

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⁻¹. 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 O₂ h⁻¹,
116 because it was the most common unit in the data set. These data were compiled in the file
117 metabolism_data.xlsx.

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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⁻¹.
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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 " notes "). Used to estimate relative body size across species in the data and to normalized optimum growth temperatures across species.	G, T _{opt}
<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 " notes "). Used to estimate relative body size across species in the data.	G, T _{opt} , 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 " notes "). Used to compare experimental temperatures to common temperatures for species.	G, T _{opt} , 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 " notes "). Used to compare experimental temperatures to common temperatures for species.	G, T _{opt} , 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 " notes "). Used to compare experimental temperatures to common temperatures for species.	G, T _{opt} , 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 " notes "). Used to compare experimental temperatures to common temperatures for species.	G, T _{opt} , 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 " unit ", source of the data (literature search or cited in paper from literature search)	G, T _{opt} , C, M
<i>reference</i>	Source (See Table S2).	G, T _{opt} , C, M

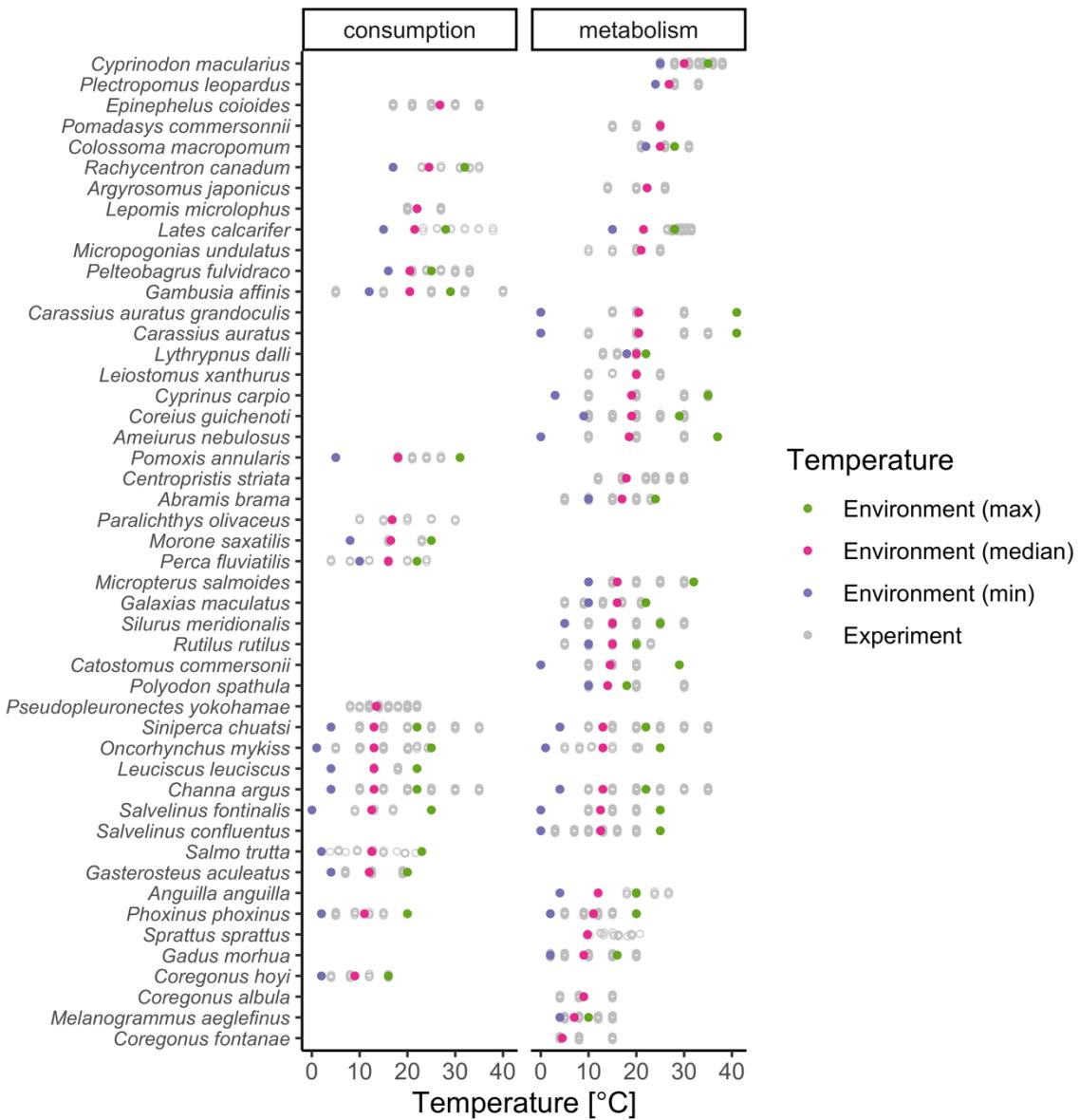
157 **Table S2** Species, common name, the data set(s) in which they appear and the sources
 158 (G=growth data, T_{opt} =optimum growth temperature data, C=maximum consumption data,
 159 M=metabolism data). If more than one data and source, the sources are in order (1 study per
 160 species and rate).

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**

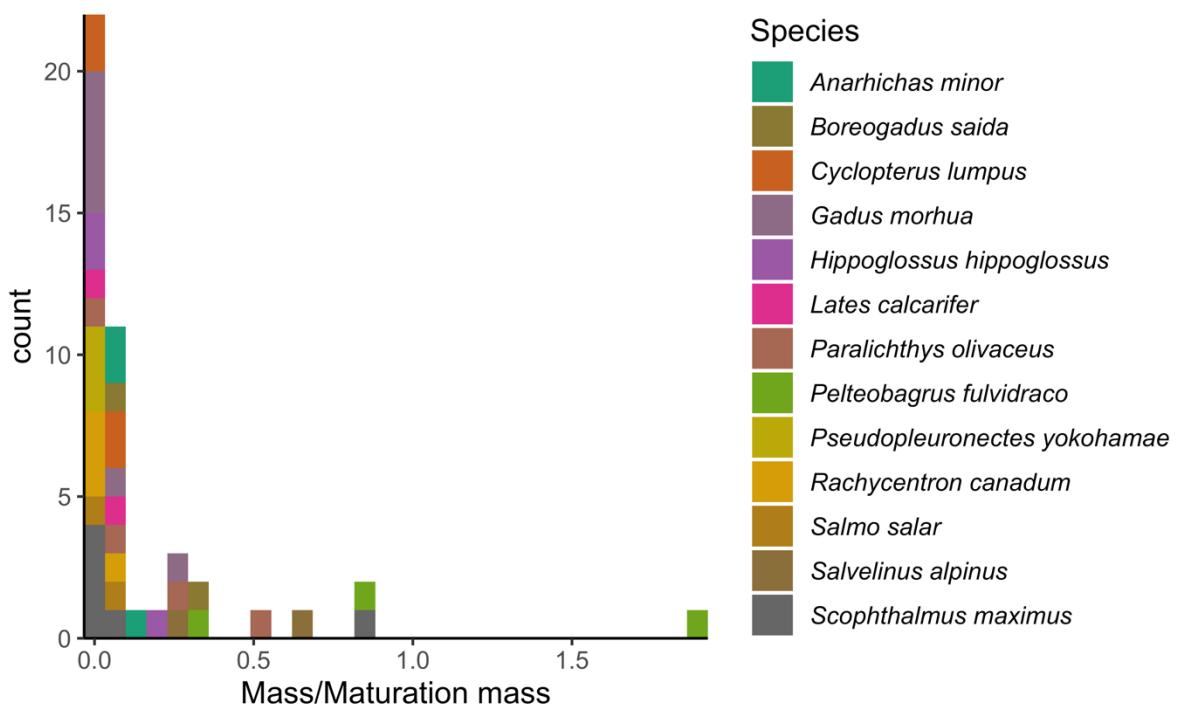


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165 *Fig. S1. Experimental temperatures (gray) and environmental (min, median and max) temperatures (purple, pink and green, respectively) of species represented in the consumption*
 166 *and metabolism (right) data sets. Missing temperatures means information was not*
 167 *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.*

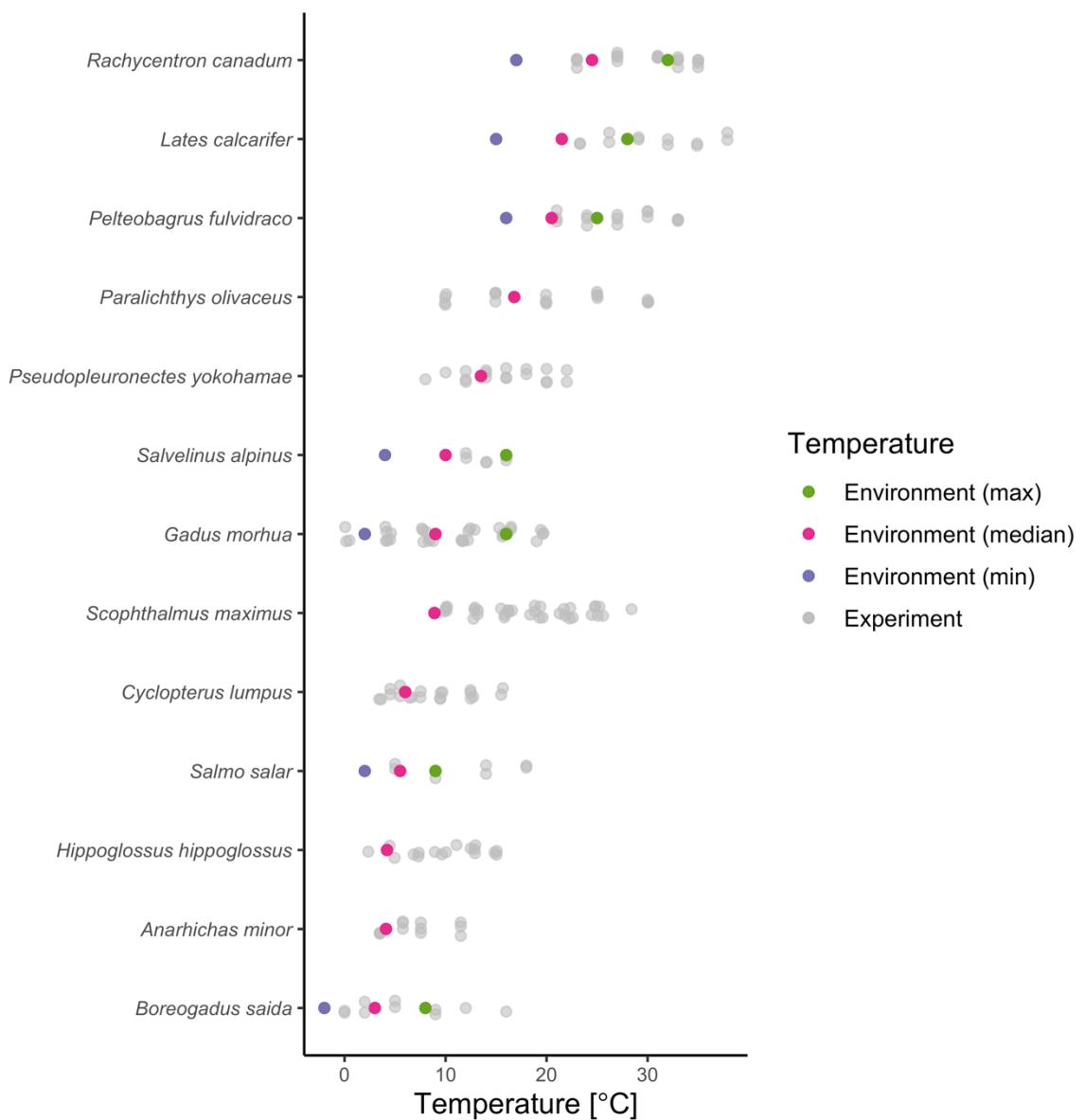
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181 *Fig. S3. Experimental temperatures (gray) in the growth rate data and environmental (min,*
 182 *median and max) temperatures (purple, pink and green, respectively). Missing temperatures*
 183 *means information was not available on FishBase. 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⁻¹) 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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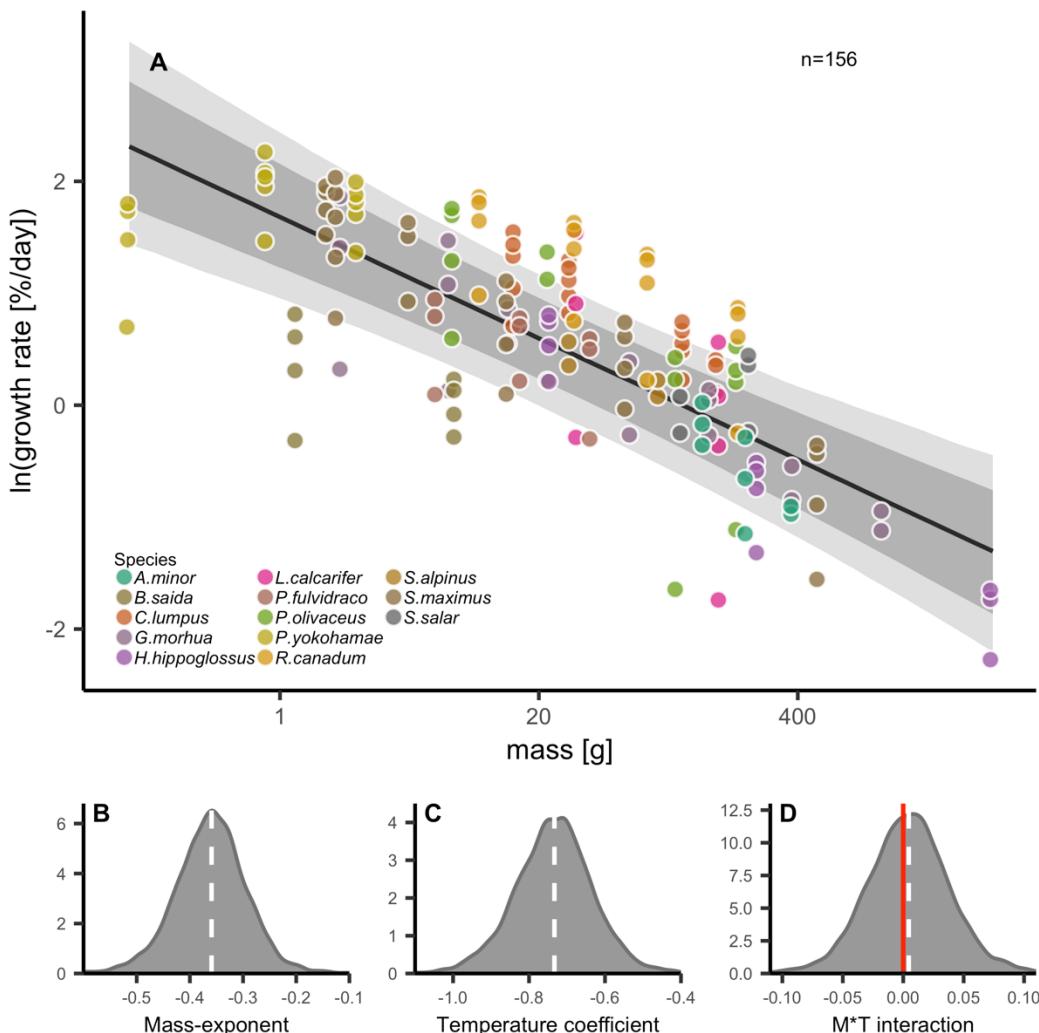
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212 *Fig. S4. Effects of temperature and body mass on body growth below optimum temperature.*

