i>	Desert pupfish	M	(Heuton <i>et al.</i> 2018)
<i>Micropogonias undulatus</i>	Atlantic croaker	M	(Horodysky <i>et al.</i> 2011)
<i>Leiostomus xanthurus</i>	Spot	M	(Horodysky <i>et al.</i> 2011)
<i>Coreius guichenoti</i>	Largemouth bronze gudgeon	M	(Luo & Wang 2012)
<i>Sprattus sprattus</i>	European sprat	M	(Meskendahl <i>et al.</i> 2010)
<i>Plectropomus leopardus</i>	Leopard coral grouper	M	(Messmer <i>et al.</i> 2017)
<i>Galaxias maculatus</i>	Common galaxias	M	(Milano <i>et al.</i> 2016)
<i>Polyodon spathula</i>	American paddlefish (alt. Mississippi paddlefish)	M	(Patterson <i>et al.</i> 2013)
<i>Argyrosomus japonicus</i>	Mulloway	M	(Pirozzi & Booth 2009)
<i>Lythrypnus dalli</i>	Bluebanded goby	M	(Rangel & Johnson 2018)
<i>Collossoma macropomum</i>	Tambaqui (alt. Cachama)	M	(Tomala <i>et al.</i> 2014)
<i>Carassius auratus grandoculis</i>	Round crucian carp (alt. Nigorobuna)	M	(Yamanaka <i>et al.</i> 2013)

162 **Data overview**

163 **Maximum consumption & metabolic rate**

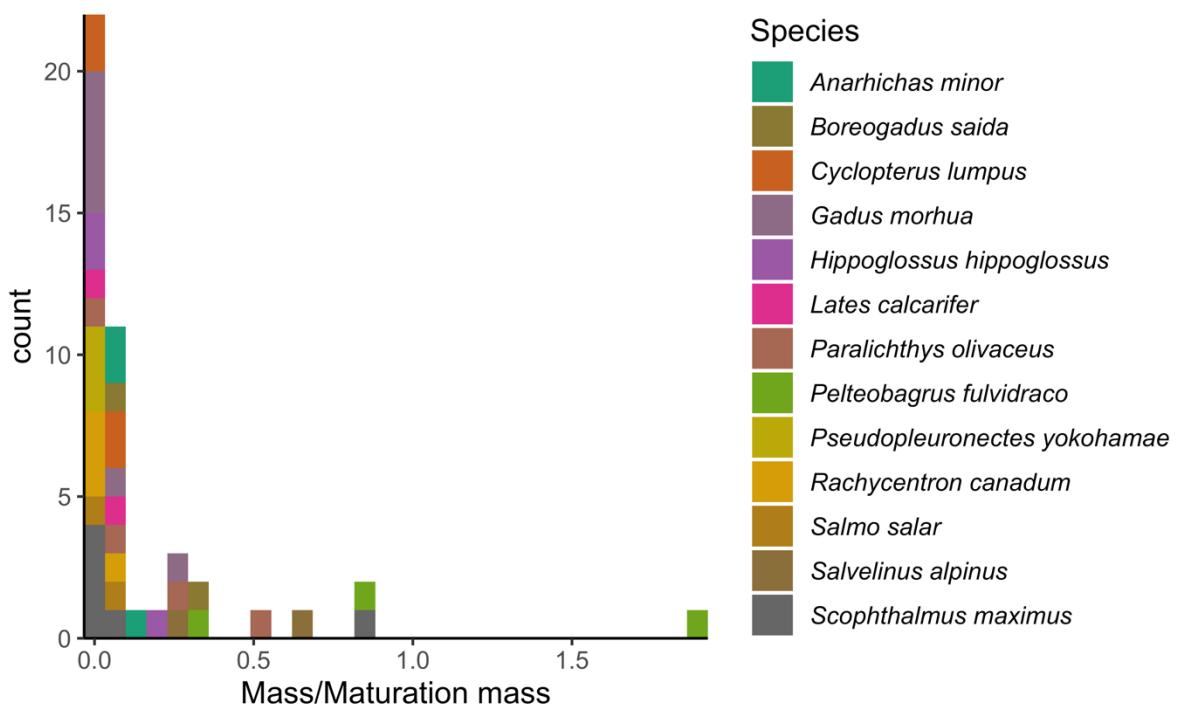


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165 *Fig. S1. Experimental temperatures (gray) and environmental (min, median and max)*  
 166 *temperatures (purple, pink and green, respectively) of species represented in the consumption*  
 167 *(left) and metabolism (right) data sets. Missing temperatures means information was not*  
 168 *available on FishBase. Experimental temperatures are jittered vertically for visibility.*

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173 Fig. S2. The distribution of rescaled masses for individual observations (mass/mass at  
174 maturation), where color indicate species.

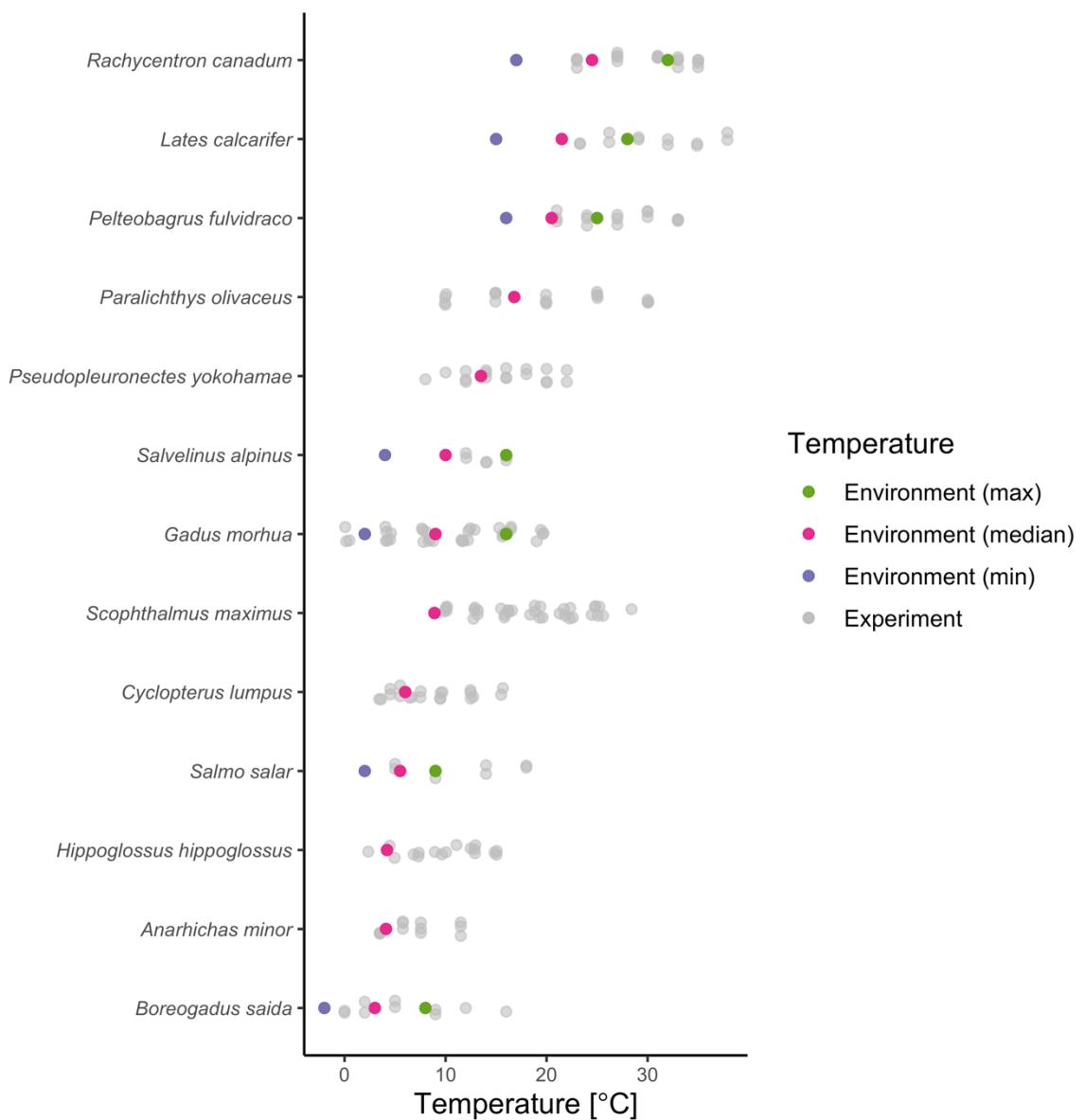
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181 *Fig. S3. Experimental temperatures (gray) in the growth rate data and environmental (min,*  
 182 *median and max) temperatures (purple, pink and green, respectively). Missing temperatures*  
 183 *means information was not available on FishBase. Experimental temperatures are jittered*  
 184 *vertically for visibility.*

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189 **Supplementary methods and analysis**

190 At below peak temperatures, the intraspecific mass- and temperature dependence of specific  
191 growth (% increase in size day<sup>-1</sup>) can be described by the equation:  $\ln(G) = 0.5 -$   
192  $0.36 \times \ln(m) - 0.74 \times t_A + 0.0046 \times t_A \times \ln(m)$  (Fig. S12), based on posterior medians of  
193 the global parameters, thus representing an average (unmeasured) fish (see *SI Appendix* Fig  
194 S15, S19, S23 and S27 for the full posteriors distributions of parameters for all models). The  
195 mass exponent of growth is estimated to be -0.36 [-0.5, -0.23] and the activation energy ( $-\mu_{\beta_2}$ )  
196 of growth 0.74 [0.95, 0.53]. This is similar to the predicted mass scaling of net energy at sub-  
197 optimum temperatures, defined as the difference between consumption and metabolism (Fig.  
198 3; see also methods on '*Net energy gain*'), which scales with a mass-specific exponent of -0.39.  
199 The estimated temperature-mass interaction coefficient is both small and uncertain (0.0046 [-  
200 0.064, 0.075]), where Bayesian 95% credible intervals are indicated in square brackets.

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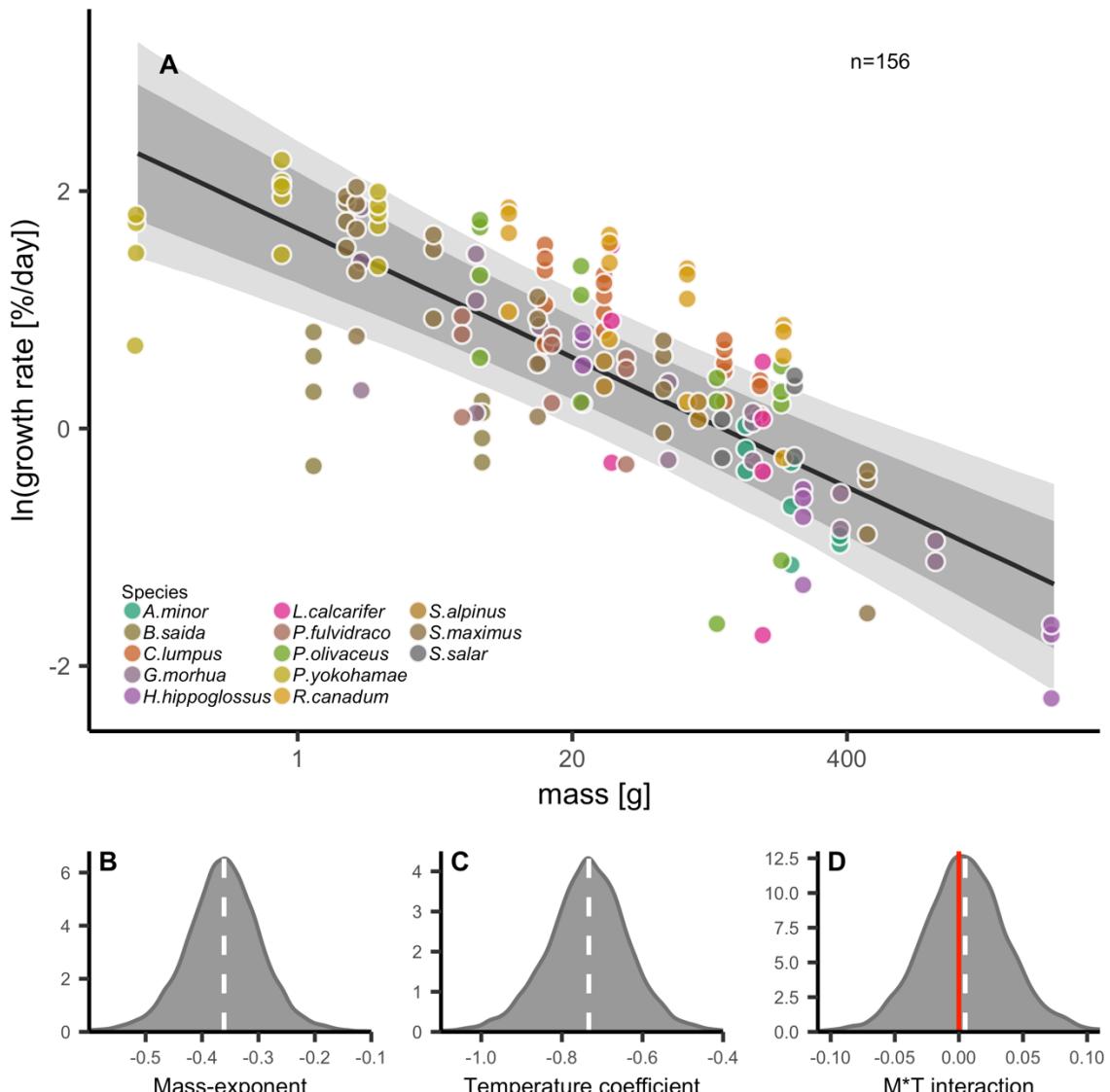
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215 *Fig. S4. Effects of temperature and body mass on body growth below optimum temperature.*

216 *Panel A) shows the natural log of specific growth rate as a function of body mass on a*

217 *logarithmic x-axis (for readability, note the model is fitted with  $\ln(\text{mass})$  as a predictor), such*

218 *that the slope corresponds to the mass-scaling exponent. Colors indicate species. The line in*

219 *panel A is the global prediction from model M1 at the mean temperature in the growth data*

220 *(14°C, but note the model is fitted using Arrhenius temperature). Shaded areas correspond to*

221 *80% and 95% credible intervals. Point colors indicate species. The bottom row shows the*

222 *posterior distributions for (B) the global mass-scaling exponent,  $\mu_{\beta_1}$ , (C) the global*

223 temperature coefficient,  $\mu_{\beta_2}$  and (D) the global mass-temperature interaction,  $\mu_{\beta_3}$ . Dashed  
 224 white line shows the posterior median and red vertical line in (D) indicates zero.

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226 **Table S3** Description of model parameters (type and their interpretation in brackets) and their  
 227 prior distributions (see ‘*Model description*’ and equations 1-3 in the main text).  $N$  refers to a  
 228 normal distribution (mean and standard deviation, s.d.) and  $U$  to a uniform distribution  
 229 (interval). For simplicity, only the parameters of the full model are shown here (i.e., with most  
 230 coefficients varying by species), but note that when a model is fitted with a common rather  
 231 than species-varying coefficient, for example  $\beta_1$  instead of  $\beta_{1j} \sim N(\mu_{\beta_1}, \sigma_{\beta_1})$ , we use the same  
 232 prior for  $\beta_1$  as for  $\mu_{\beta_1}$ .

Model	Parameter	Description	Prior distribution
<b>Log-linear regressions for growth, consumption and metabolism</b>	$\mu_{\beta_{0s}}$	Hyperparameter (average intercept for standard metabolic rate across species). <i>Only for metabolism model.</i>	$N(-2, 5)$
	$\mu_{\beta_{0r}}$	Hyperparameter (average intercept for routine and resting metabolic rate across species). <i>Only for metabolism model.</i>	$N(-1, 5)$
	$\mu_{\beta_0}$	Hyperparameter (average intercept across species). <i>Only for consumption and growth models.</i>	$N(0, 5)$
	$\mu_{\beta_1}$	Hyperparameter (average mass coefficient across species). <u>Note for growth we use <math>N(-0.25, 1)</math> as it is in unit % day<sup>-1</sup></u>	$N(0.75, 1)$
	$\mu_{\beta_2}$	Hyperparameter (average temperature coefficient across species)	$N(-0.6, 1)$
	$\mu_{\beta_3}$	Hyperparameter (average interaction coefficient across species)	$N(0, 1)$
	$\sigma_{\beta_{0s}}$	Hyperparameter (s.d. of species-intercepts for standard metabolic rate)	$U(0, 10)$
	$\sigma_{\beta_{0r}}$	Hyperparameter (s.d. of species-intercepts for routine and resting metabolic rate)	$U(0, 10)$

	$\sigma_{\beta_1}$	Hyperparameter (s.d. of species mass coefficients)	$U(0, 10)$
	$\sigma_{\beta_2}$	Hyperparameter (s.d. of species temperature coefficients)	$U(0, 10)$
	$\sigma_{\beta_3}$	Hyperparameter (s.d. of species interaction coefficients)	$U(0, 10)$
	$\sigma$	Parameter (s.d.)	$U(0, 10)$
<b>Sharpe-Schoolfield (unimodal consumption data)</b>	$\mu_{C_{0j}}$	Hyperparameter (average consumption at reference temperature [-10 on centered scale] across species)	$N(1, 1)$
	$\mu_{E_j}$	Hyperparameter (average activation energy across species)	$N(0.5, 0.5)$
	$E_h$	Parameter (common rate of decline with temperature)	$N(2, 2)$
	$T_h$	Parameter (common temperature at which half the rate is reduced due to high temperatures)	$N(5, 2)$
	$\sigma_{E_j}$	Hyperparameter (s.d. of species-varying activation energies)	$U(0, 3)$
	$\sigma_{C_{0j}}$	Hyperparameter (s.d. of species-varying average consumption)	$U(0, 3)$
	$\sigma$	Parameter (s.d.)	$U(0, 3)$
<b>Linear <math>T_{opt}</math> models</b>	$\mu_{\beta_0}$	Hyperparameter (average intercept across species)	$N(0, 5)$
	$\mu_{\beta_1}$	Hyperparameter (average mass coefficient across species)	$N(0, 5)$
	$\sigma_{\beta_0}$	Hyperparameter (s.d. of species-intercepts)	$U(0, 10)$
	$\sigma_{\beta_1}$	Hyperparameter (s.d. of species mass coefficients)	$U(0, 10)$
	$\sigma$	Parameter (s.d.)	$U(0, 10)$

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245 **Table S4.** Model comparison for the log-linear regressions of how consumption, metabolism  
 246 and growth depend on mass and temperature below optimum temperatures (see ‘*Model*  
 247 *description*’ and equations 1-3 in the main text). The column m\*t indicates whether the model  
 248 for the rate includes an interactive effect of mass and temperature. The models differ in which  
 249 coefficients vary among species and which are common, where  $\beta_0$  is the intercept,  $\beta_1$  mass  
 250 coefficient (mass-exponent on linear scale),  $\beta_2$  temperature coefficient (corresponding to the  
 251 negative activation energy) and  $\beta_3$  interaction between mass and temperature. The WAIC  
 252 columns shows  $\Delta\text{WAIC}$  and absolute WAIC in brackets, rounded to the nearest decimal, where  
 253  $\Delta\text{WAIC}$  is the difference between each models’ WAIC and the lowest WAIC across models.  
 254 Bold indicates models with  $\Delta\text{WAIC} < 2$ .

Model	m*t	Species-varying parameter(s)	WAIC metabolism	WAIC consumption	WAIC growth
M1	Yes	$\beta_0, \beta_1, \beta_2, \beta_3$	<b>0 (274.6)</b>	3.1 (563.7)	<b>0 (47.2)</b>
M2		$\beta_0, \beta_1, \beta_2$	<b>0.3 (274.9)</b>	2 (562.6)	7.2 (54.4)
M3a		$\beta_0, \beta_1$	305.7 (580.3)	147.1 (707.7)	23.4 (70.6)
M3b		$\beta_0, \beta_2$	385.3 (659.9)	70.5 (631.1)	32.6 (79.8)
M4		$\beta_0$	648.6 (923.2)	190 (750.6)	43.5 (90.7)
M5	No	$\beta_0, \beta_1, \beta_2$	6.1 (280.6)	<b>0 (560.6)</b>	5.5 (52.7)
M6a		$\beta_0, \beta_1$	348.2 (622.8)	165.8 (726.4)	22.1 (69.3)
M6b		$\beta_0, \beta_2$	386.6 (661.2)	73.4 (634)	34.3 (81.5)
M7		$\beta_0$	681.5 (956.1)	213 (773.6)	44.9 (92.1)

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261 **Table S5.** Comparison of the two models fitted to optimum growth temperature data. The  
262 WAIC columns shows  $\Delta$ WAIC and absolute WAIC in brackets, rounded to the nearest decimal,  
263 where  $\Delta$ WAIC is the difference between each models' WAIC and the lowest WAIC across  
264 models. Bold indicates models with  $\Delta$ WAIC < 2.

Model	Species-varying parameter(s)	WAIC
<b>M1</b>	$\beta_0, \beta_1$	<b>0 (177.3)</b>
<b>M2</b>	$\beta_0$	<b>1 (178.3)</b>

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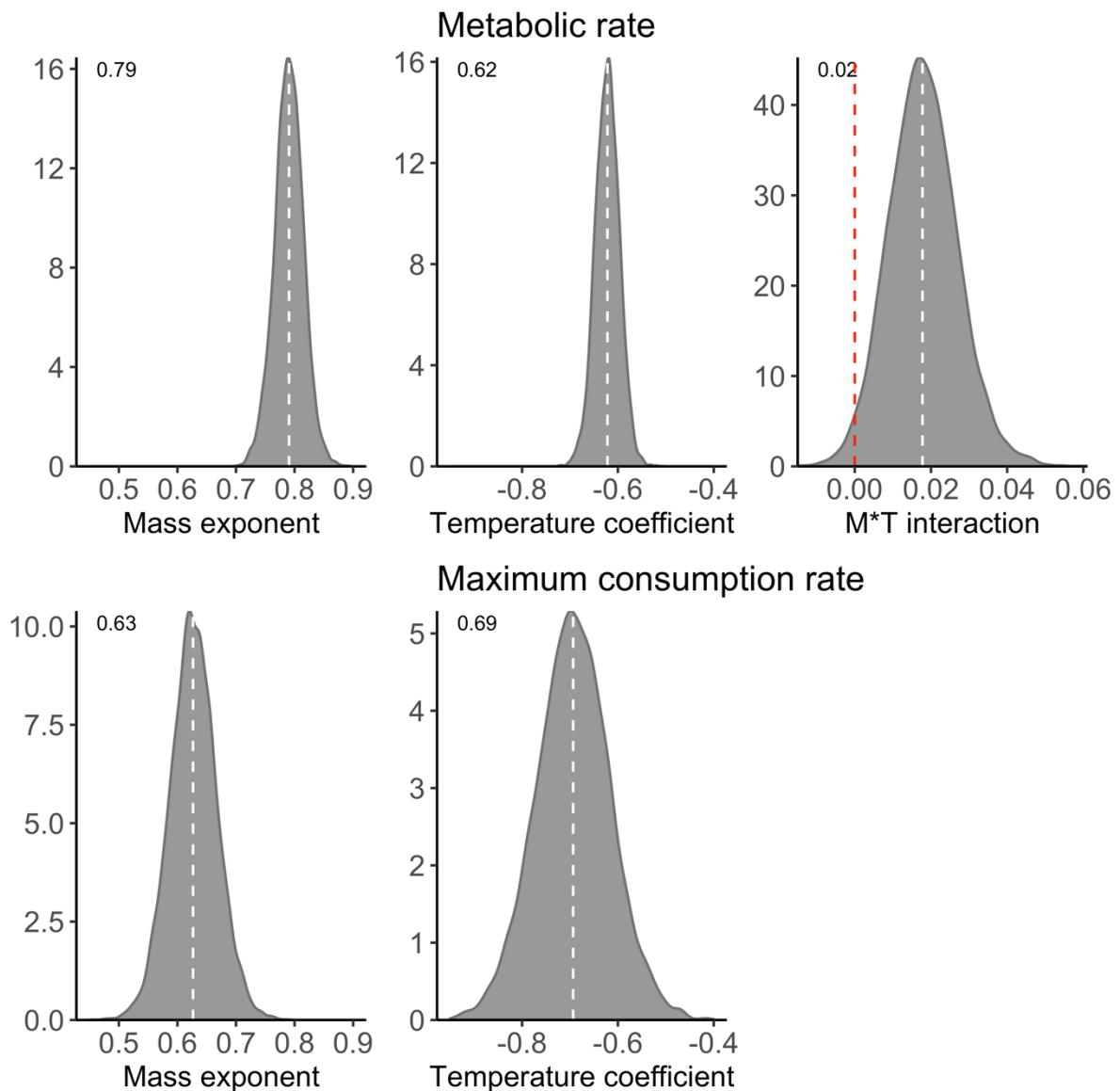
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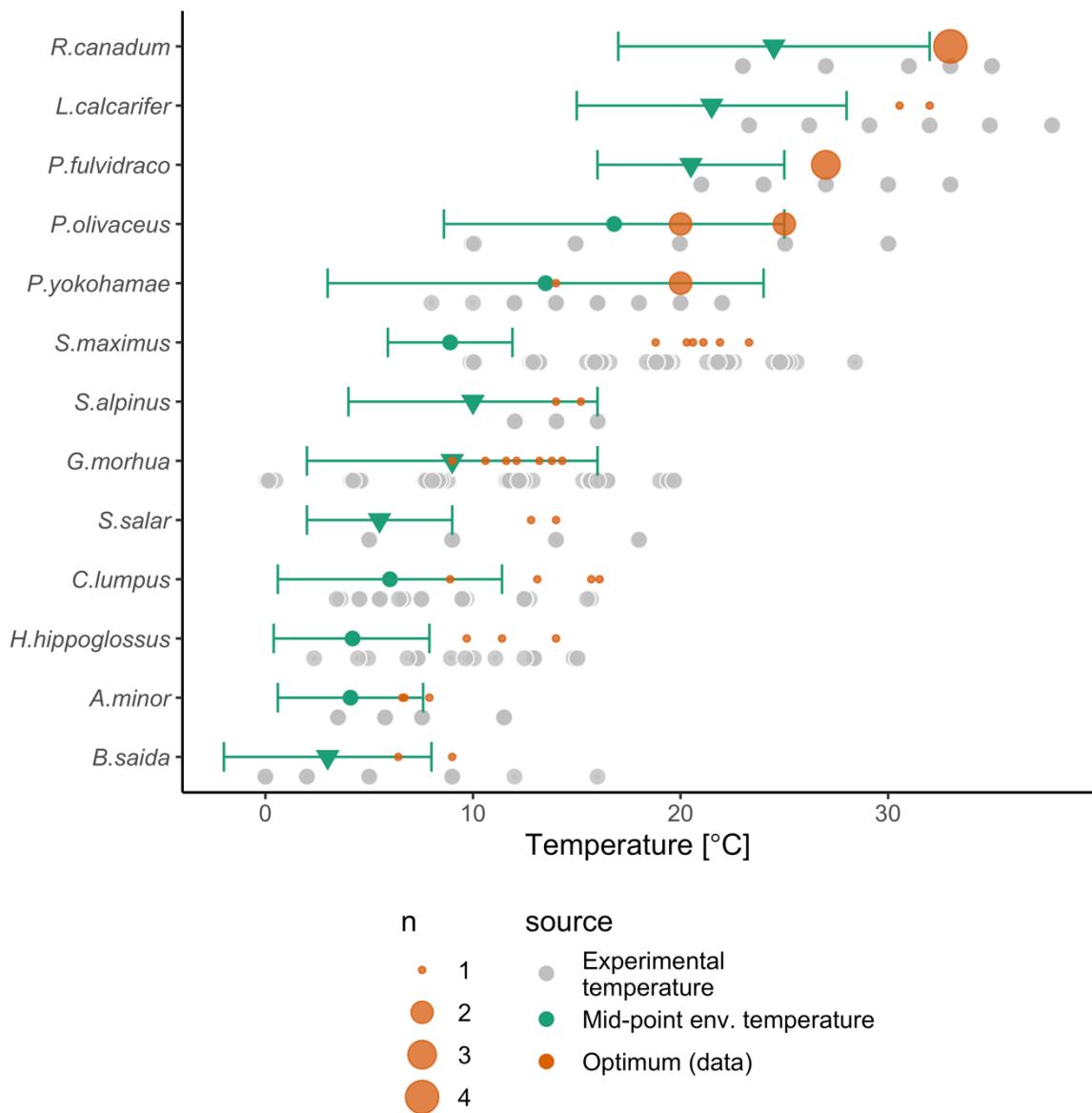
284

285 *Fig. S5. Posterior distributions of the global intraspecific mass exponents ( $\mu_{\beta_1}$ ) and*  
286 *temperature coefficients ( $\mu_{\beta_2}$ ) for metabolic rate (top) and maximum consumption rate*  
287 *(bottom). For metabolism, the global interaction coefficient ( $\mu_{\beta_3}$ ) is also shown (estimated and*  
288 *presented on an Arrhenius temperature scale), but for consumption this term was not included*

289 in the selected model. Numbers in the top left corner correspond to the posterior median. The  
290 axes are the same for each parameter for comparison between the two rates.