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

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

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

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

217 *(14°C, but note the model is fitted using Arrhenius temperature). Shaded areas correspond to*

218 *80% and 95% credible intervals. Point colors indicate species. The bottom row shows the*

219 *posterior distributions for (B) the global mass-scaling exponent, μ_{β_1} , (C) the global*

220 *temperature coefficient, μ_{β_2} and (D) the global mass-temperature interaction, μ_{β_3} . Dashed*

221 *white line shows the posterior median and red vertical line in (D) indicates zero.*

222 **Table S3** Description of model parameters (type and their interpretation in brackets) and their
 223 prior distributions (see ‘*Model description*’ and equations 1-3 in the main text). N refers to a
 224 normal distribution (mean and standard deviation, s.d.) and U to a uniform distribution
 225 (interval). For simplicity, only the parameters of the full model are shown here (i.e., with most
 226 coefficients varying by species), but note that when a model is fitted with a common rather
 227 than species-varying coefficient, for example β_1 instead of $\beta_{1j} \sim N(\mu_{\beta_1}, \sigma_{\beta_1})$, we use the same
 228 prior for β_1 as for μ_{β_1} .

Model	Parameter	Description	Prior distribution
Log-linear regressions for growth, consumption and metabolism	$\mu_{\beta_{0s}}$	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>	$N(-1, 5)$
	μ_{β_0}	Hyperparameter (average intercept across species). <i>Only for consumption and growth models.</i>	$N(0, 5)$
	μ_{β_1}	Hyperparameter (average mass coefficient across species)	$N(0.75, 1)$
	μ_{β_2}	Hyperparameter (average temperature coefficient across species)	$N(-0.6, 1)$
	μ_{β_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)	$U(0, 10)$
	σ_{β_1}	Hyperparameter (s.d. of species mass coefficients)	$U(0, 10)$
	σ_{β_2}	Hyperparameter (s.d. of species temperature coefficients)	$U(0, 10)$
	σ_{β_3}	Hyperparameter (s.d. of species interaction coefficients)	$U(0, 10)$
	σ	Parameter (s.d.)	$U(0, 10)$
Sharpe-Schoolfield	$\mu_{C_{0j}}$	Hyperparameter consumption at reference	$N(1, 1)$

(unimodal consumption data)		temperature [-10 on centered scale] across species)	
	μ_{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)	$N(5, 2)$
	σ_{E_j}	Hyperparameter (s.d. of species-varying activation energies)	$U(0, 3)$
	σ_{C_0j}	Hyperparameter (s.d. of species-varying average consumption)	$U(0, 3)$
	σ	Parameter (s.d.)	$U(0, 3)$
Linear T_{opt} models	μ_{β_0}	Hyperparameter (average intercept across species)	$N(0, 5)$
	μ_{β_1}	Hyperparameter (average mass coefficient across species)	$N(0, 5)$
	σ_{β_0}	Hyperparameter (s.d. of species-intercepts)	$U(0, 10)$
	σ_{β_1}	Hyperparameter (s.d. of species mass coefficients)	$U(0, 10)$
	σ	Parameter (s.d.)	$U(0, 10)$

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241 **Table S4.** Model comparison for the log-linear regressions of how consumption, metabolism
 242 and growth depend on mass and temperature below optimum temperatures (see ‘*Model*
 243 *description*’ and equations 1-3 in the main text). The column m*t indicates whether the model
 244 for the rate includes an interactive effect of mass and temperature. The models differ in which
 245 coefficients vary among species and which are common, where β_0 is the intercept, β_1 mass
 246 coefficient (mass-exponent on linear scale), β_2 temperature coefficient (corresponding to the
 247 negative activation energy) and β_3 interaction between mass and temperature. The WAIC
 248 columns shows Δ WAIC and absolute WAIC in brackets, rounded to the nearest decimal, where
 249 Δ WAIC is the difference between each models’ WAIC and the lowest WAIC across models.
 250 Bold indicates models with Δ WAIC < 2.

Model	m*t	Species-varying parameter(s)	WAIC metabolism	WAIC consumption	WAIC growth
M1	Yes	$\beta_0, \beta_1, \beta_2, \beta_3$	0 (274.6)	3.1 (563.7)	0 (47.2)
M2		$\beta_0, \beta_1, \beta_2$	0.3 (274.9)	2 (562.6)	7.2 (54.4)
M3a		β_0, β_1	305.7 (580.3)	147.1 (707.7)	23.4 (70.6)
M3b		β_0, β_2	385.3 (659.9)	70.5 (631.1)	32.6 (79.8)
M4		β_0	648.6 (923.2)	190 (750.6)	43.5 (90.7)
M5	No	$\beta_0, \beta_1, \beta_2$	6.1 (280.6)	0 (560.6)	5.5 (52.7)
M6a		β_0, β_1	348.2 (622.8)	165.8 (726.4)	22.1 (69.3)
M6b		β_0, β_2	386.6 (661.2)	73.4 (634)	34.3 (81.5)
M7		β_0	681.5 (956.1)	213 (773.6)	44.9 (92.1)

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257 **Table S5.** Comparison of the two models fitted to optimum growth temperature data. The
258 WAIC columns shows Δ WAIC and absolute WAIC in brackets, rounded to the nearest decimal,
259 where Δ WAIC is the difference between each models' WAIC and the lowest WAIC across
260 models. Bold indicates models with Δ WAIC < 2.

Model	Species-varying parameter(s)	WAIC
M1	β_0, β_1	0 (177.3)
M2	β_0	1 (178.3)

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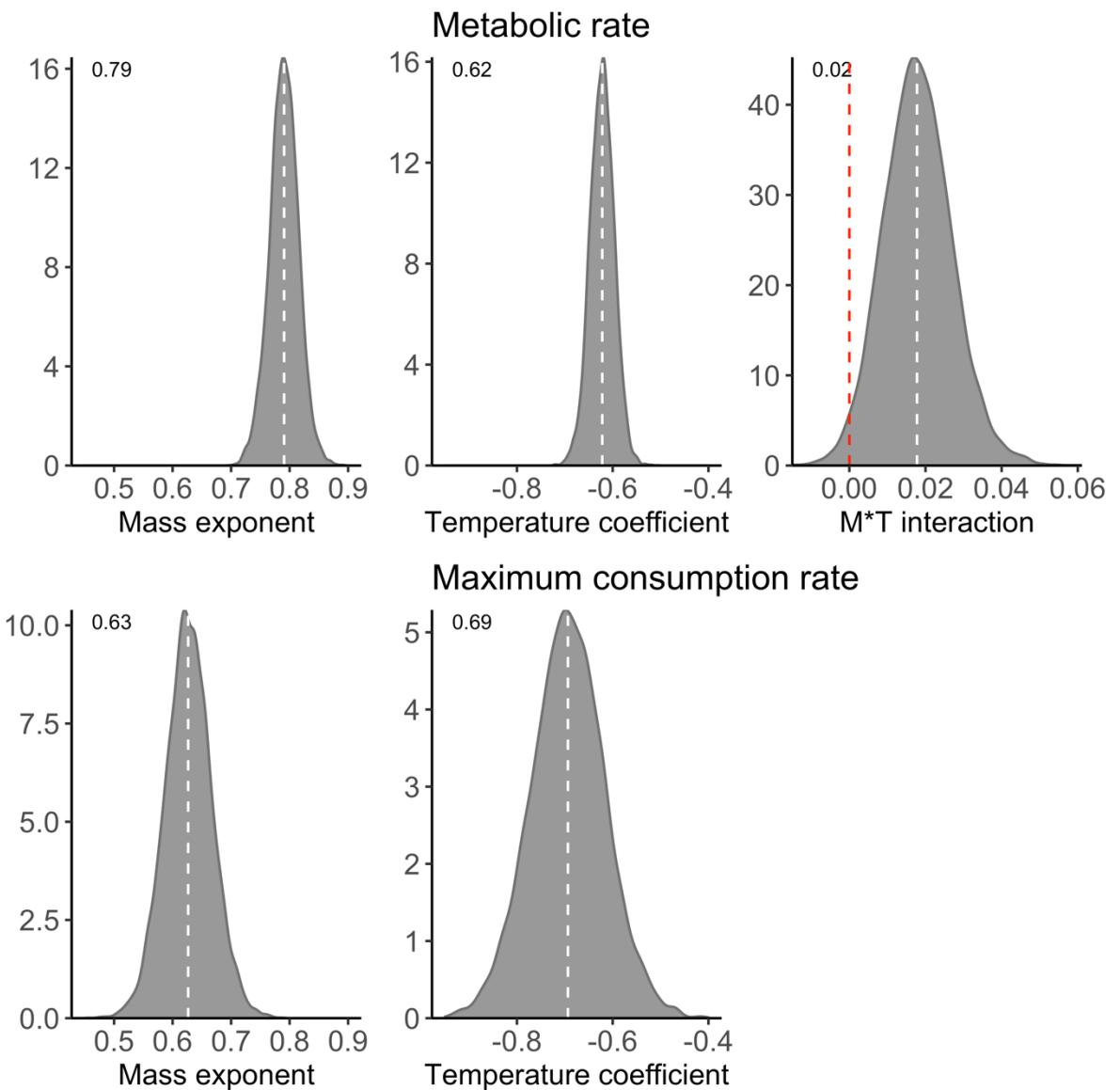
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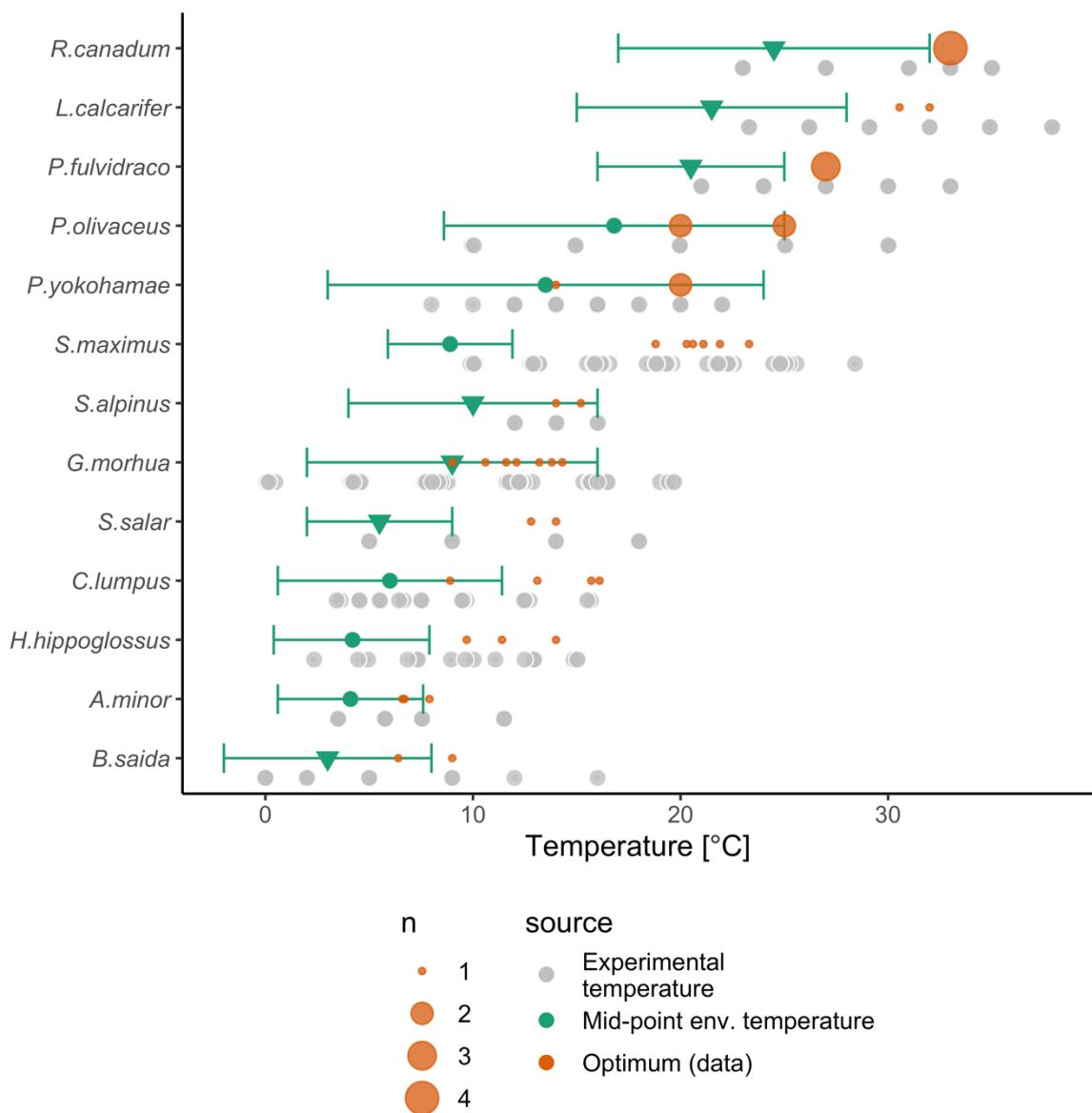