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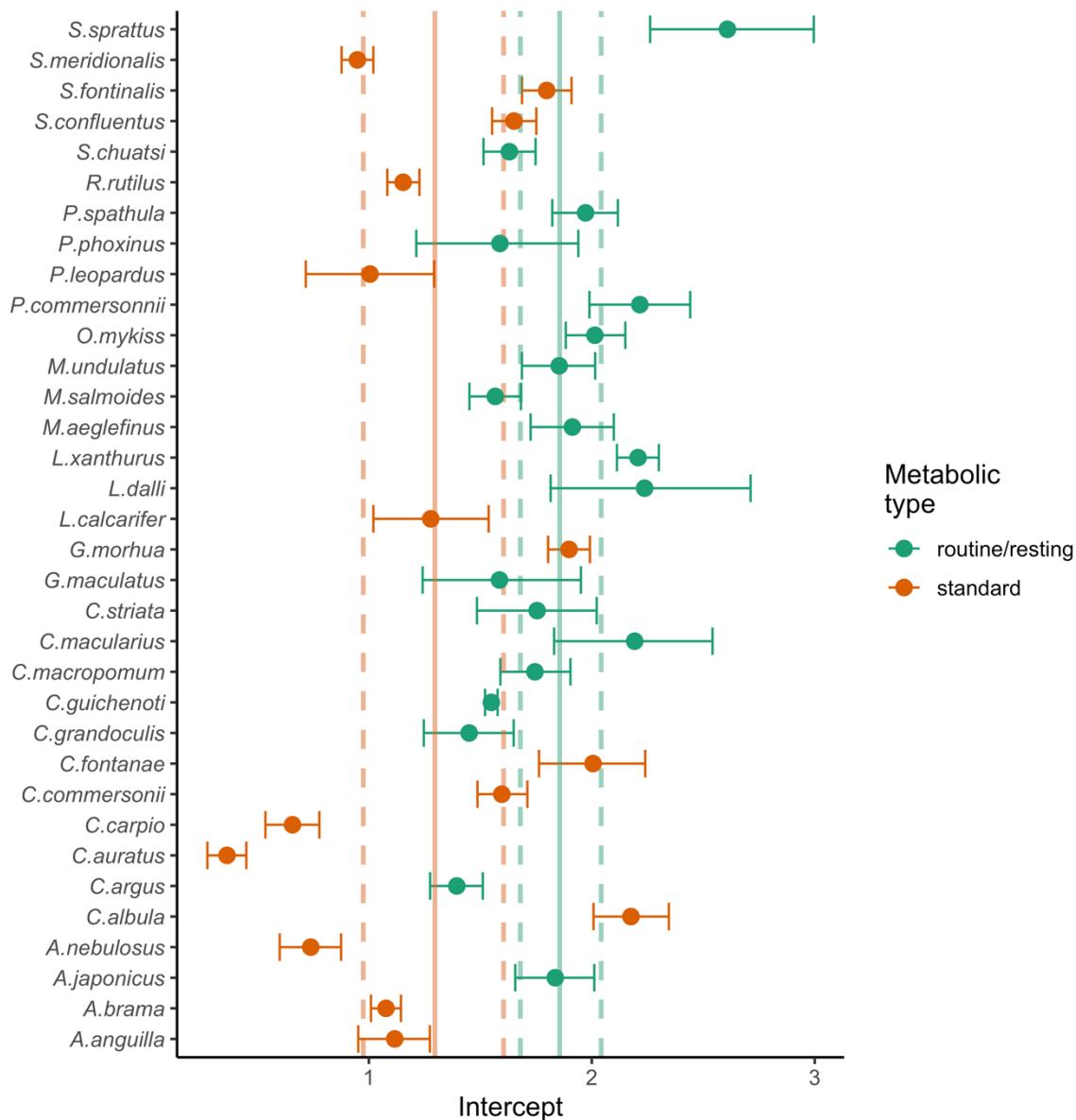


293

294 Fig. S6. Experimental temperatures (grey) overlap environmental temperatures (green), and  
295 optimum growth temperatures (orange) are typically at the upper end or above the  
296 environmental range. Horizontal green lines show the minimum and maximum environmental  
297 temperature based on either temperature in distribution range (triangles) or modelled

298 distribution maps (circles), both taken from FishBase. The optimum growth temperatures are  
299 depicted for all size-classes per species, where the circle size is proportional to number of  
300 observations at that temperature.

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302  
303 Fig. S7. Posterior median of species-level intercepts (points) and their 95% credible interval  
304 (horizontal error bars). Colors indicate the type of metabolism measurement for each species.  
305 Vertical solid lines are the posterior medians of the global intercepts (orange for standard

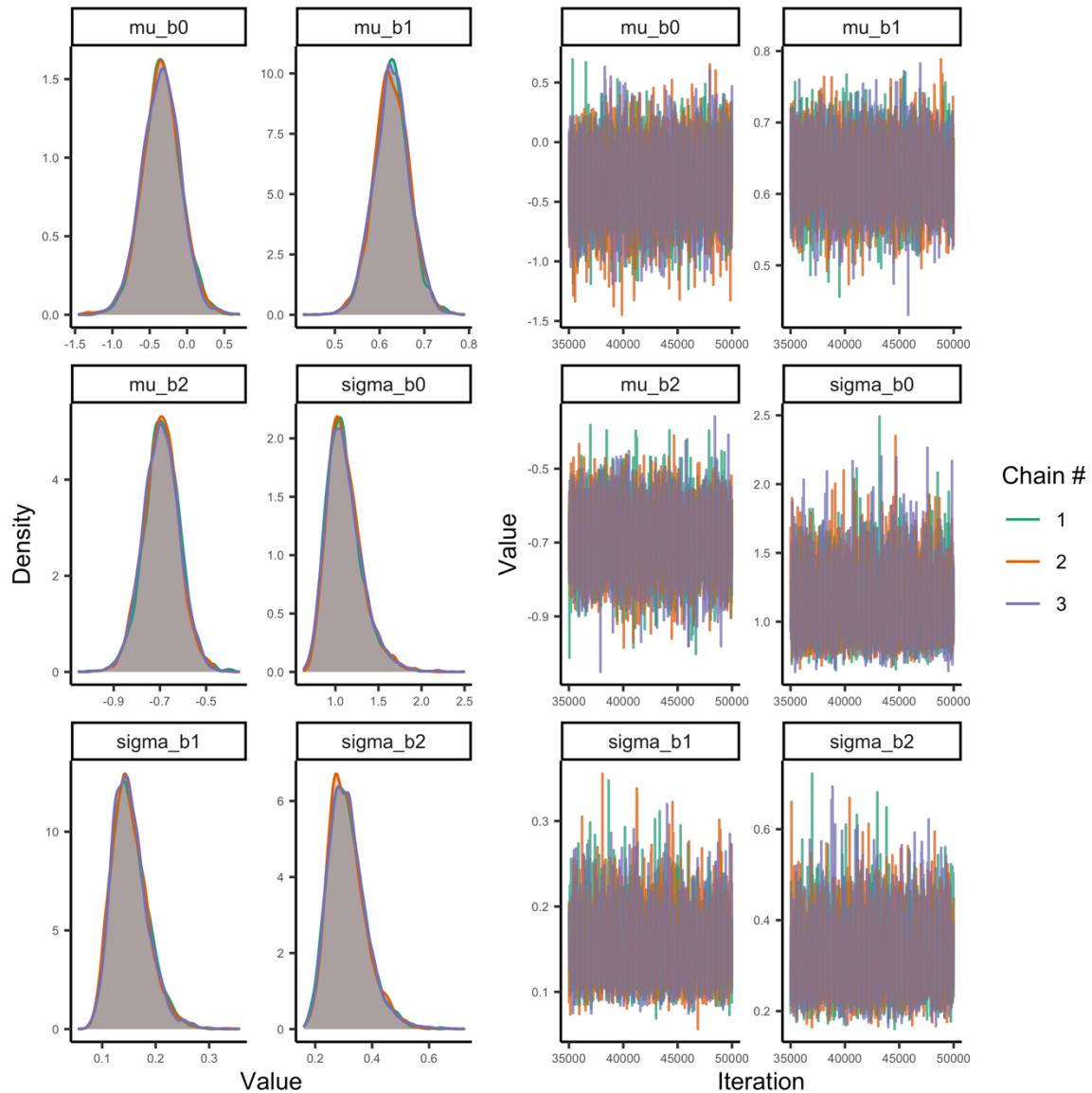
306 metabolic rate,  $\mu_{\beta_0s}$ , and green for routine or resting metabolic rate,  $\mu_{\beta_0r}$ ), and the dashed  
307 vertical lines show the 95% credible intervals for the global parameters.

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## 309 Model validation and fit

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

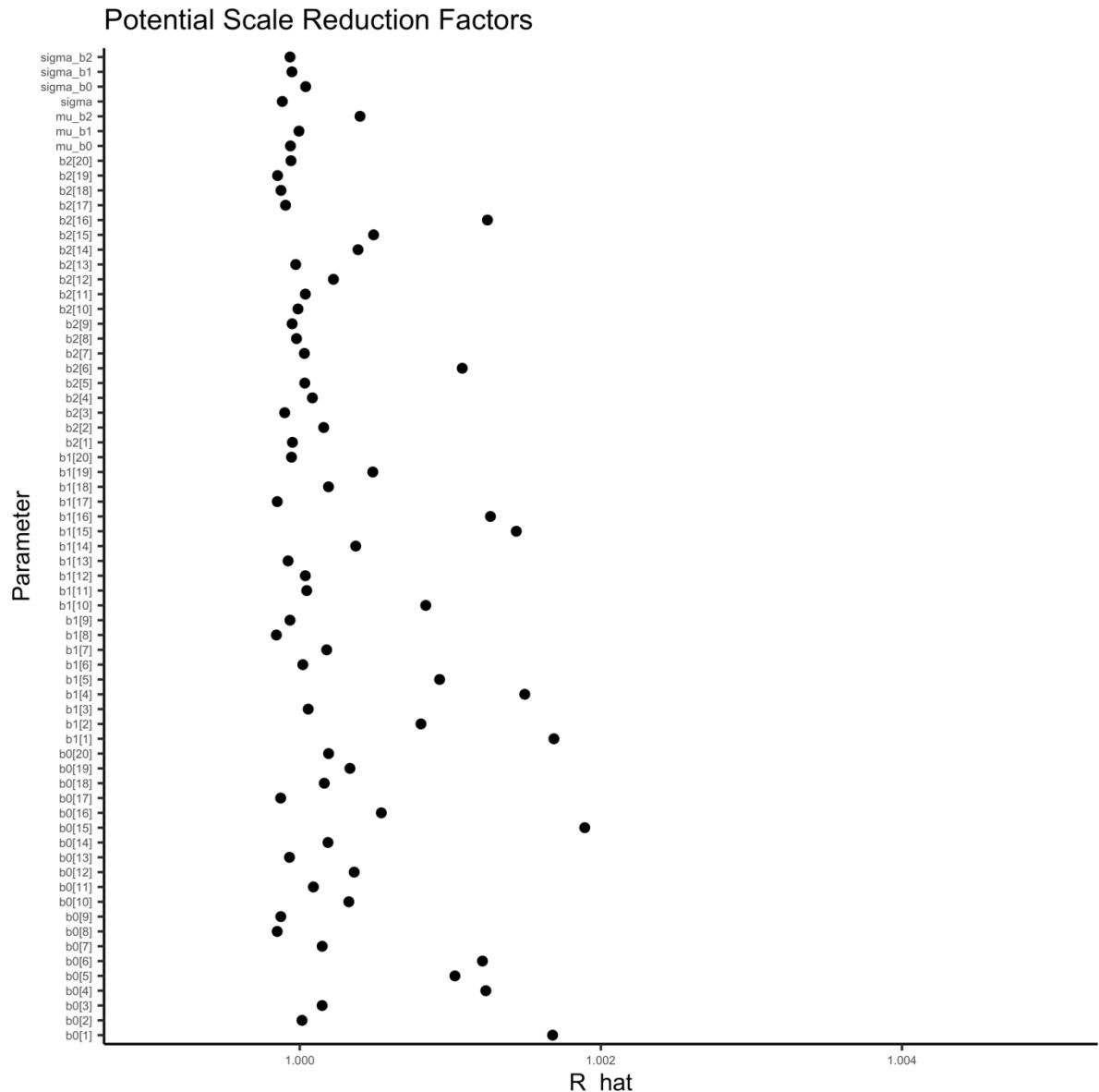
312 **Maximum consumption rate – below peak temperatures**



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314 Fig. S8. Posterior densities and trace plots for evaluation of chain convergence (by chain,  
315 indicated by color), for the global-level parameters for the log-linear maximum consumption  
316 rate model at temperatures below peak temperatures.

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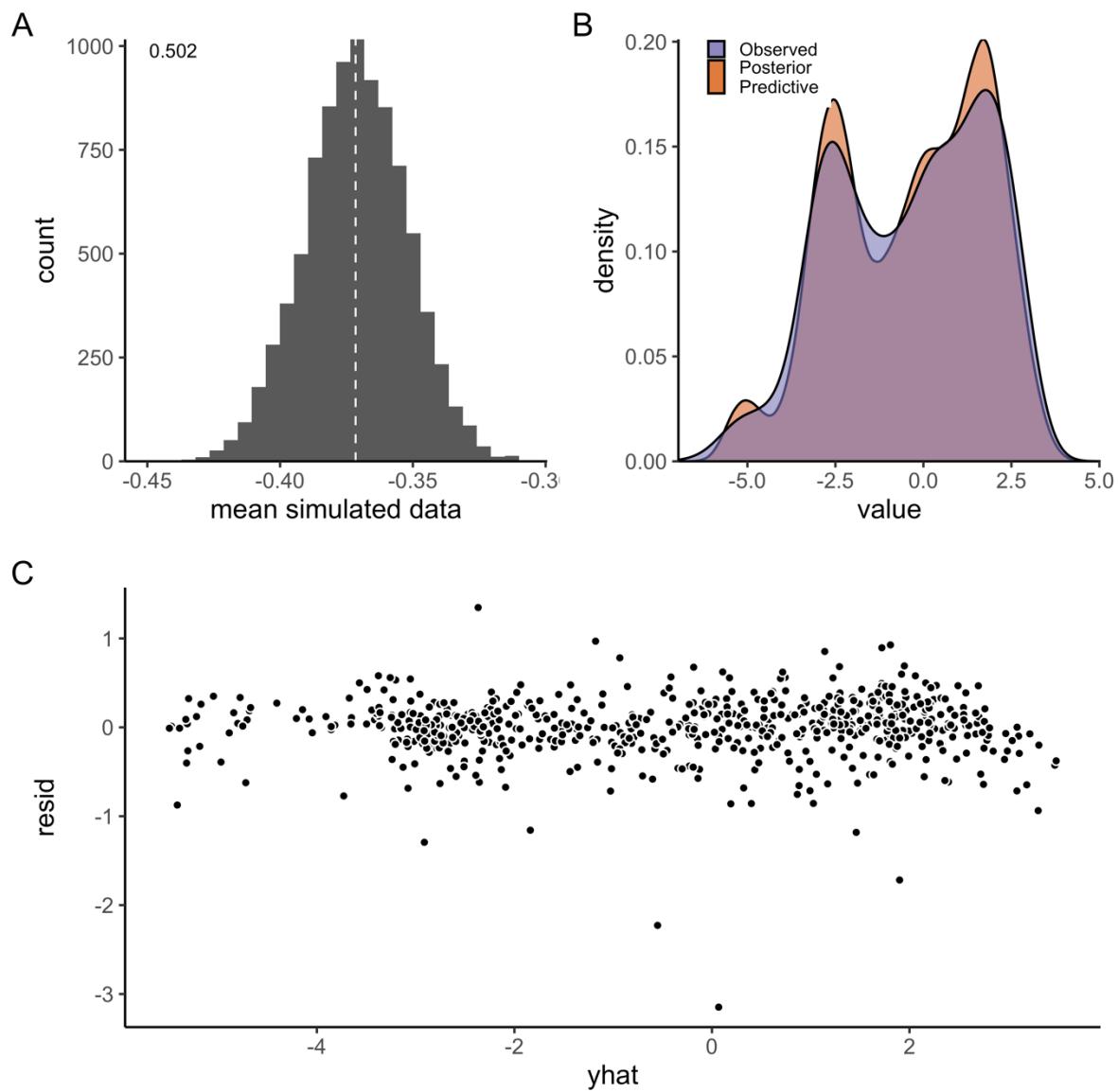
319 Fig. S9. Potential scale reduction factor ( $\hat{R}$ ) for the log-linear maximum consumption rate  
320 model. This factor is based on the comparison of between and within-chain variation for the  
321 same parameter. A value close to one implies chains converged to the same distribution. The

322 index of the parameter corresponds to species. The index of the parameter corresponds to  
323 species in alphabetical order.

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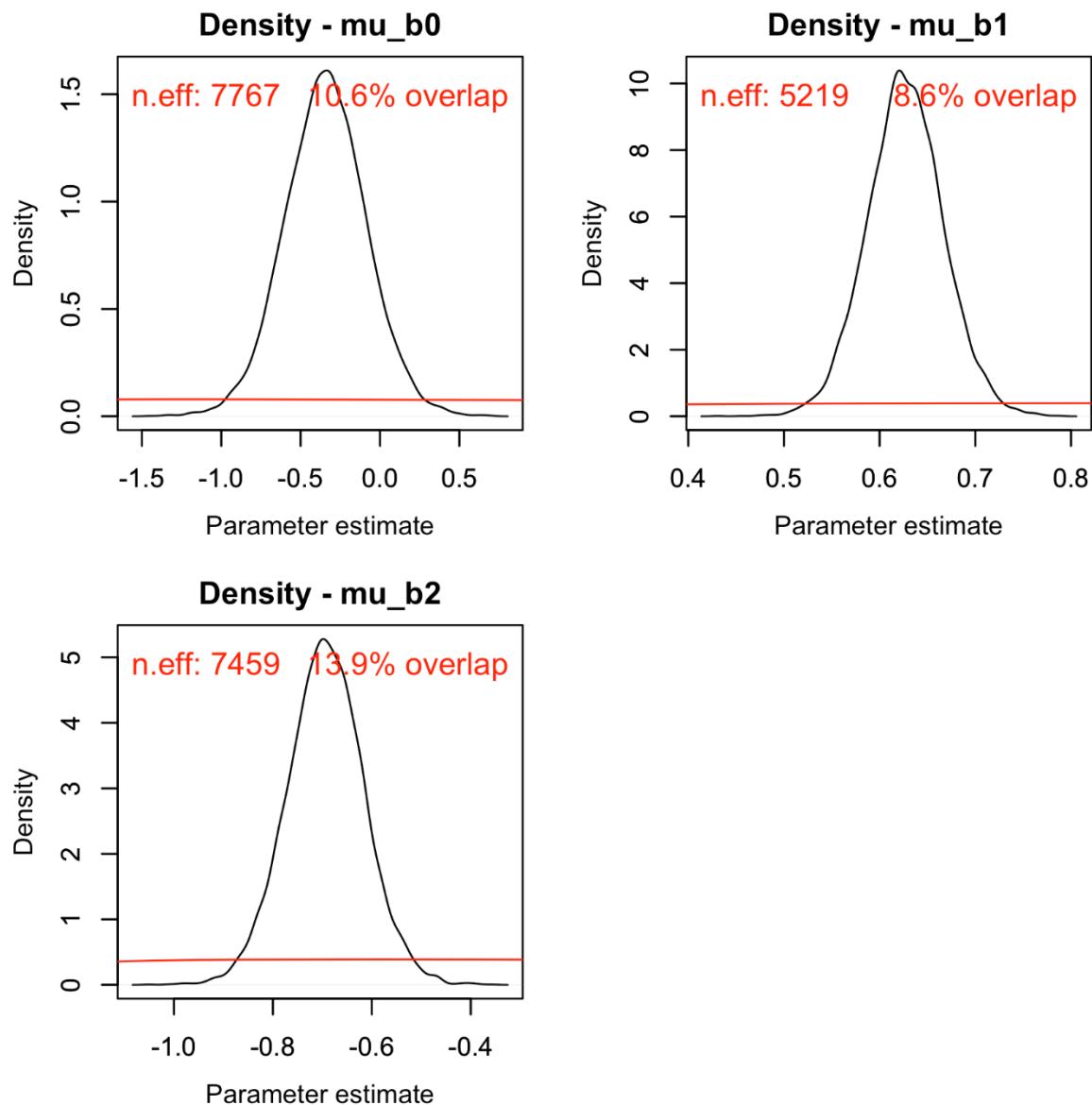
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328 Fig. S10. A) Model fit (mean) for the log-linear model of maximum consumption rate at  
329 temperatures below temperature peak (by species). Fit is evaluated by simulating data from  
330 the likelihood (at each iteration of the MCMC chain), to compare how well it matches the

331 original data. Each simulated data point is assigned a 0 or 1 if it is below or above the mean  
 332 data point (the vertical line corresponds to the mean in data). The number in the plot  
 333 corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive distribution  
 334 (orange) and distribution of data (purple). C) Difference between the observed value and the  
 335 posterior median of the predicted value, plotted against fitted value.



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 337 Fig. S11. Posterior (black) and prior distribution (red) for the global parameters in the log-  
 338 linear model for maximum consumption rate, including their % overlap and effective sample  
 339 size (n.eff).

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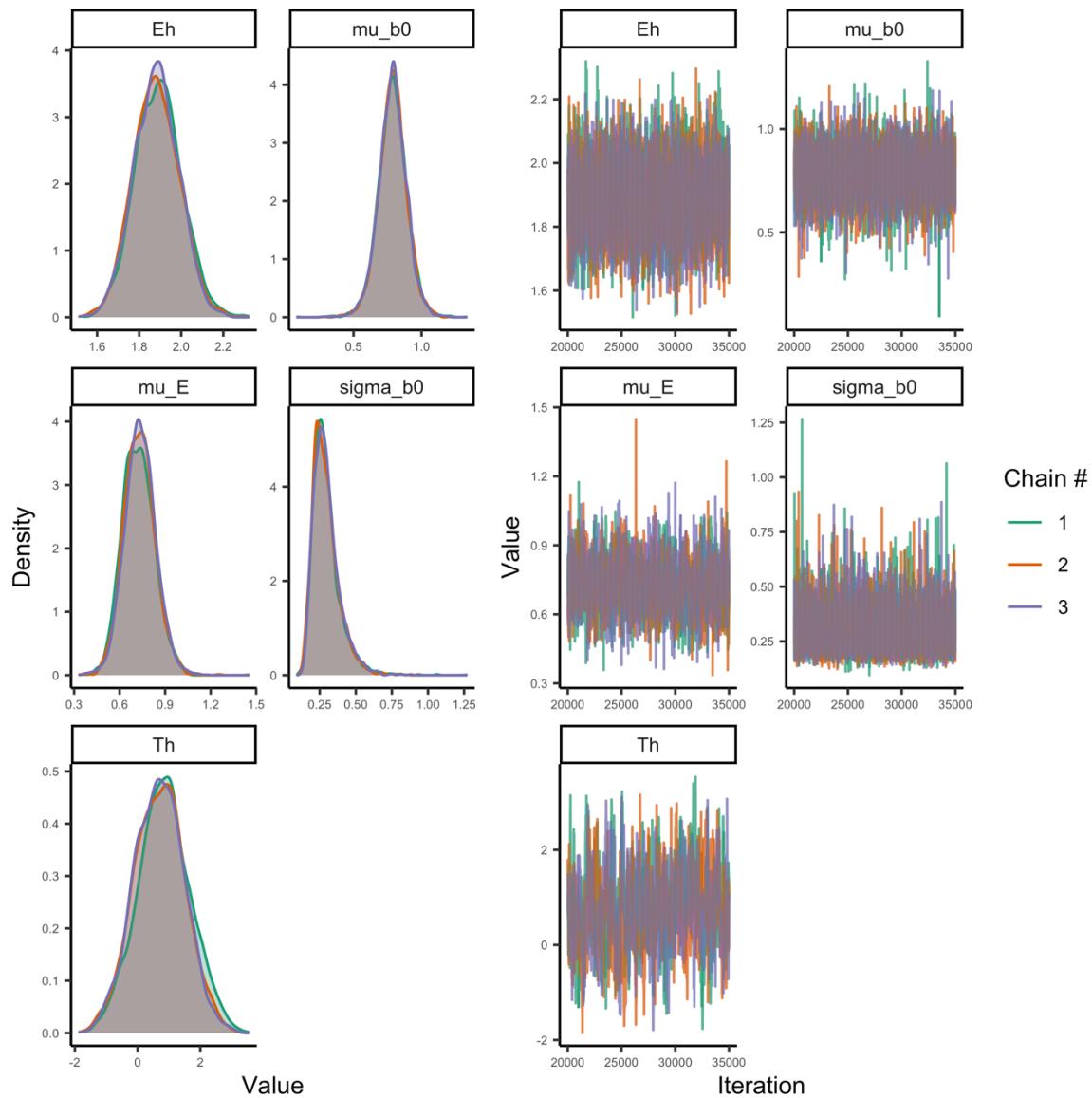
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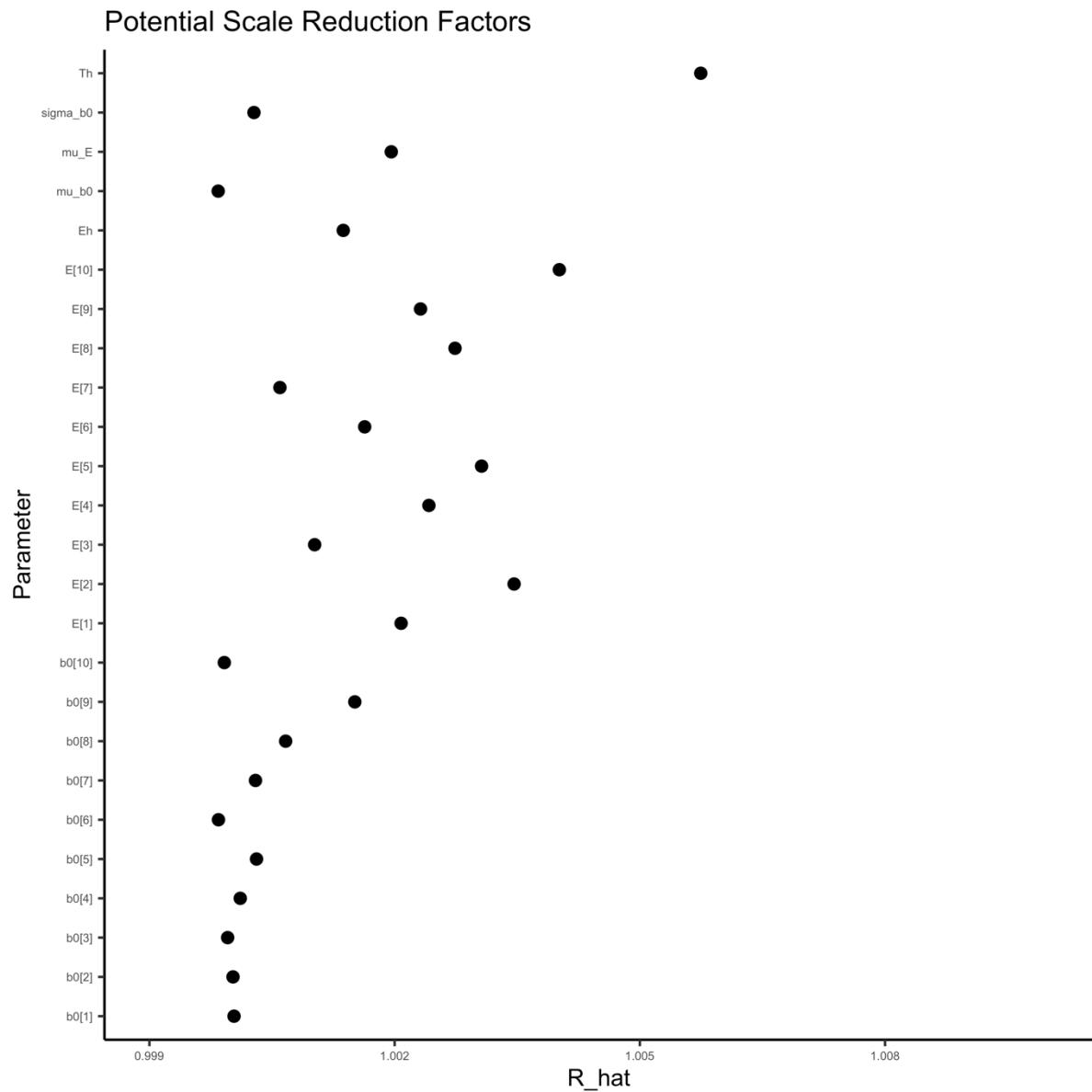
345 **Maximum consumption rate – including beyond peak temperatures**