280

281 *Fig. S5. Posterior distributions of the global intraspecific mass exponents (μ_{β_1}) and*
 282 *temperature coefficients (μ_{β_2}) for metabolic rate (top) and maximum consumption rate*
 283 *(bottom). For metabolism, the global interaction coefficient (μ_{β_3}) is also shown (estimated and*
 284 *presented on an Arrhenius temperature scale), but for consumption this term was not included*
 285 *in the selected model. Numbers in the top left corner correspond to the posterior median. The*
 286 *axes are the same for each parameter for comparison between the two rates.*

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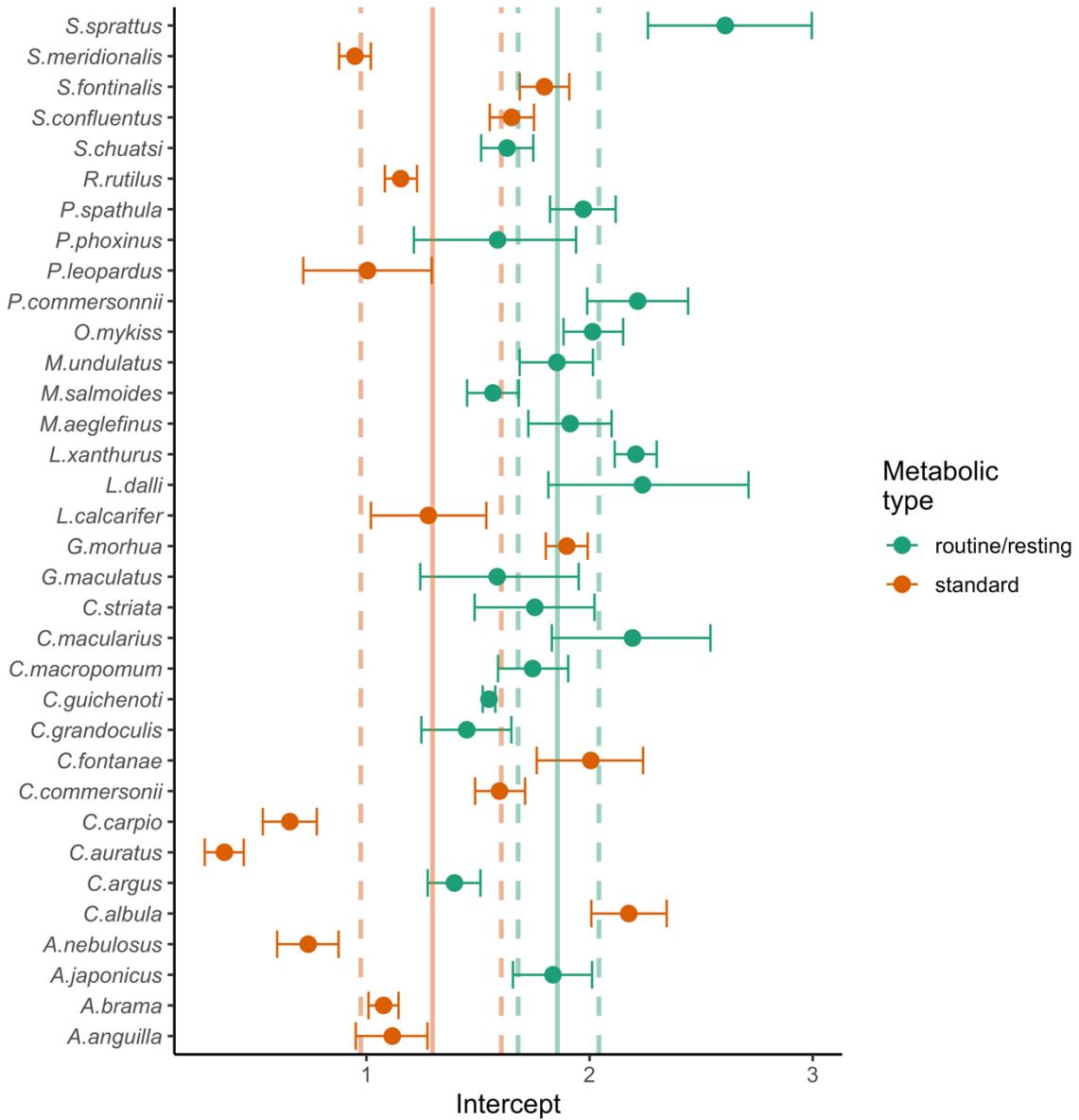
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290 *Fig. S6. Experimental temperatures (grey) overlap environmental temperatures (green), and*
 291 *optimum growth temperatures (orange) are typically at the upper end or above the*
 292 *environmental range. Horizontal green lines show the minimum and maximum environmental*
 293 *temperature based on either temperature in distribution range (triangles) or modelled*
 294 *distribution maps (circles), both taken from FishBase. The optimum growth temperatures are*
 295 *depicted for all size-classes per species, where the circle size is proportional to number of*
 296 *observations at that temperature.*

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298

299 *Fig. S7. Posterior median of species-level intercepts (points) and their 95% credible interval*
300 *(horizontal error bars). Colors indicate the type of metabolism measurement for each species.*
301 *Vertical solid lines are the posterior medians of the global intercepts (orange for standard*
302 *metabolic rate, μ_{β_0s} , and green for routine or resting metabolic rate, μ_{β_0r}), and the dashed*
303 *vertical lines show the 95% credible intervals for the global parameters.*

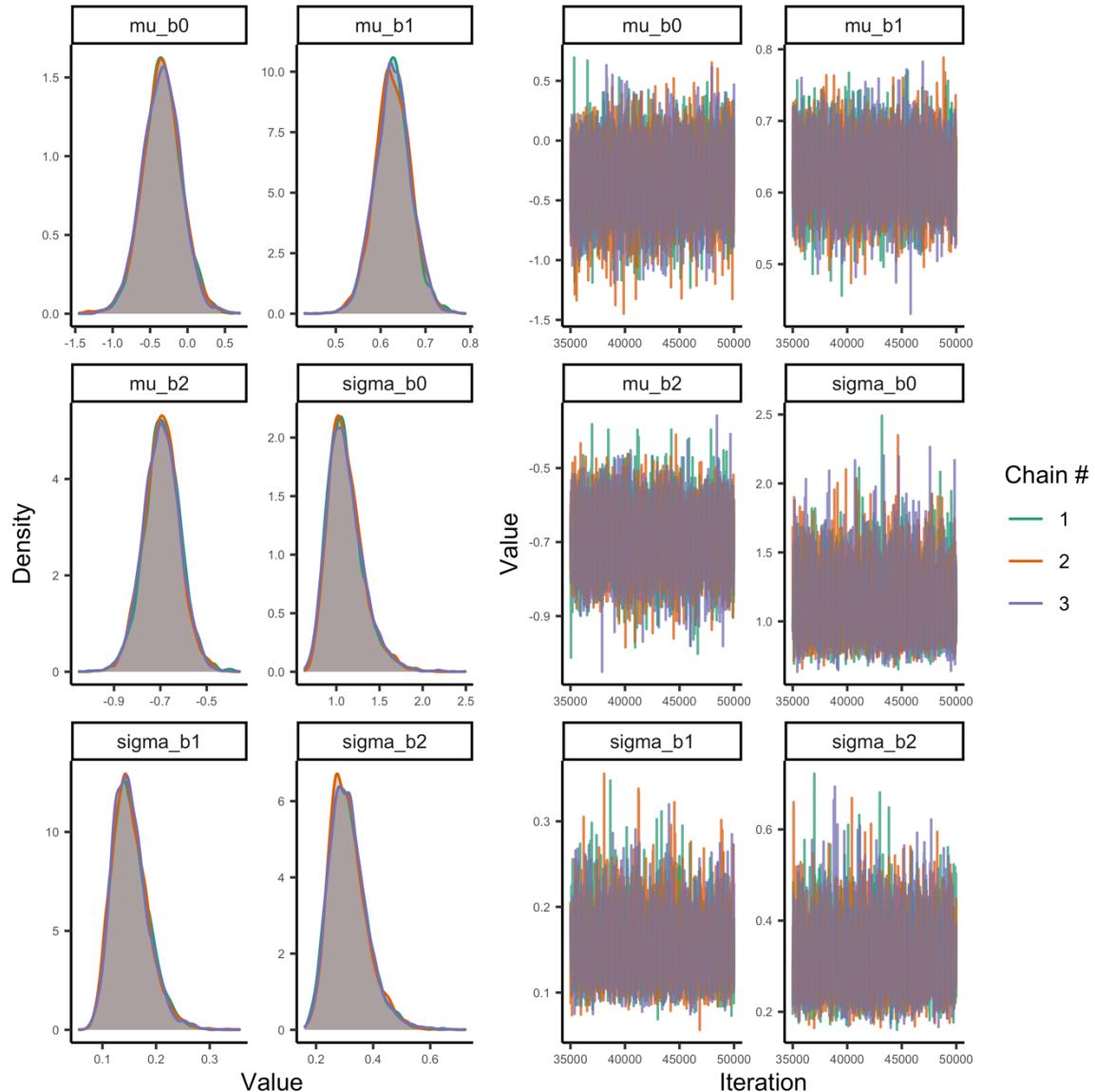
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305 **Model validation and fit**

306 Figures showing convergence of species-level parameters can be found on:

307 <https://github.com/maxlindmark/scaling>, in this section only global parameters are visualized.

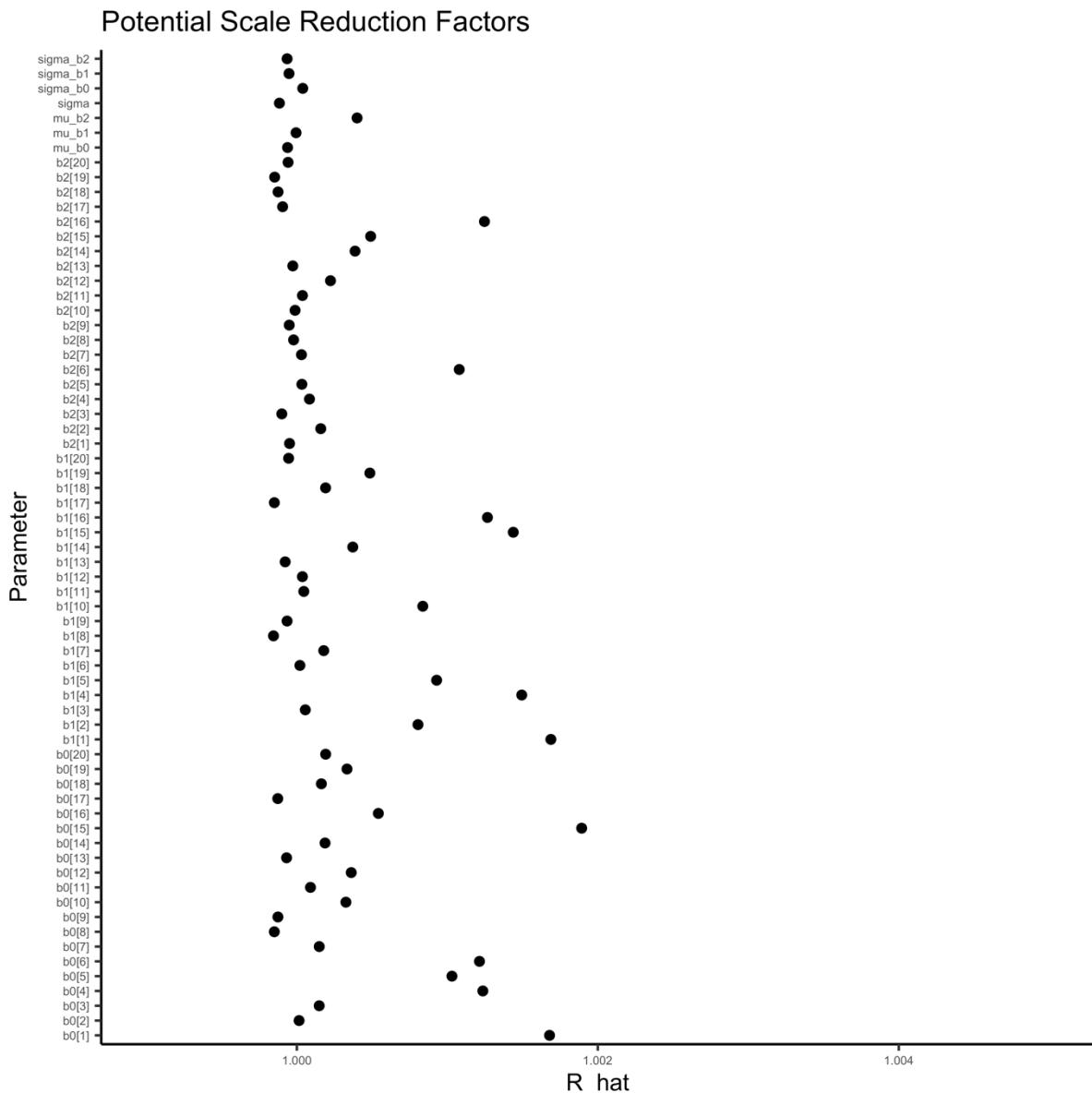
308 **Maximum consumption rate – below peak temperatures**