346

347 *Fig. S12. Posterior densities and trace plots for evaluation of chain convergence (by chain,  
348 indicated by color), for the global-level parameters for the Sharpe-Schoolfield model fitted to  
349 maximum consumption rate data with temperatures including beyond peak temperatures.*

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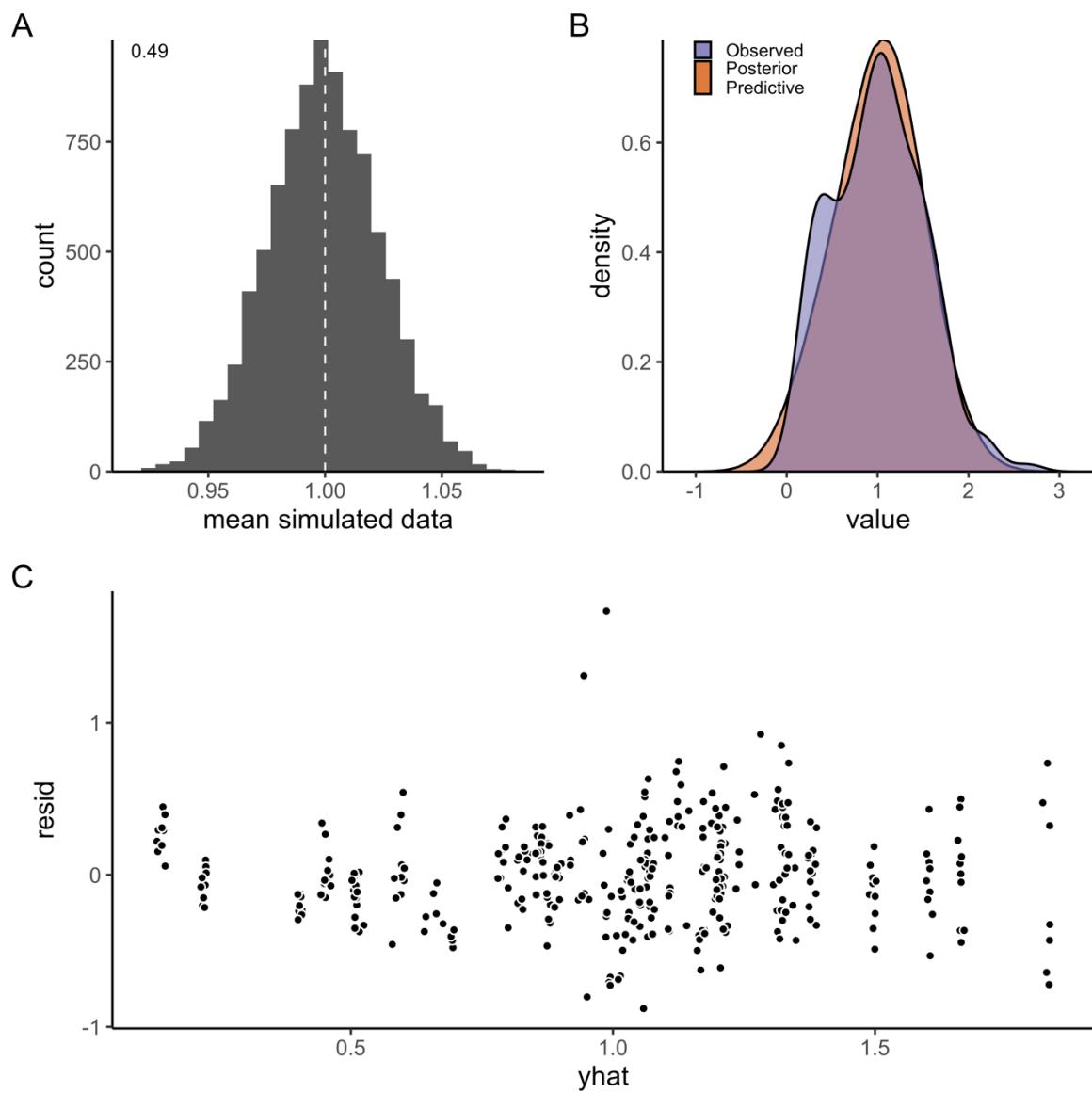
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356     Fig. S13. Potential scale reduction factor ( $\hat{R}$ ) for the Sharpe-Schoolfield model fitted to  
357     maximum consumption rate data (including data beyond peak). This factor is based on the  
358     comparison of between and within-chain variation for the same parameter. A value close to

359 one implies chains converged to the same distribution. The index of the parameter corresponds  
360 to species in alphabetical order.

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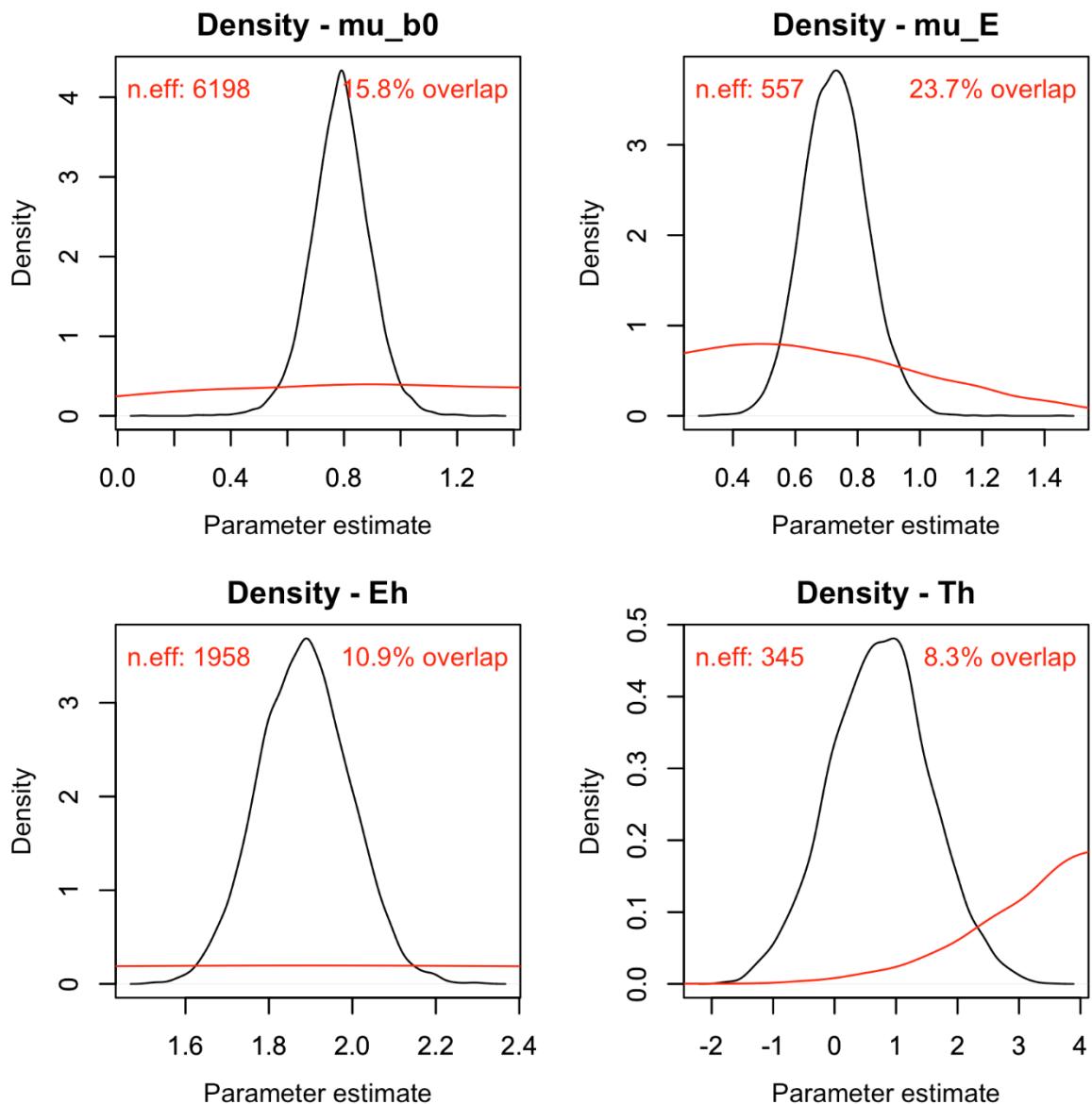
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365 Fig. S14. A) Model fit (mean) for the Sharpe-Schoolfield model fitted to maximum consumption  
366 rate data including temperatures beyond peak (by species). Fit is evaluated by simulating data  
367 from the likelihood (at each iteration of the MCMC chain), to compare how well it matches the

368 original data. Each simulated data point is assigned a 0 or 1 if it is below or above the mean  
 369 data point (the vertical line corresponds to the mean in data). The number in the plot  
 370 corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive distribution  
 371 (orange) and distribution of data (purple). C) Difference between the observed value and the  
 372 posterior median of the predicted value, plotted against fitted value.



373  
 374 Fig. S15. Posterior (black) and prior distribution (red) for the global parameters in the Sharpe-  
 375 Schoolfield model for maximum consumption rate including data beyond peak, including their  
 376 % overlap (rounded) and effective sample size (n.eff).

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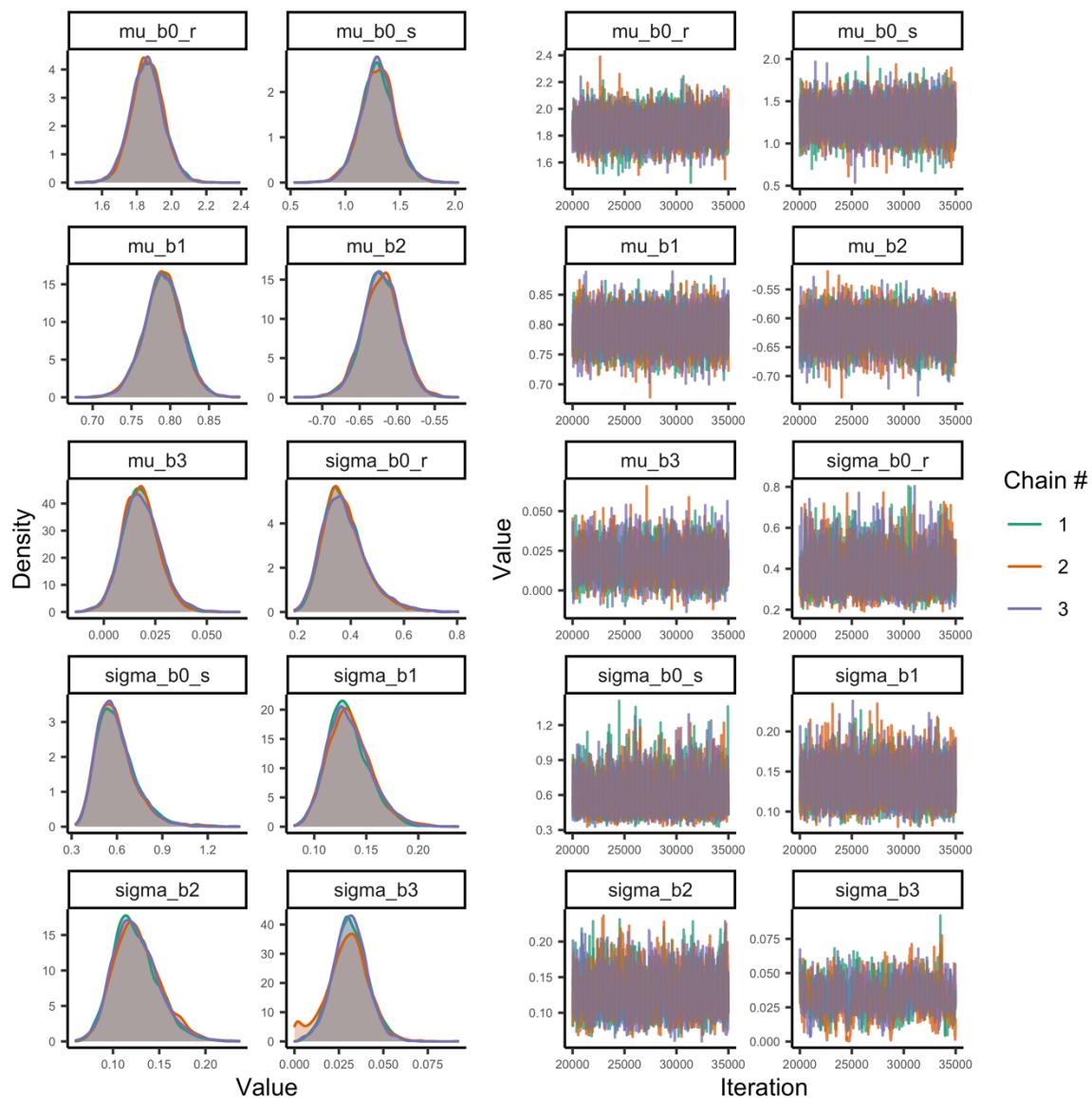
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382 **Metabolic rate**



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384 *Fig. S16. Posterior densities and trace plots for evaluation of chain convergence (by chain,  
385 indicated by color), for the global-level parameters for the metabolic rate model at  
386 temperatures below peak temperatures.*