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

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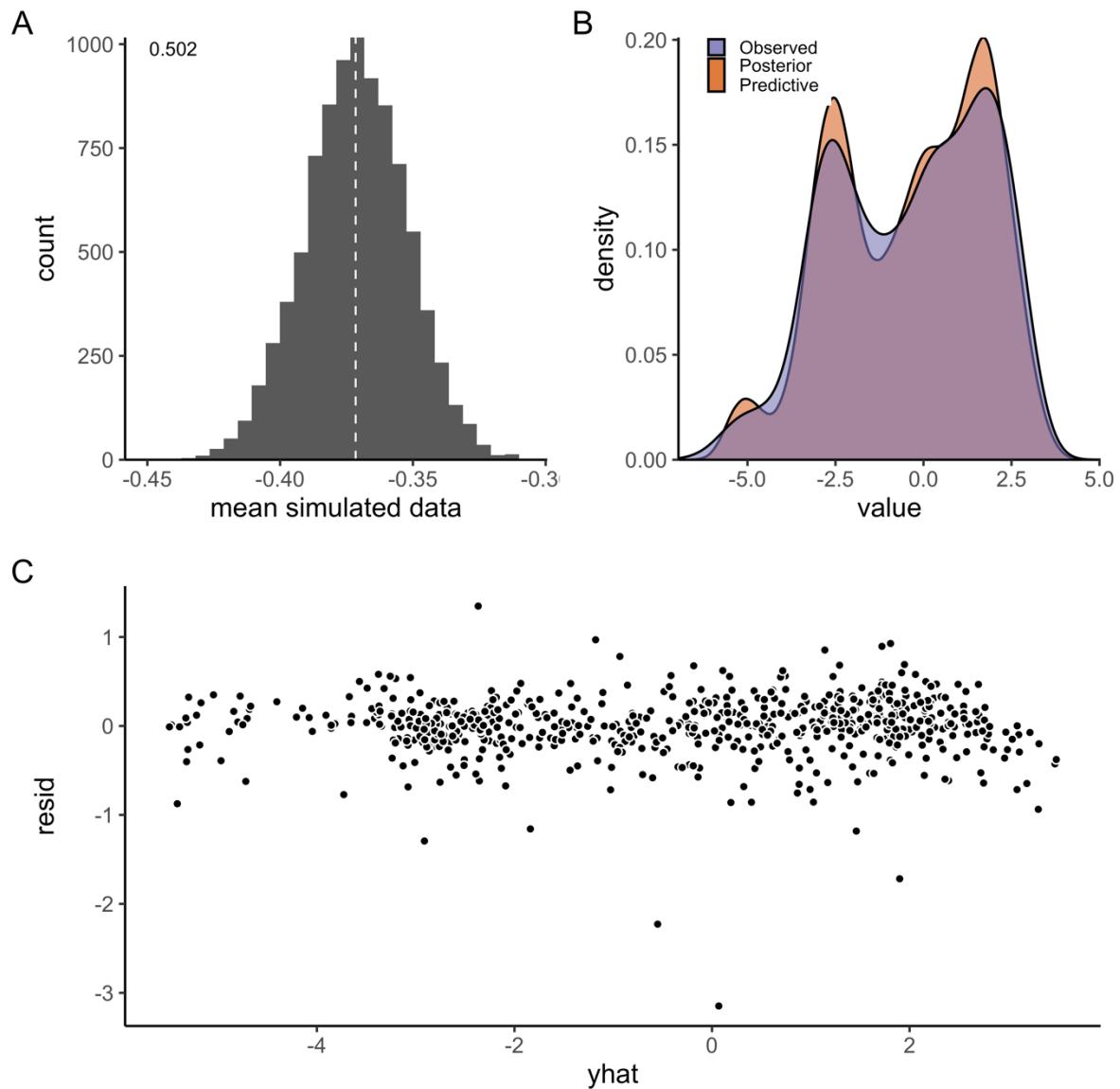
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315 *Fig. S9. Potential scale reduction factor (\hat{R}) for the log-linear maximum consumption rate*
 316 *model. This factor is based on the comparison of between and within-chain variation for the*
 317 *same parameter. A value close to one implies chains converged to the same distribution. The*
 318 *index of the parameter corresponds to species. The index of the parameter corresponds to*
 319 *species in alphabetical order.*

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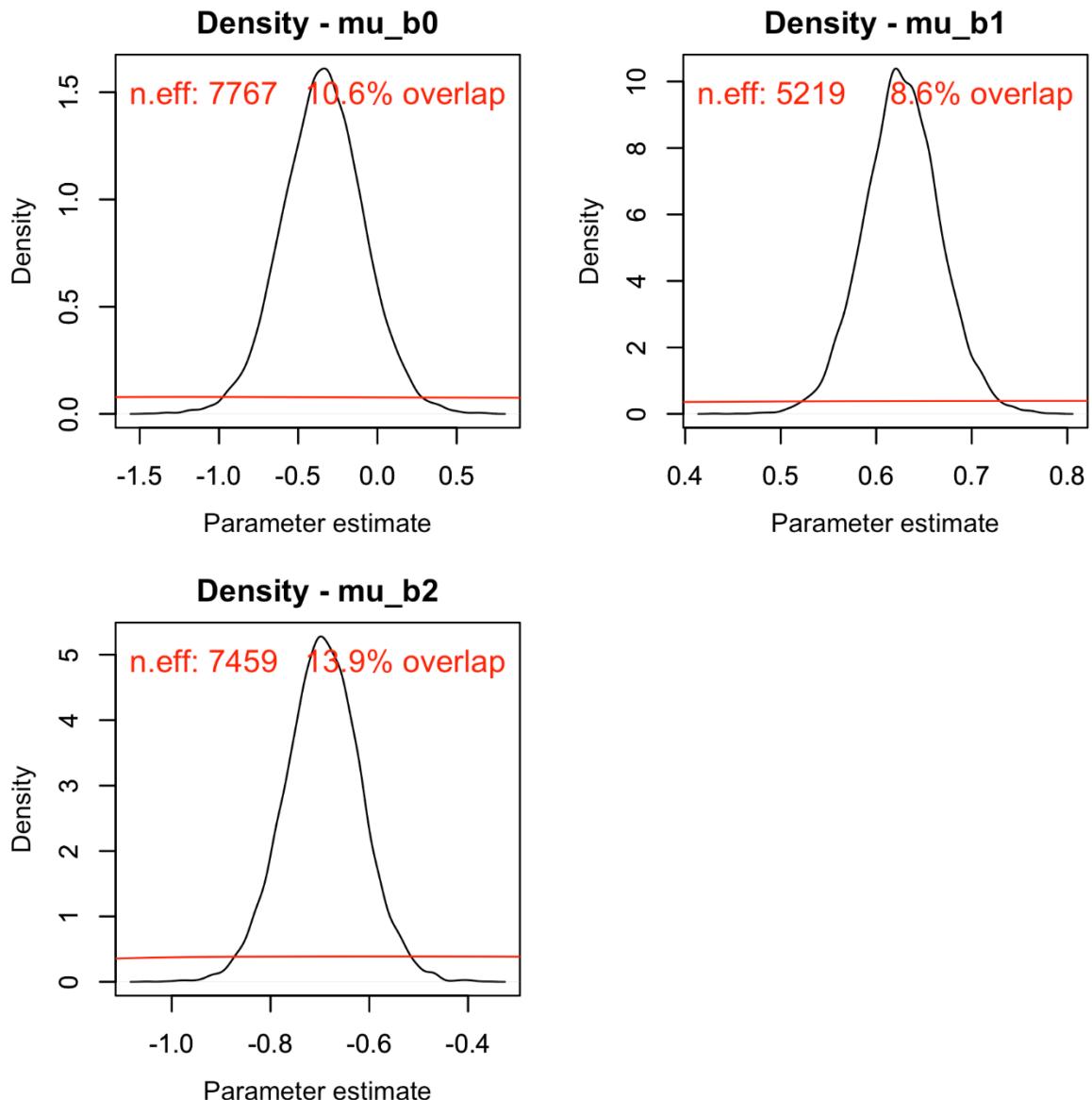
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324 Fig. S10. A) Model fit (mean) for the log-linear model of maximum consumption rate at
 325 temperatures below temperature peak (by species). Fit is evaluated by simulating data from
 326 the likelihood (at each iteration of the MCMC chain), to compare how well it matches the
 327 original data. Each simulated data point is assigned a 0 or 1 if it is below or above the mean
 328 data point (the vertical line corresponds to the mean in data). The number in the plot
 329 corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive distribution
 330 (orange) and distribution of data (purple). C) Difference between the observed value and the
 331 posterior median of the predicted value, plotted against fitted value.



332

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

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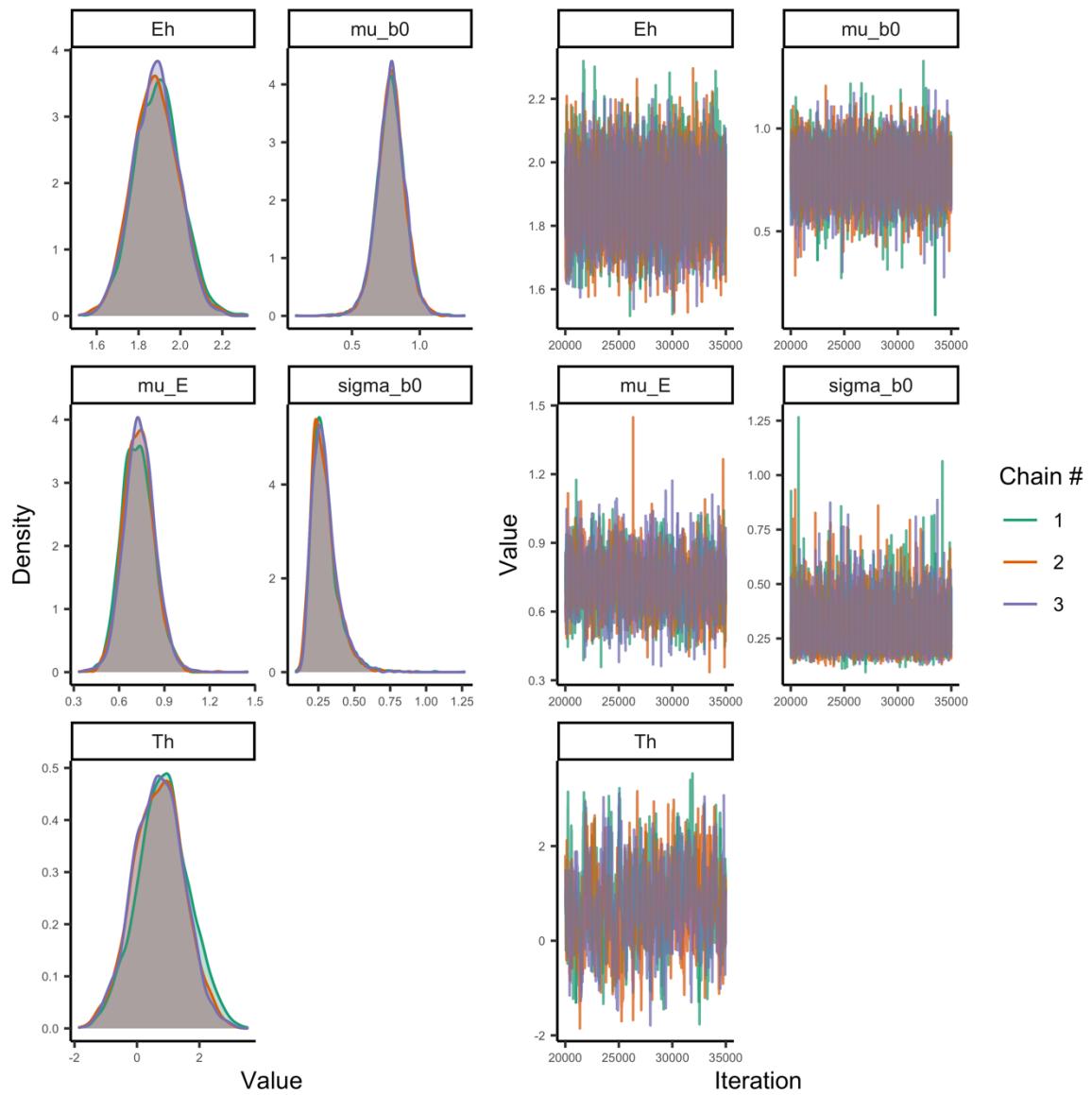
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341 **Maximum consumption rate – including beyond peak temperatures**