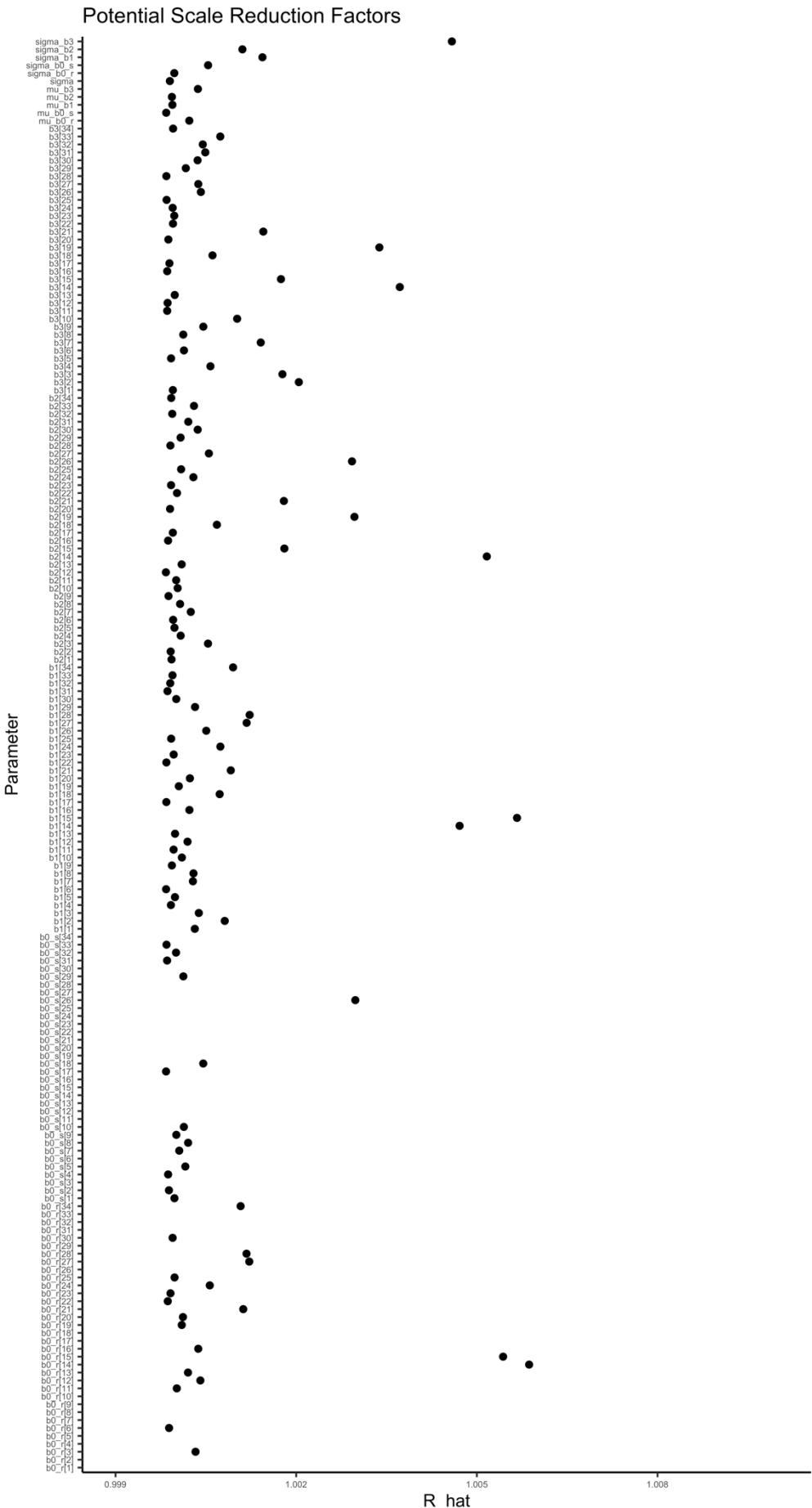
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393 Fig. S17. Potential scale reduction factor ( $\hat{R}$ ) for the metabolic rate model. This factor is based  
394 on the comparison of between and within-chain variation for the same parameter. A value close  
395 to one implies chains converged to the same distribution. The index of the parameter  
396 corresponds to species in alphabetical order. Note that species with routine metabolism do not  
397 have estimates for a standard metabolic rate intercept and vice versa, hence, not all parameters  
398 in the graph have  $\hat{R}$  values.

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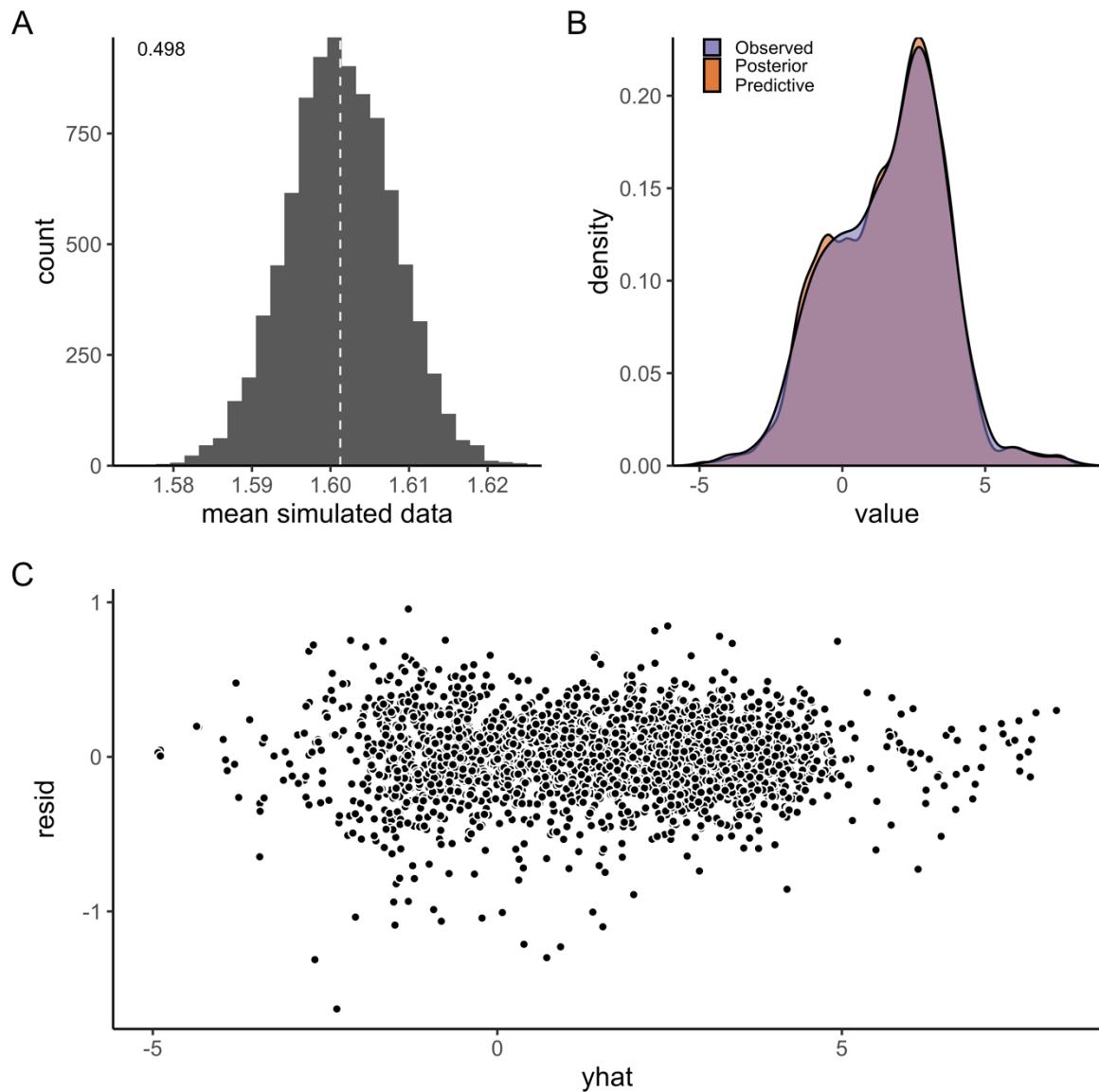
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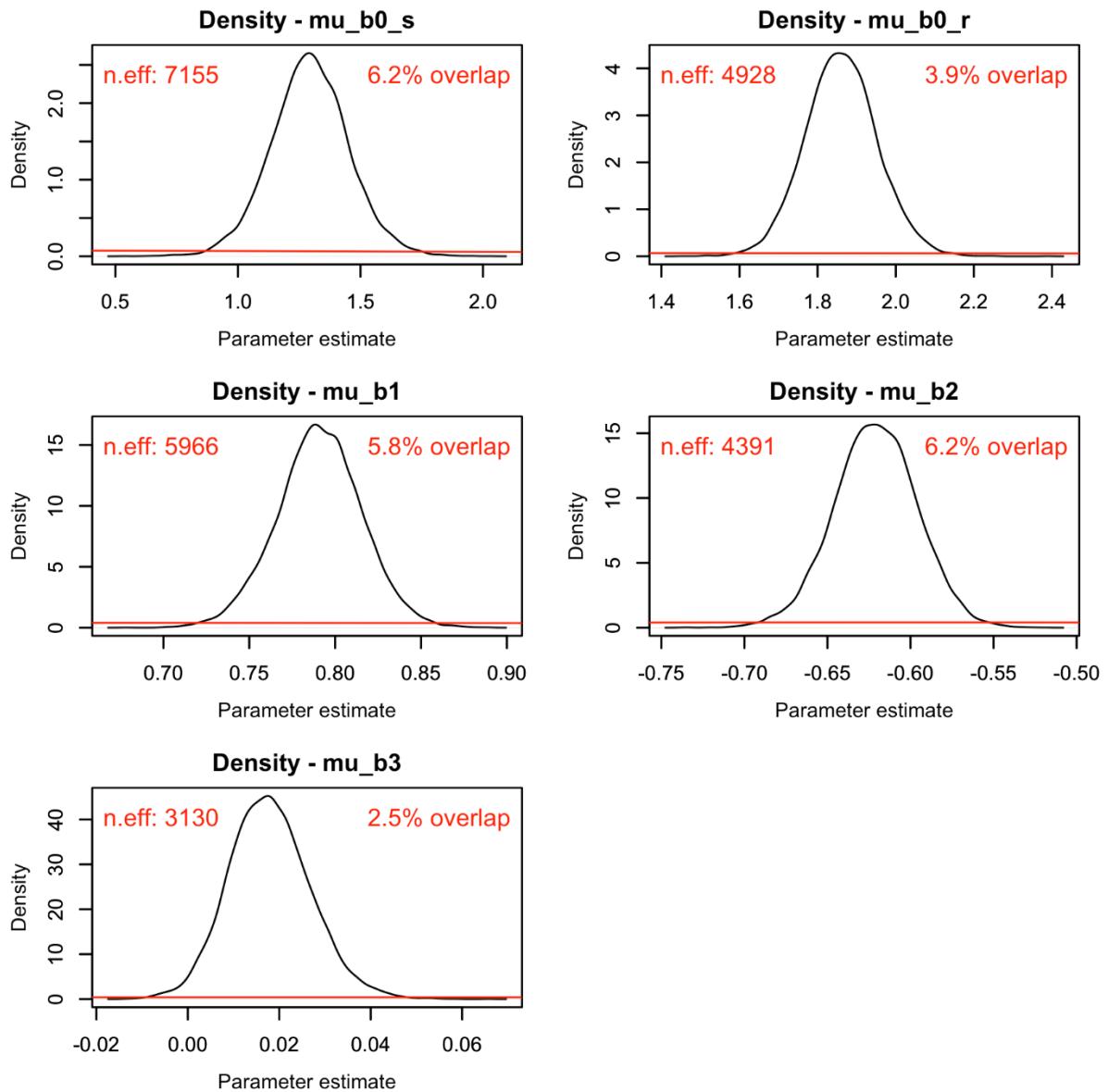
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418

419 *Fig. S18. A) Model fit (mean) for the log-linear model of metabolic rate. Fit is evaluated by*  
 420 *simulating data from the likelihood (at each iteration of the MCMC chain), to compare how*  
 421 *well it matches the original data. Each simulated data point is assigned a 0 or 1 if it is below*  
 422 *or above the mean data point (the vertical line corresponds to the mean in data). The number*  
 423 *in the plot corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive*  
 424 *distribution (orange) and distribution of data (purple). C) Difference between the observed*  
 425 *value and the posterior median of the predicted value, plotted against fitted value.*

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428 *Fig. S19. Posterior (black) and prior distribution (red) for the global parameters in the model*  
 429 *for metabolic rate, including their % overlap and effective sample size (n.eff).*

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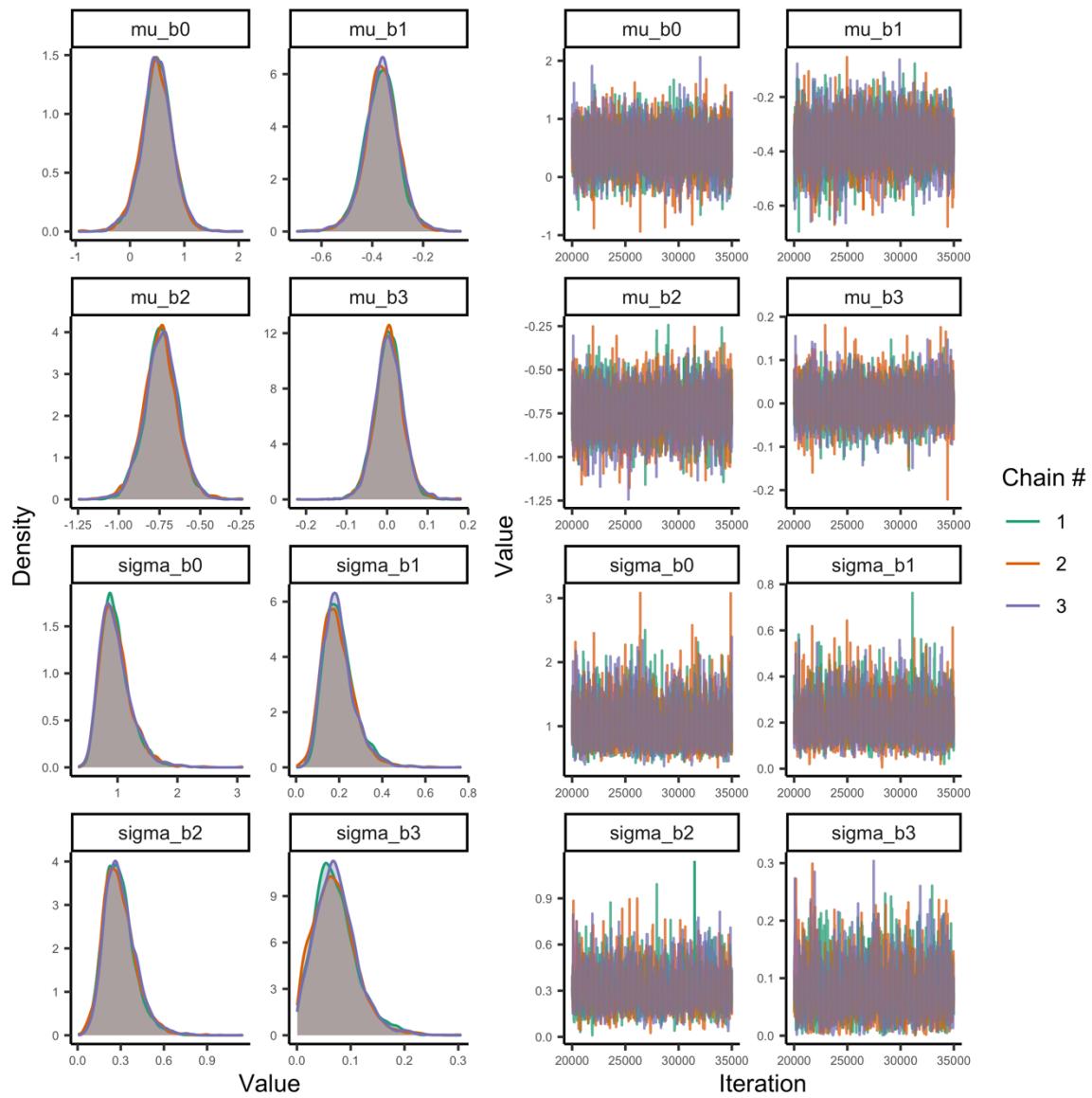
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436 **Growth rate**