342

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

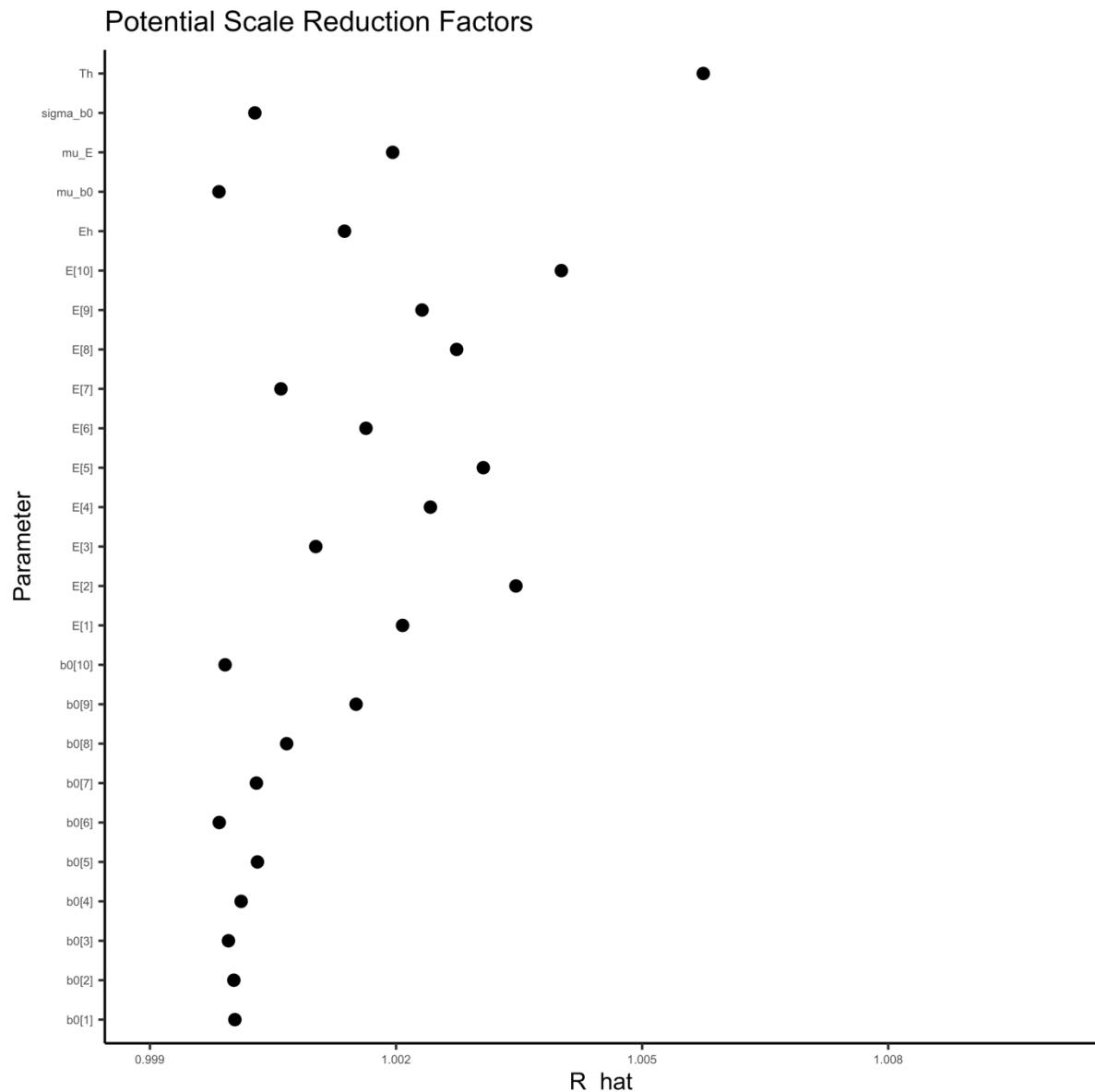
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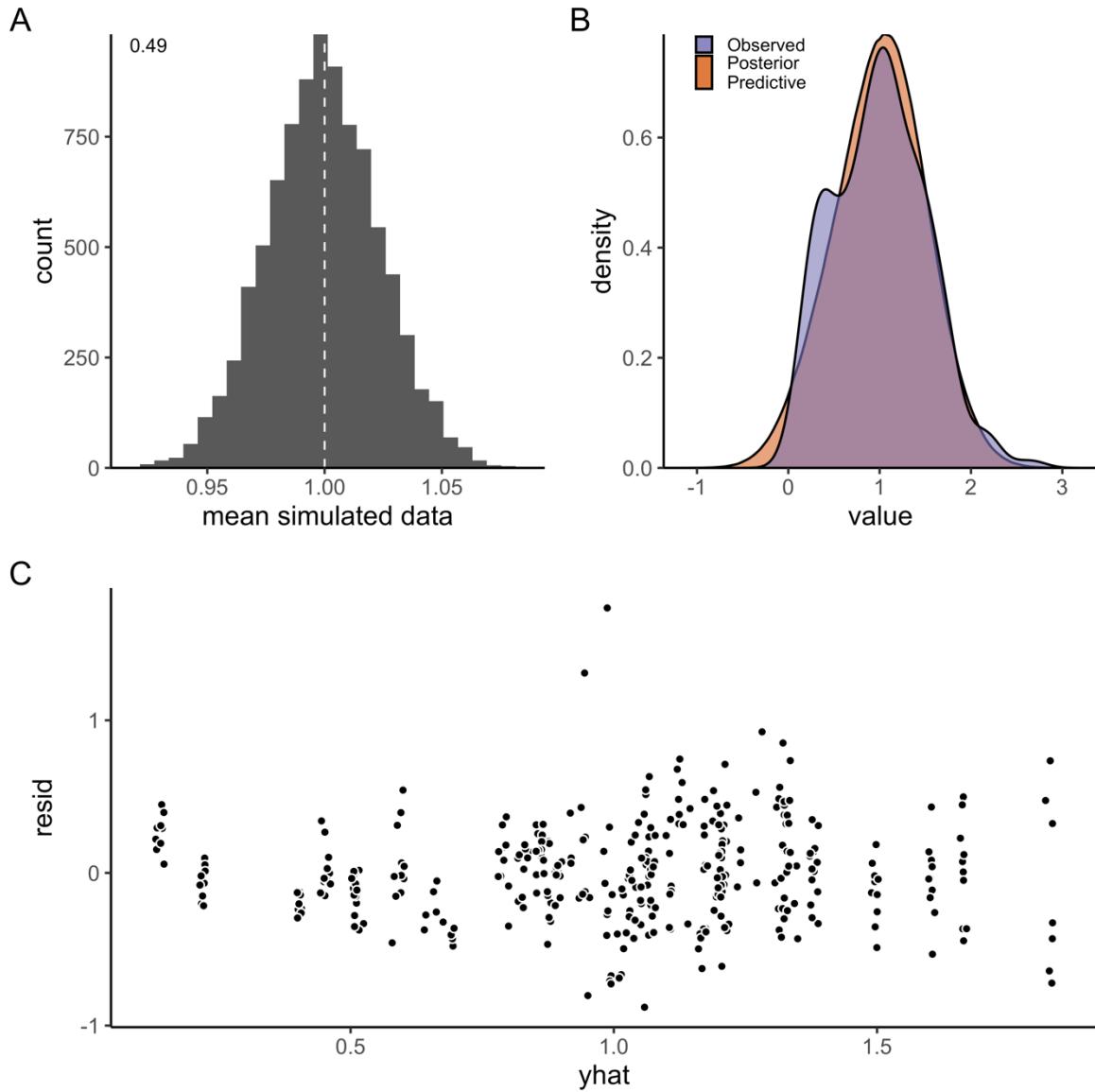
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352 *Fig. S13.* Potential scale reduction factor (\hat{R}) for the Sharpe-Schoolfield model fitted to
 353 maximum consumption rate data (including data beyond peak). This factor is based on the
 354 comparison of between and within-chain variation for the same parameter. A value close to
 355 one implies chains converged to the same distribution. The index of the parameter corresponds
 356 to species in alphabetical order.

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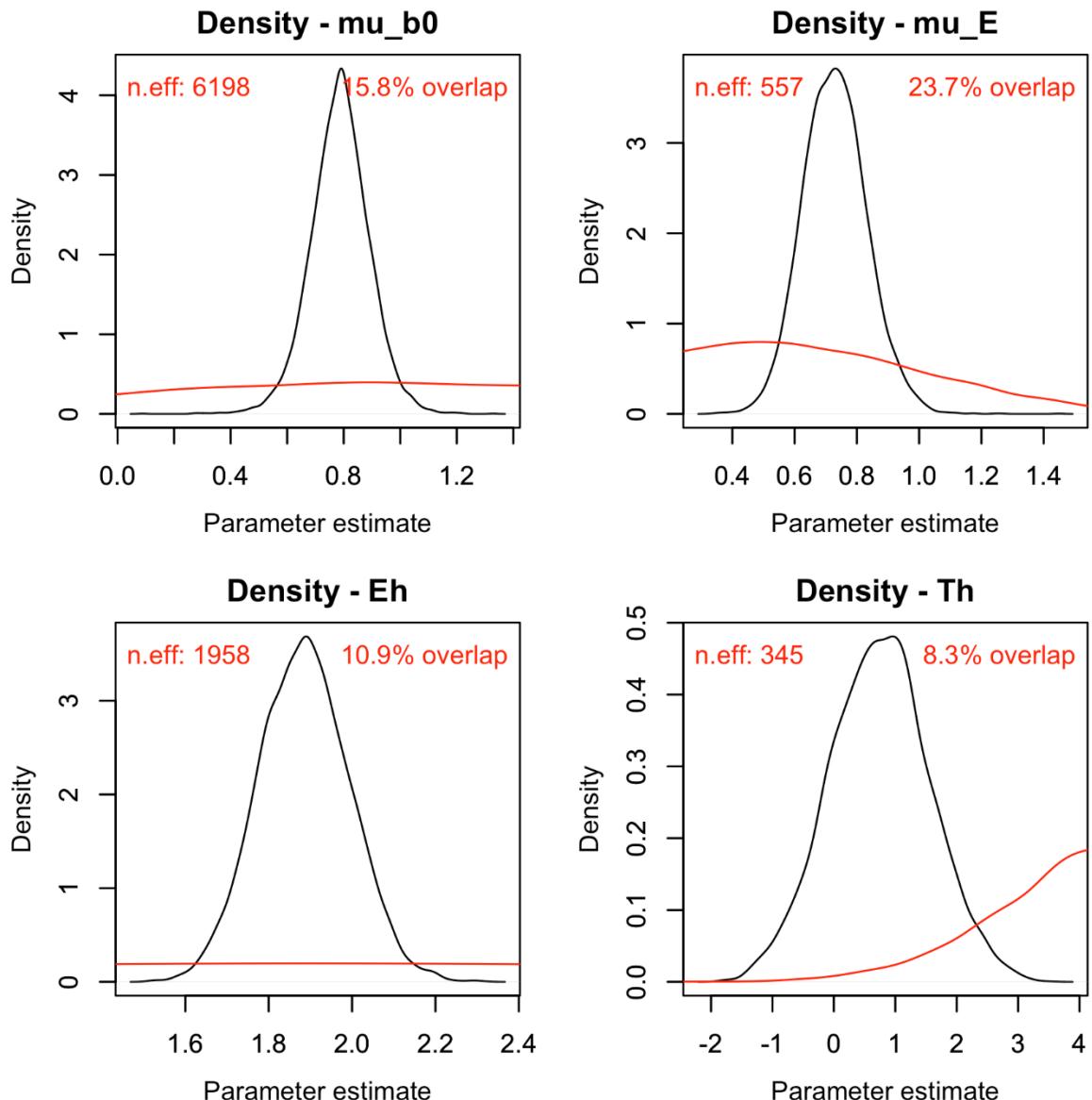
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361 *Fig. S14. A) Model fit (mean) for the Sharpe-Schoolfield model fitted to maximum consumption*
 362 *rate data including temperatures beyond peak (by species). Fit is evaluated by simulating data*
 363 *from the likelihood (at each iteration of the MCMC chain), to compare how well it matches the*
 364 *original data. Each simulated data point is assigned a 0 or 1 if it is below or above the mean*
 365 *data point (the vertical line corresponds to the mean in data). The number in the plot*
 366 *corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive distribution*
 367 *(orange) and distribution of data (purple). C) Difference between the observed value and the*
 368 *posterior median of the predicted value, plotted against fitted value.*



369

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

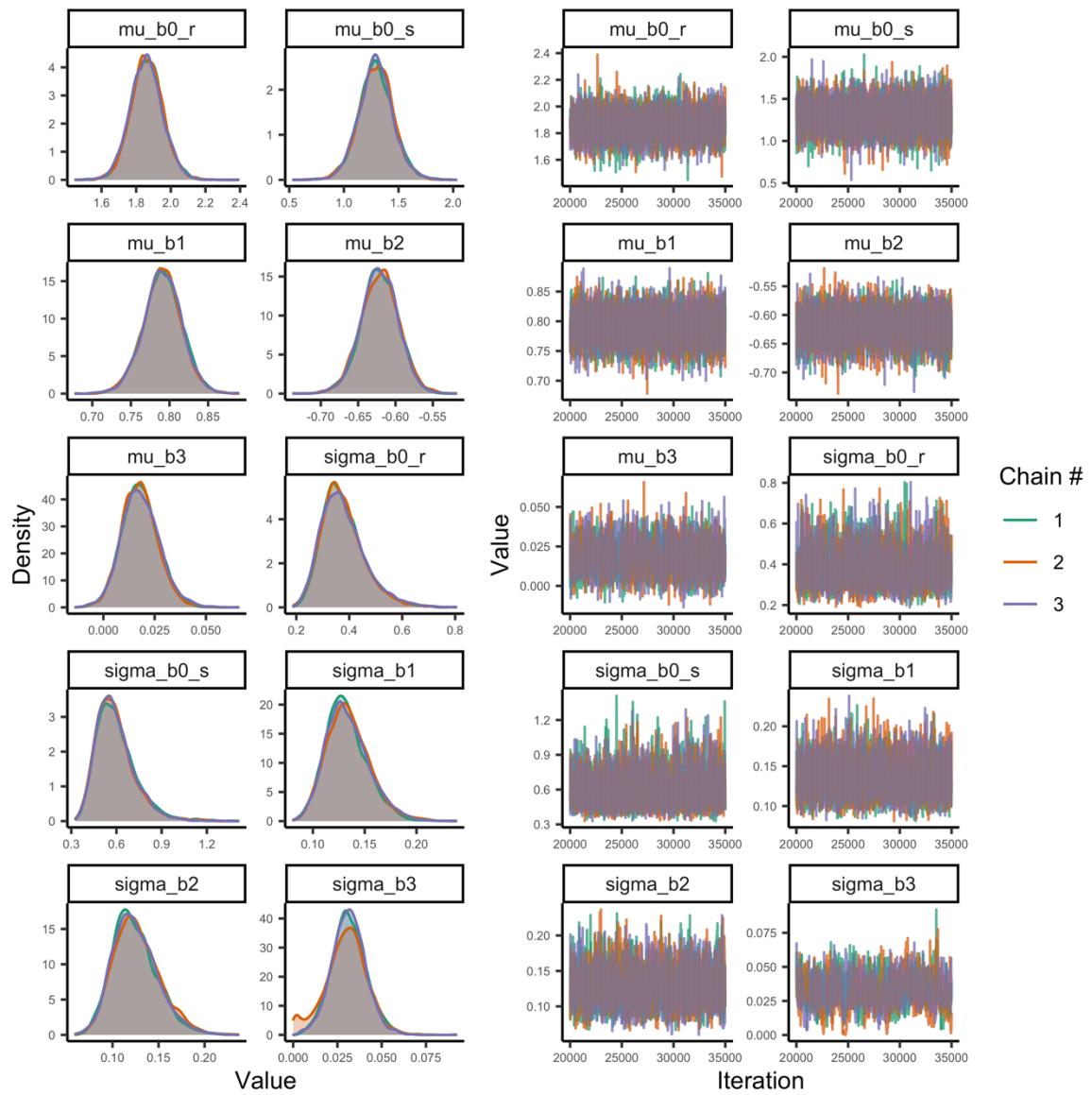
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378 **Metabolic rate**