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438 *Fig. S20. Posterior densities and trace plots for evaluation of chain convergence (by chain,  
439 indicated by color), for the global-level parameters for the growth rate model at temperatures  
440 below optimum temperatures.*

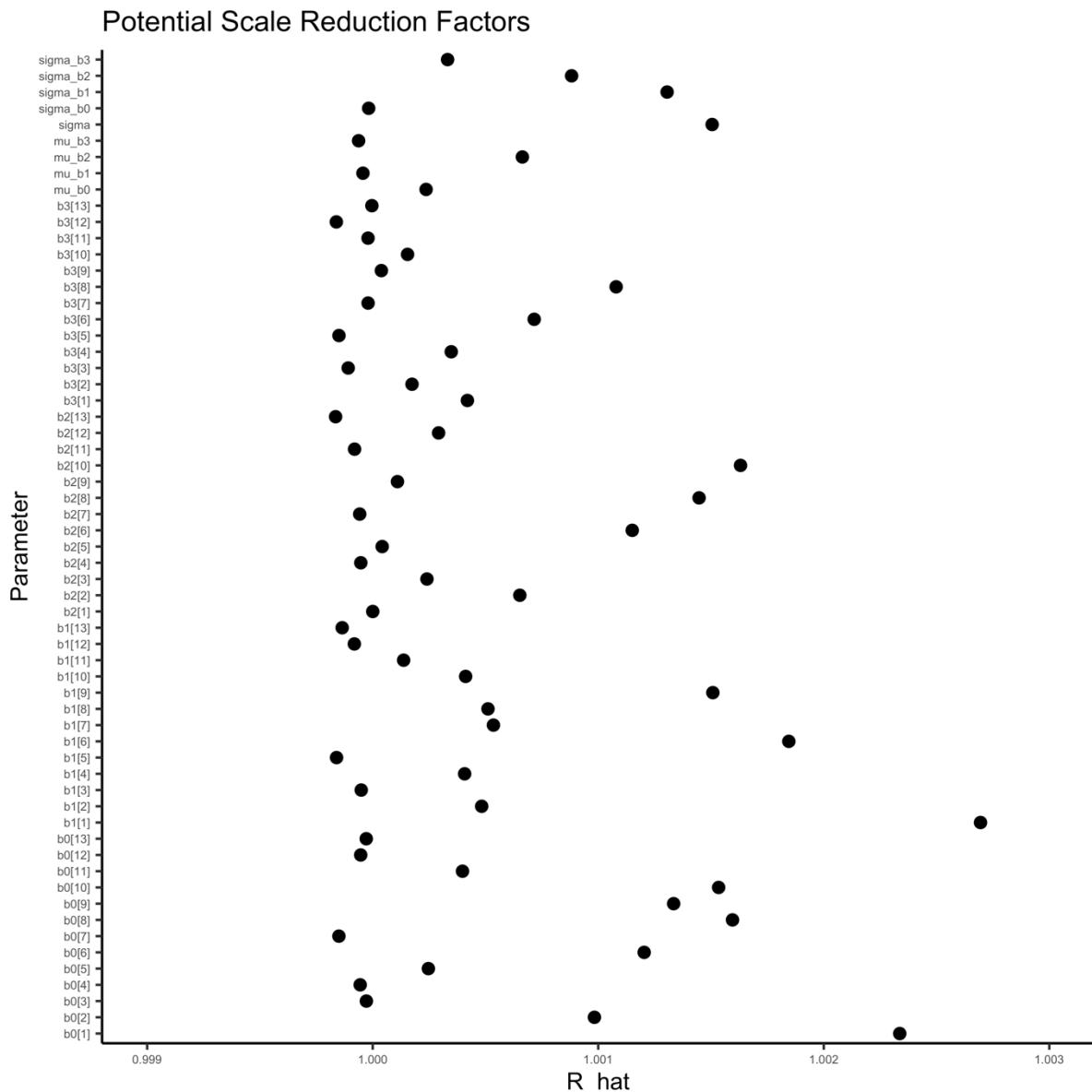
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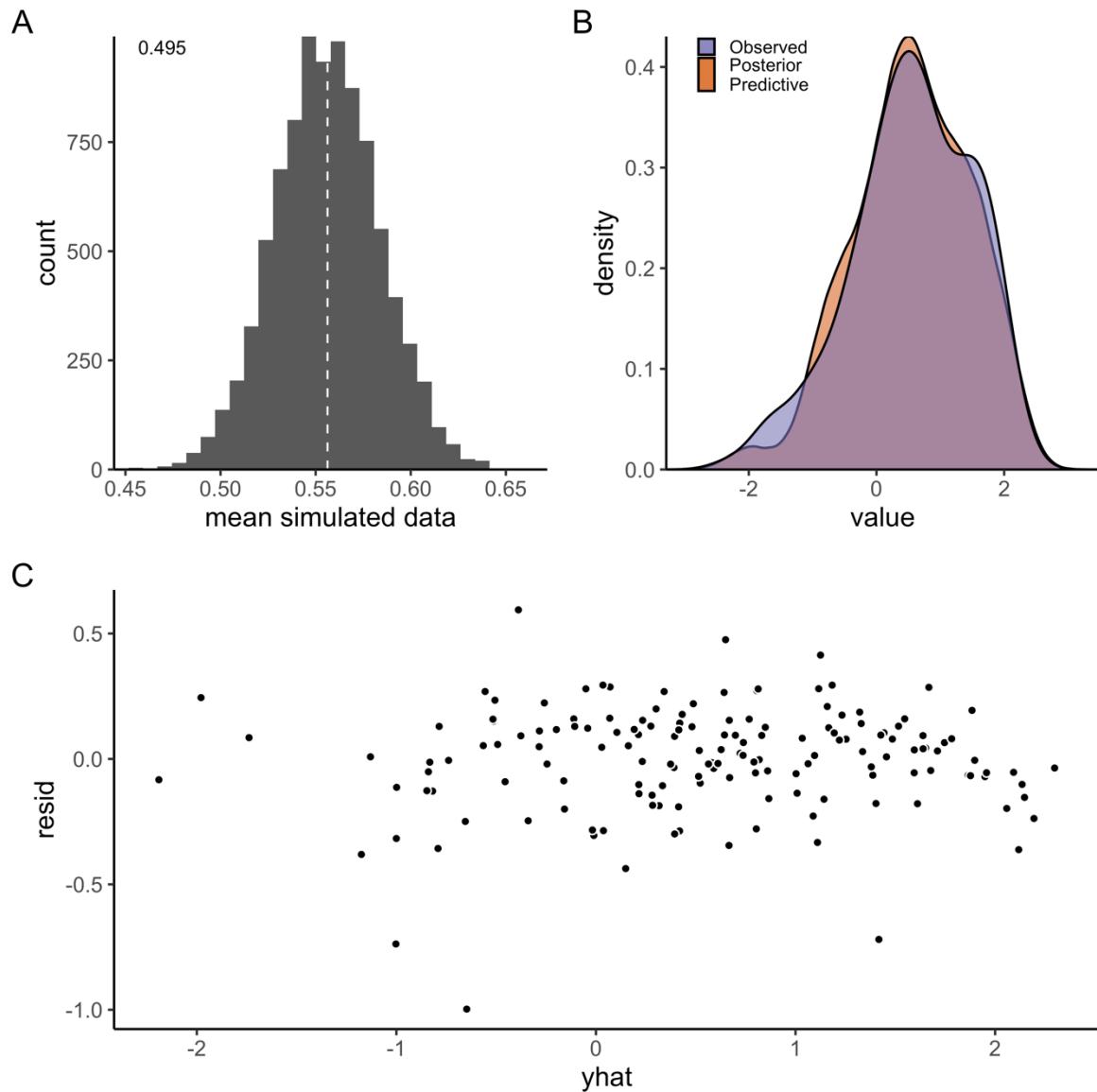
447 *Fig. S21. Potential scale reduction factor ( $\hat{R}$ ) for the growth rate model. This factor is based*  
 448 *on the comparison of between and within-chain variation for the same parameter. A value close*  
 449 *to one implies chains converged to the same distribution. The index of the parameter*  
 450 *corresponds to species in alphabetical order.*

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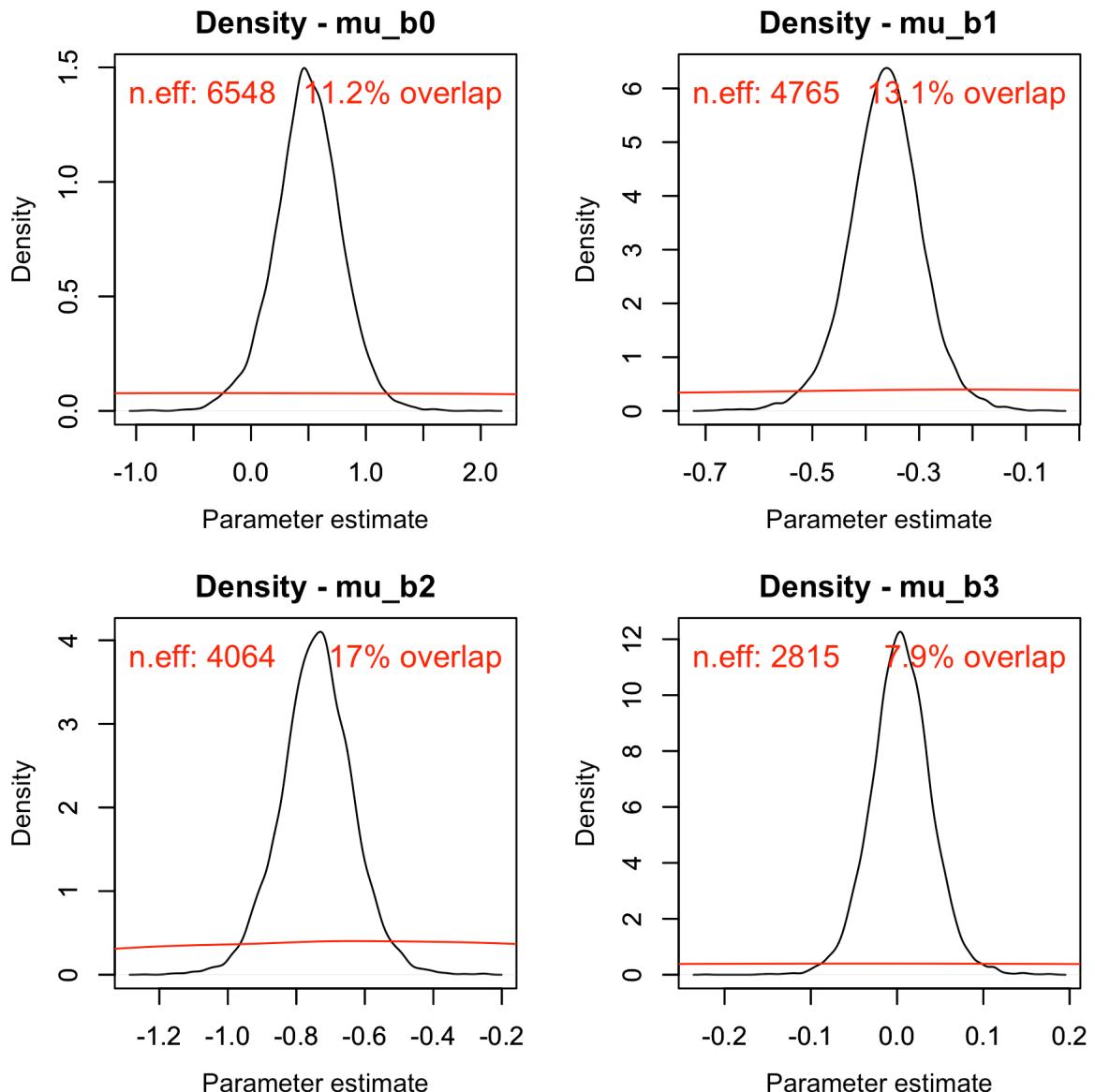
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456 *Fig. S22. A) Model fit (mean) for the model of growth at temperatures below temperature*  
 457 *optimum (by species). Fit is evaluated by simulating data from the likelihood (at each iteration*  
 458 *of the MCMC chain), to compare how well it matches the original data. Each simulated data*  
 459 *point is assigned a 0 or 1 if it is below or above the mean data point (the vertical line*  
 460 *corresponds to the mean in data). The number in the plot corresponds to the mean of the vector*  
 461 *of 0's and 1's. B) Posterior predictive distribution (orange) and distribution of data (purple).*  
 462 *C) Difference between the observed value and the posterior median of the predicted value,*  
 463 *plotted against fitted value.*



464

465 *Fig. S23. Posterior (black) and prior distribution (red) for the global parameters in the model*  
 466 *for growth rate, including their % overlap and effective sample size (n.eff).*

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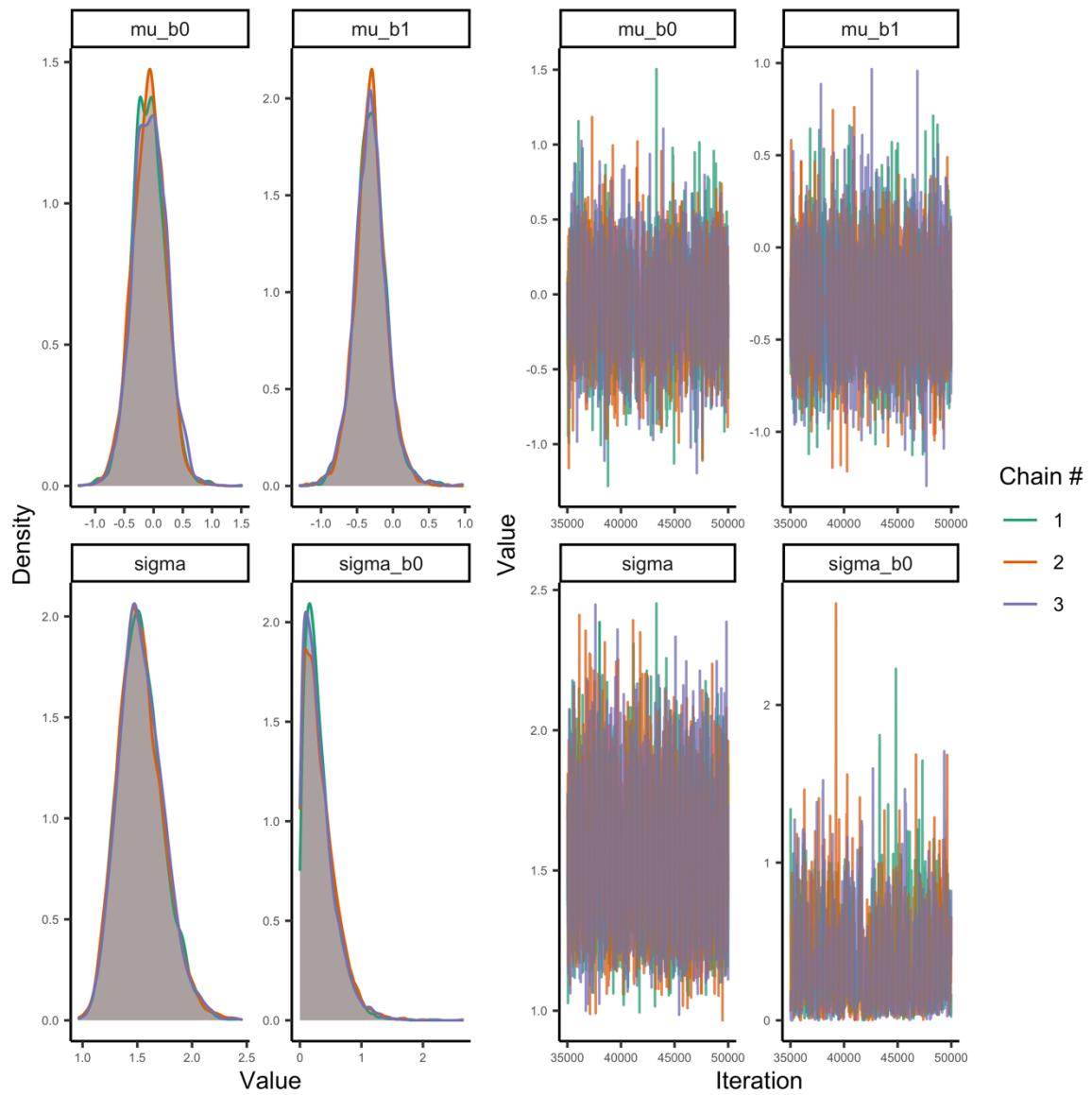
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473    ***Optimum growth temperature***



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475    Fig. S24. Posterior densities and trace plots for evaluation of chain convergence (by chain,

476    indicated by color), for the global-level parameters for the  $T_{opt}$  model.

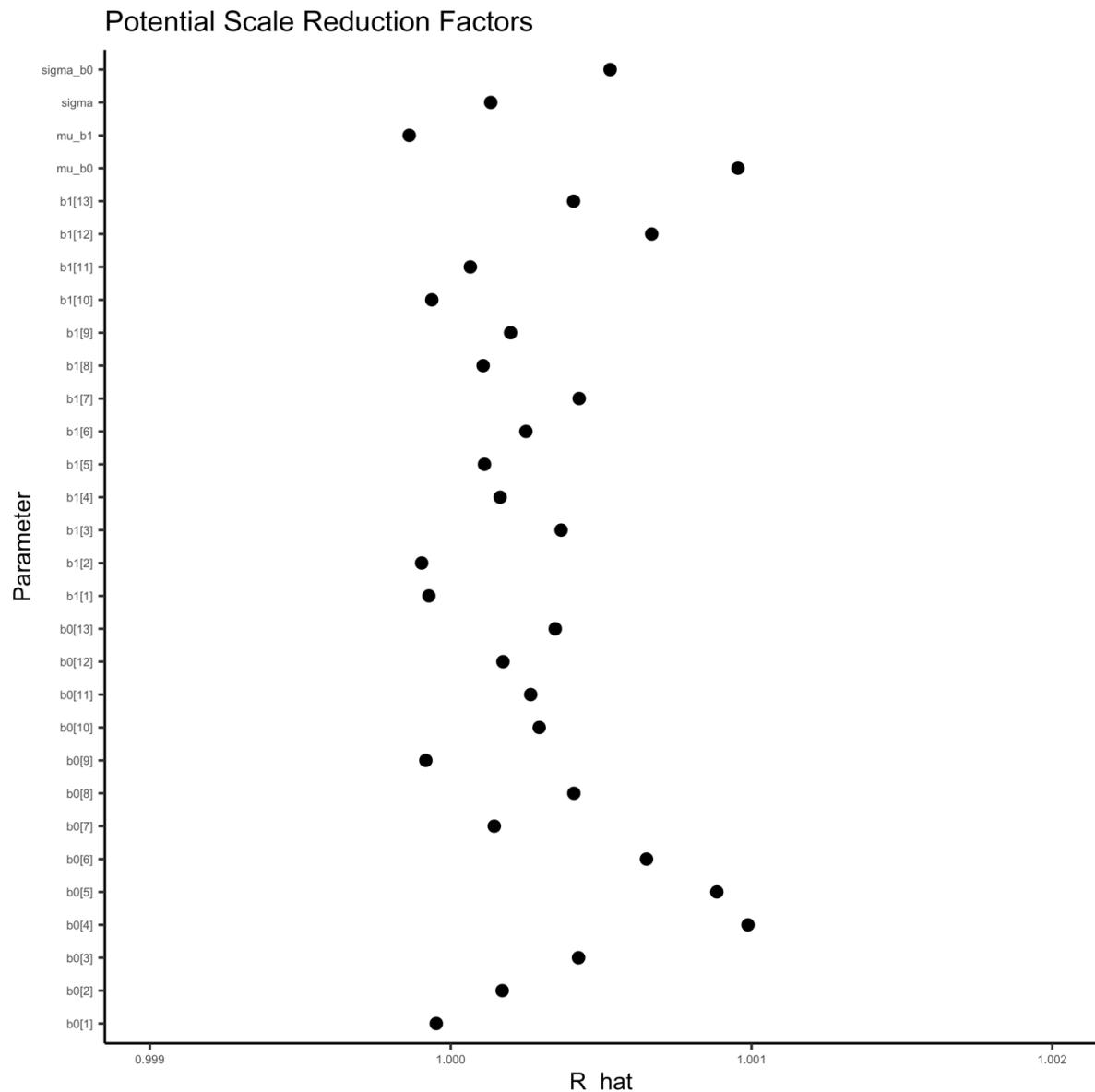
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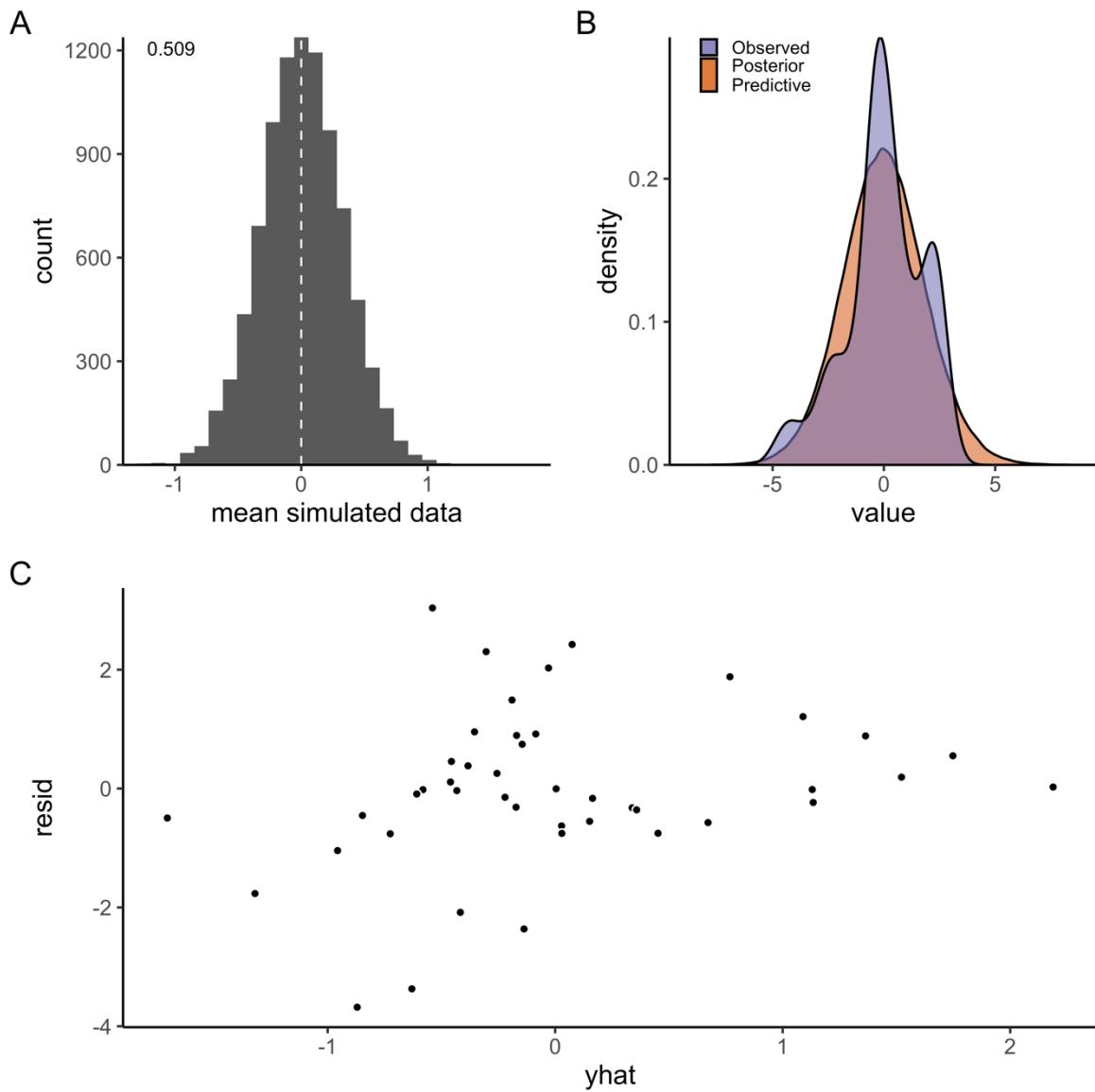
483    Fig. S25. Potential scale reduction factor ( $\hat{R}$ ) for the  $T_{opt}$  model. This factor is based on the  
 484    comparison of between and within-chain variation for the same parameter. A value close to  
 485    one implies chains converged to the same distribution. The index of the parameter corresponds  
 486    to species in alphabetical order.

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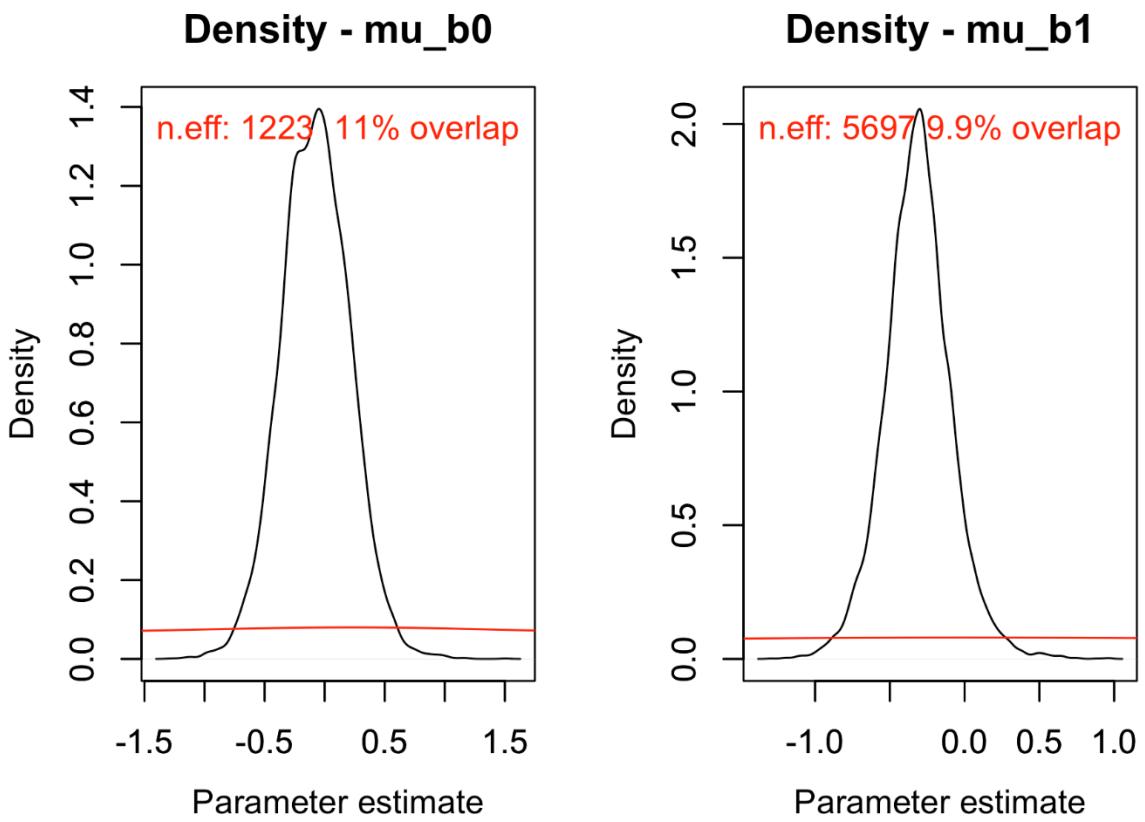
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492 Fig. S26. A) Model fit (mean) for the model of optimum growth temperature as a function of  
 493 body mass. Fit is evaluated by simulating data from the likelihood (at each iteration of the  
 494 MCMC chain), to compare how well it matches the original data. Each simulated data point is  
 495 assigned a 0 or 1 if it is below or above the mean data point (the vertical line corresponds to  
 496 the mean in data). The number in the plot corresponds to the mean of the vector of 0's and 1's.  
 497 B) Posterior predictive distribution (orange) and distribution of data (purple). C) Difference  
 498 between the observed value and the posterior median of the predicted value, plotted against  
 499 fitted value.



500

501 *Fig. S27. Posterior (black) and prior distribution (red) for the global parameters in the model*  
 502 *for  $T_{opt}$ , including their % overlap and effective sample size (n.eff).*

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