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

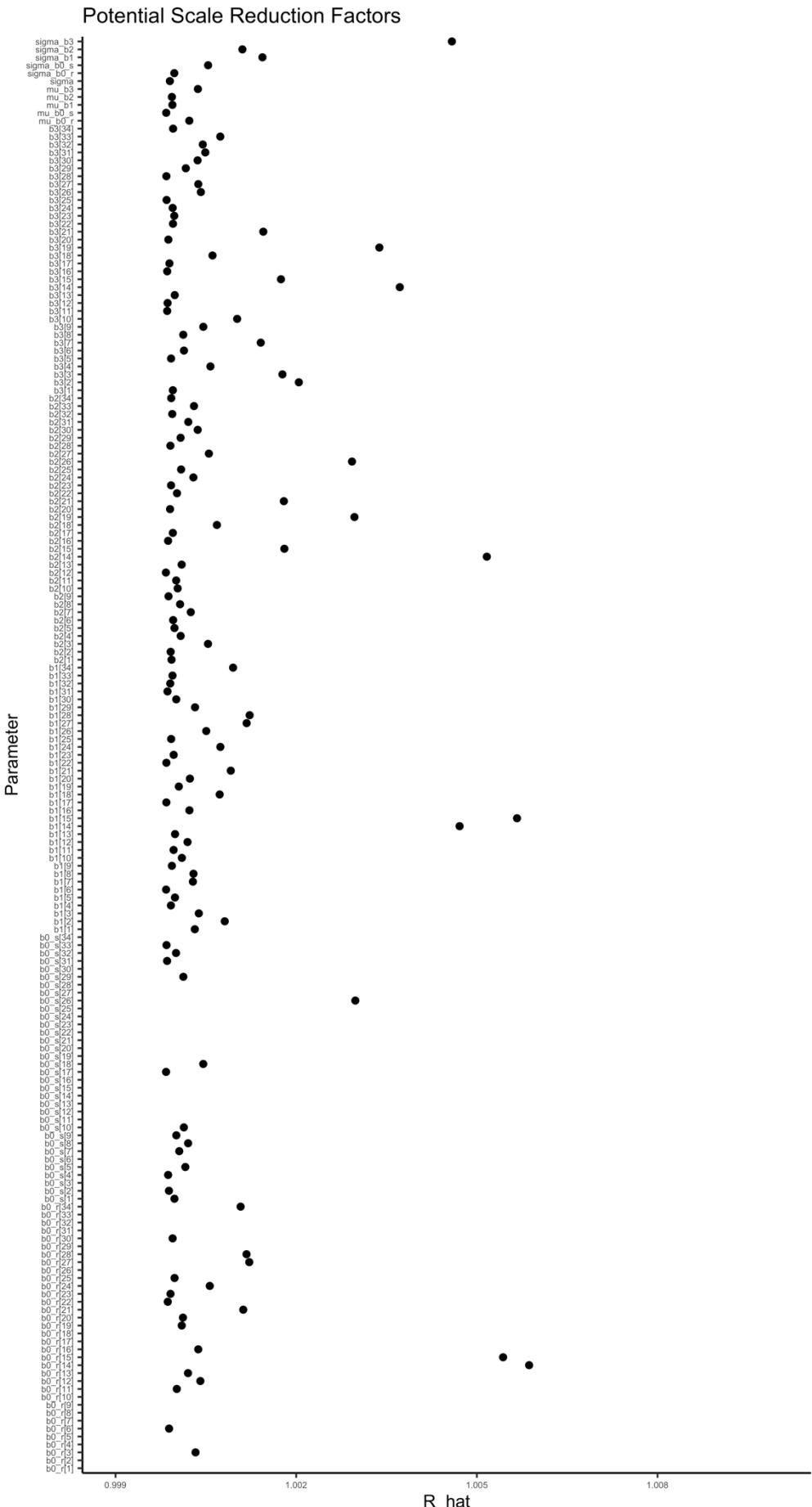
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389 *Fig. S17. Potential scale reduction factor (\hat{R}) for the metabolic rate model. This factor is based*
390 *on the comparison of between and within-chain variation for the same parameter. A value close*
391 *to one implies chains converged to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

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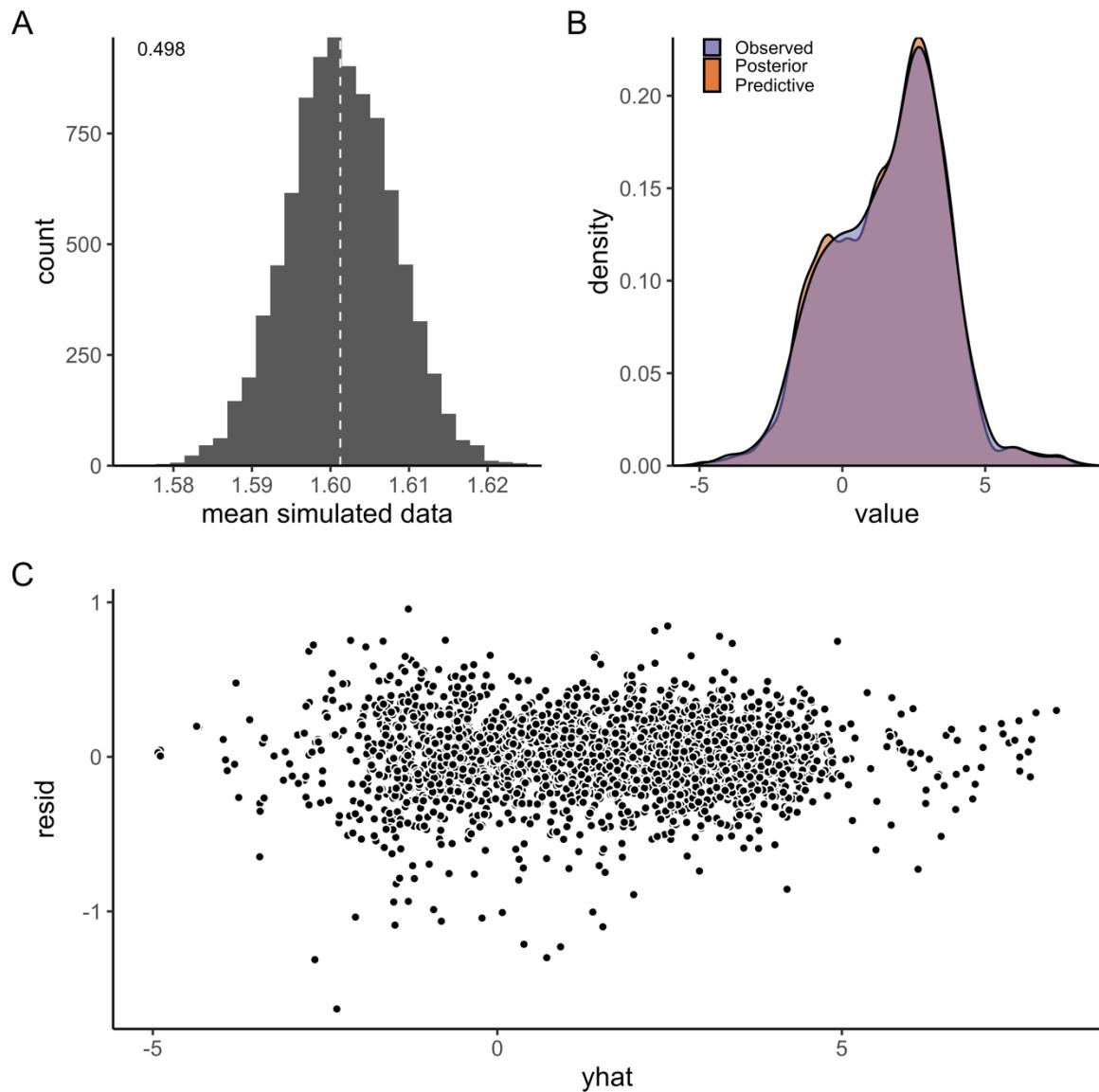
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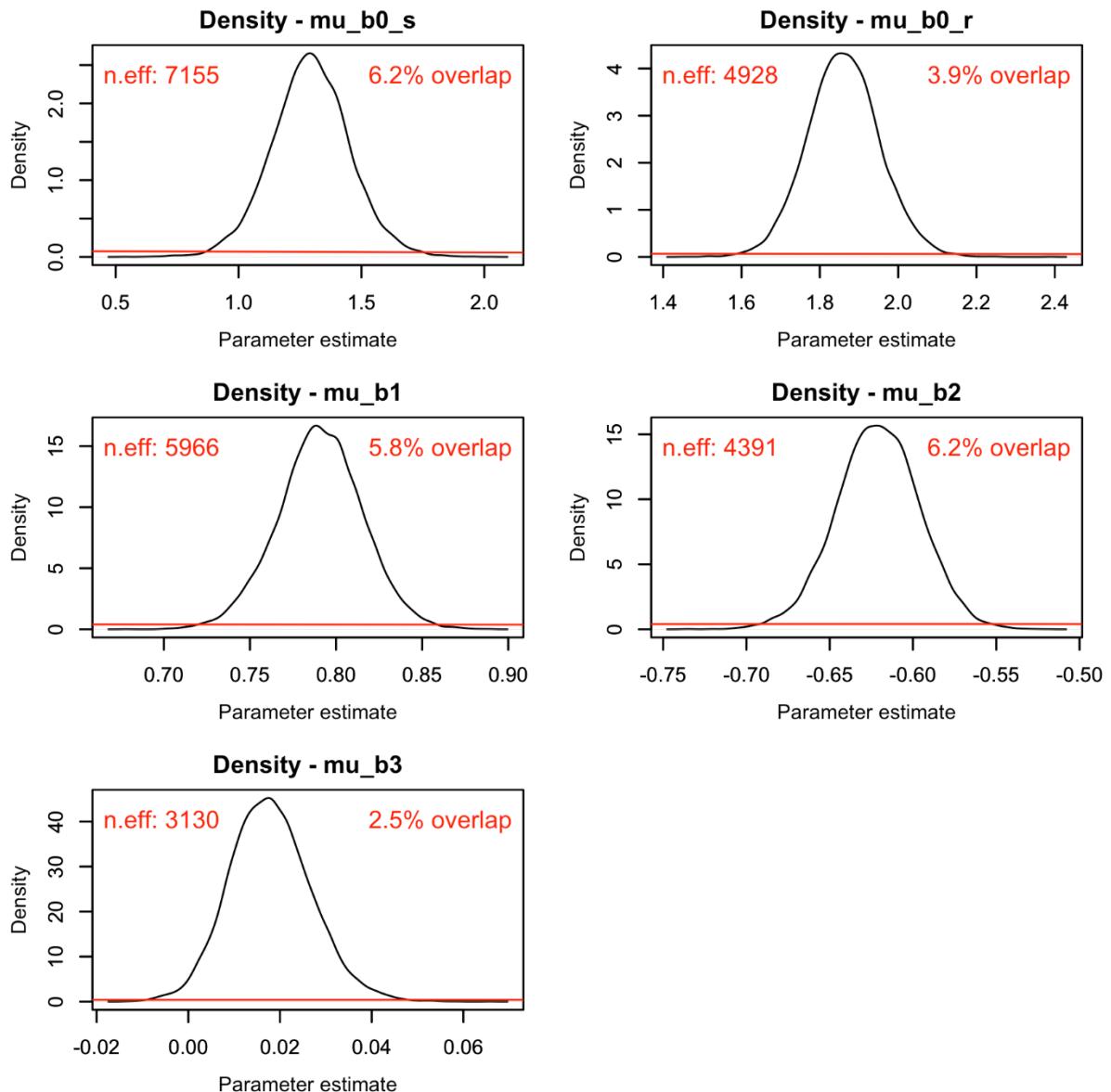
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414

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

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423

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

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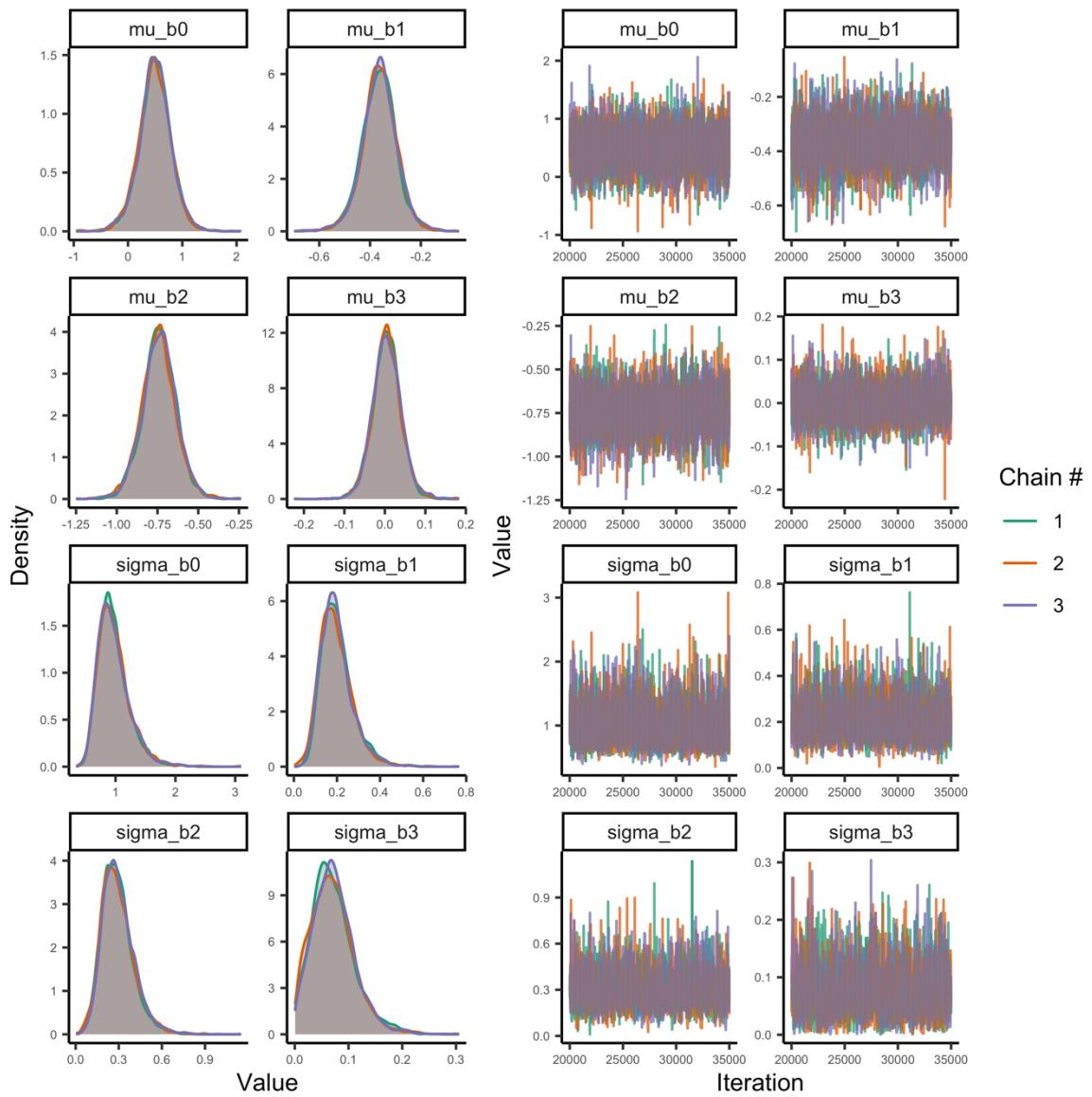
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434 *Fig. S20. Posterior densities and trace plots for evaluation of chain convergence (by chain,
 435 indicated by color), for the global-level parameters for the growth rate model at temperatures
 436 below optimum temperatures.*

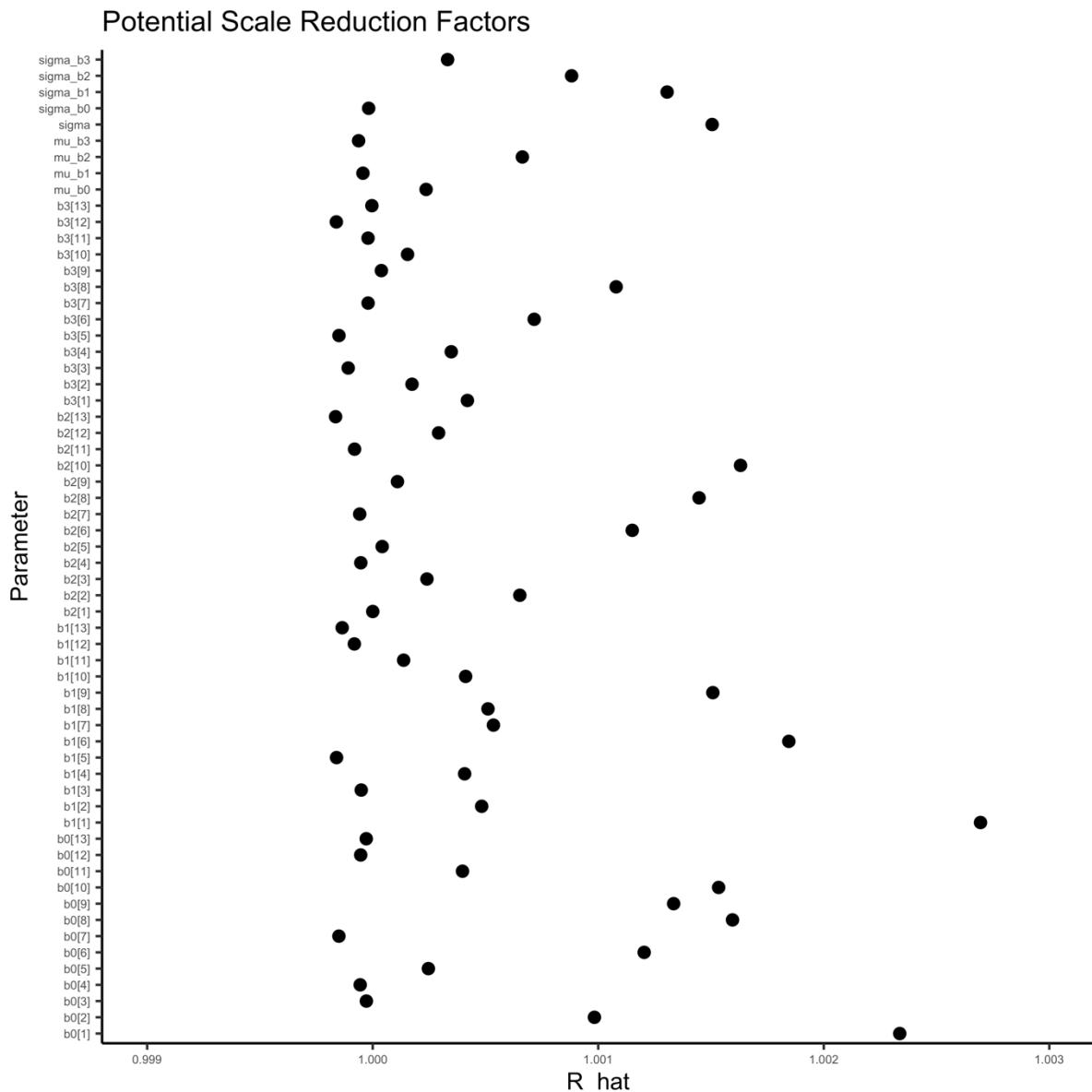
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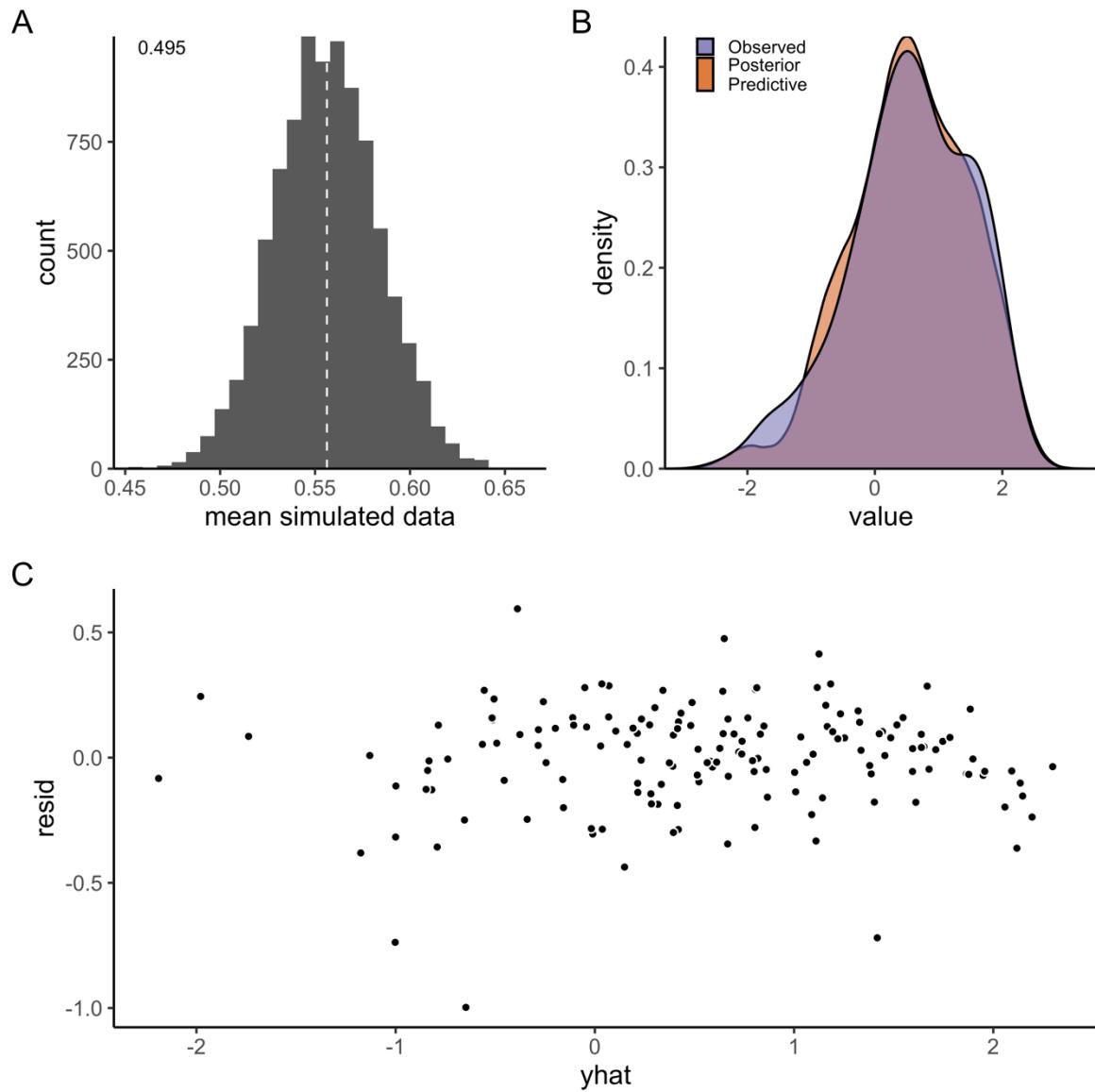
443 *Fig. S21. Potential scale reduction factor (\hat{R}) for the growth rate model. This factor is based
444 on the comparison of between and within-chain variation for the same parameter. A value close
445 to one implies chains converged to the same distribution. The index of the parameter
446 corresponds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

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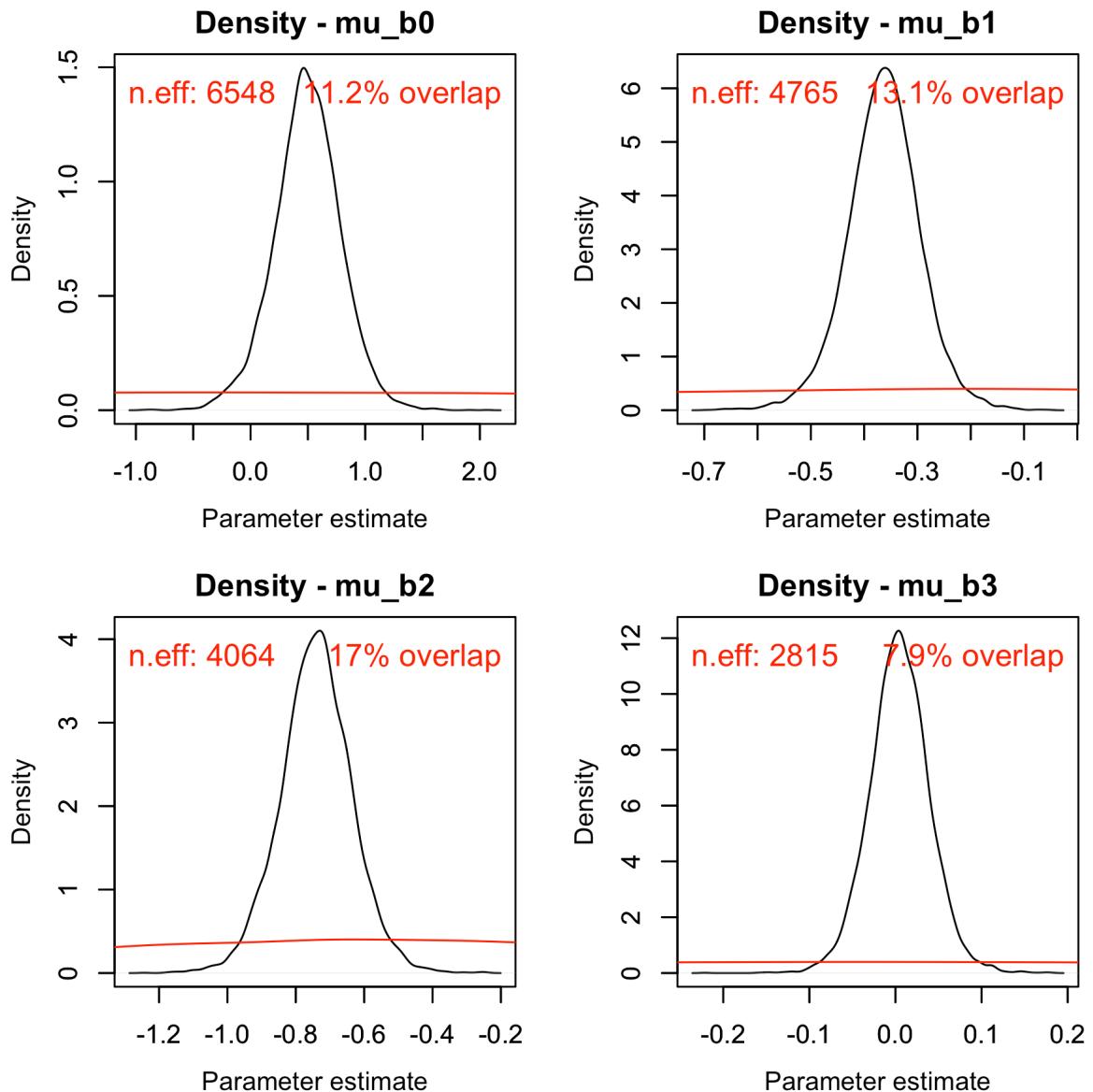
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451

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



460

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

463

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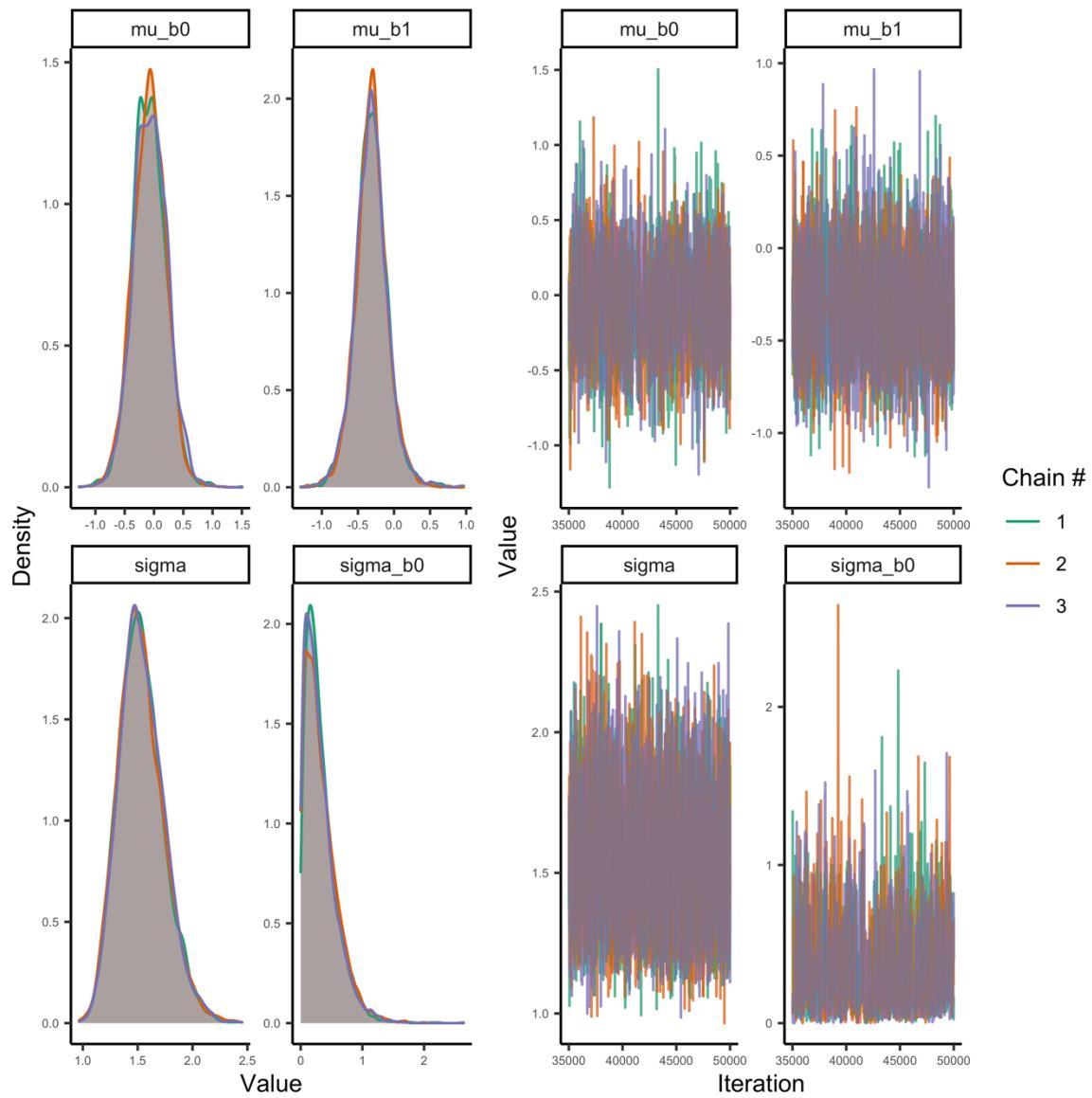
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469 *Optimum growth temperature*



470

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

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

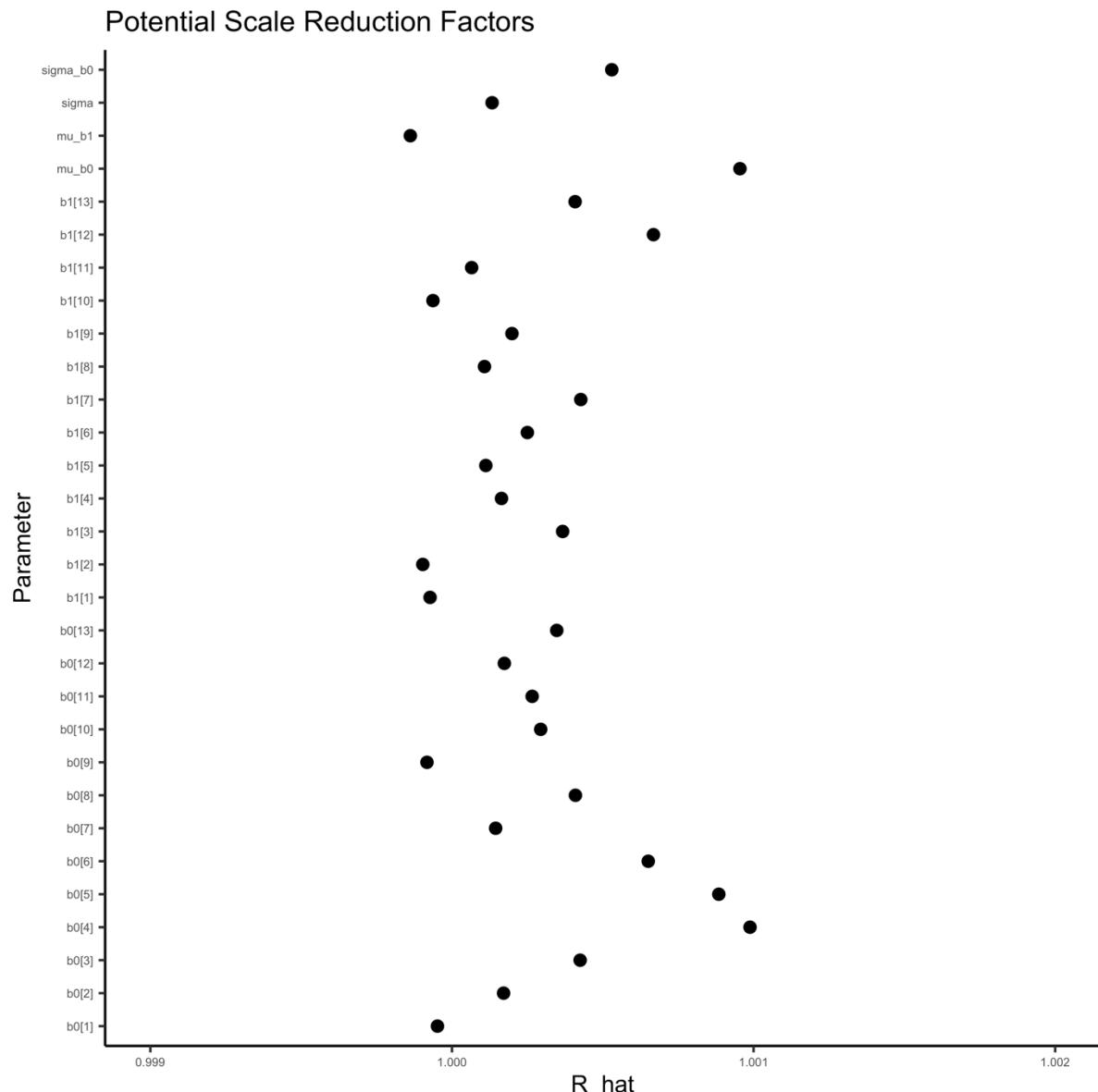
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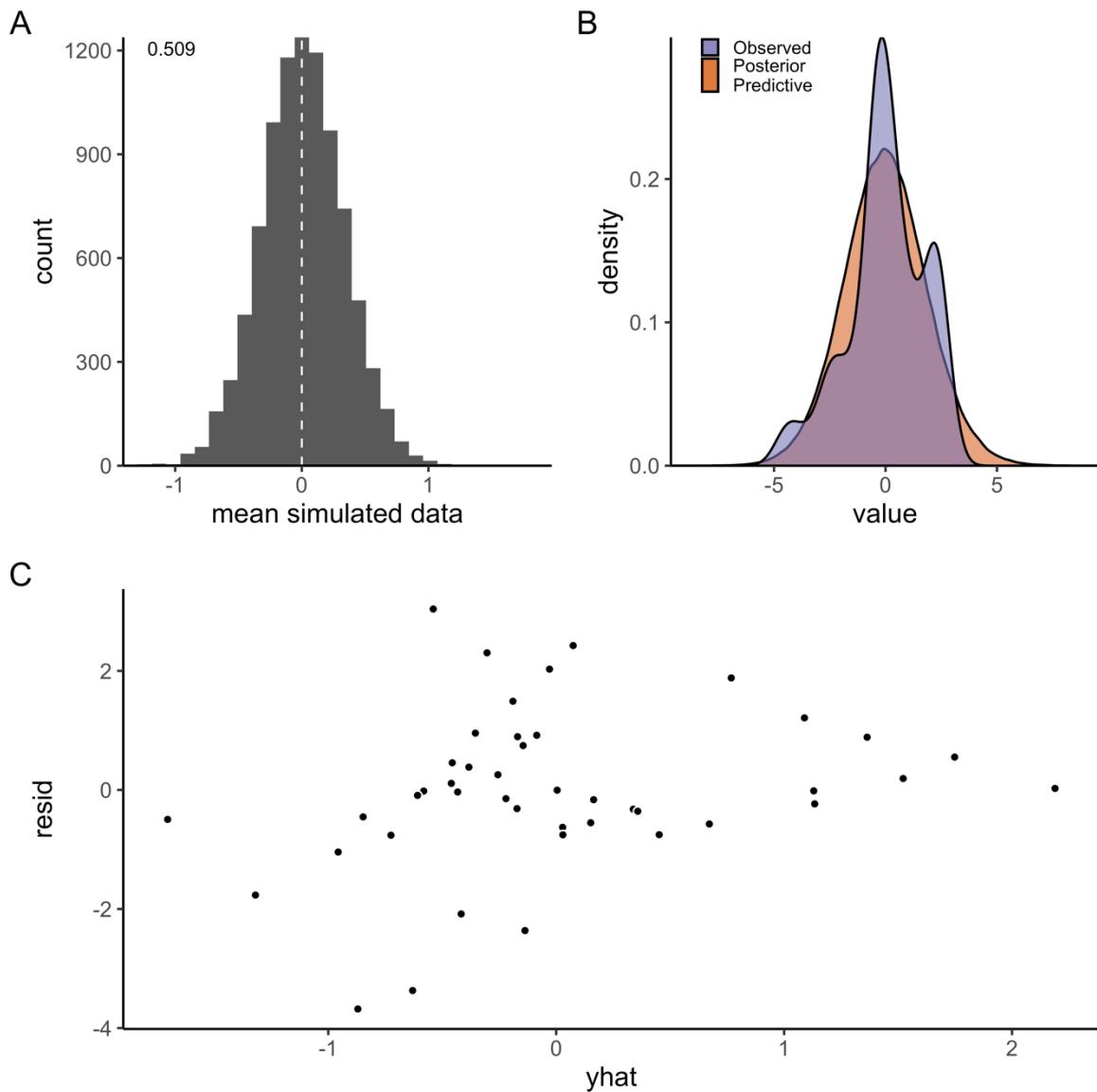
479 Fig. S25. Potential scale reduction factor (\hat{R}) for the T_{opt} model. This factor is based on the
 480 comparison of between and within-chain variation for the same parameter. A value close to
 481 one implies chains converged to the same distribution. The index of the parameter corresponds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

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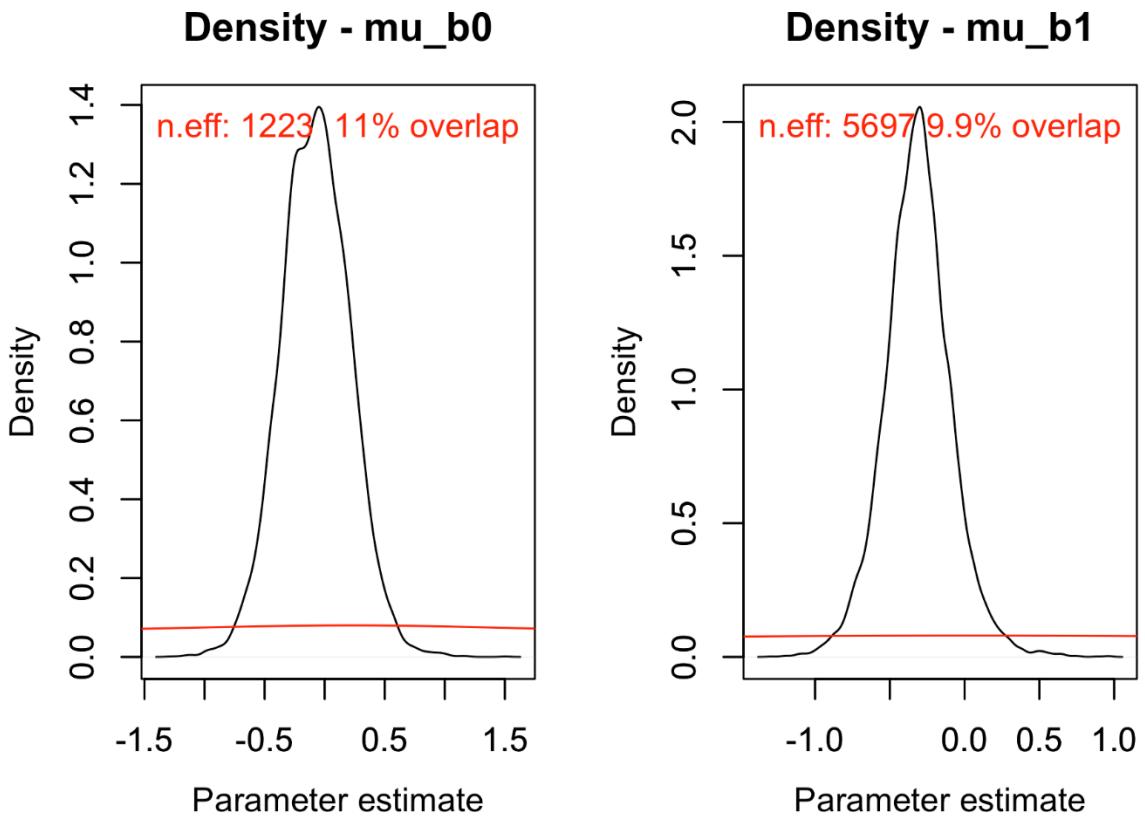
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488 Fig. S26. A) Model fit (mean) for the model of optimum growth temperature as a function of
 489 body mass. Fit is evaluated by simulating data from the likelihood (at each iteration of the
 490 MCMC chain), to compare how well it matches the original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



496

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

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509 **References**

- 510 Árnason, T., Björnsson, B., Steinarsson, A. & Oddgeirsson, M. (2009). Effects of
511 temperature and body weight on growth rate and feed conversion ratio in turbot
512 (*Scophthalmus maximus*). *Aquaculture*, 295, 218–225.
- 513 Baldwin, N.S. (1957). Food Consumption and Growth of Brook Trout at Different
514 Temperatures. *Transactions of the American Fisheries Society*, 86, 323–328.
- 515 Beamish, F.W.H. (1964). Respiration of fishes with special emphasis on standard oxygen
516 consumption II. Influence of weight and temperature on respiration of several
517 species'. *Canadian Journal of Zoology/Revue Canadienne de Zoologie*, 42, 177–188.
- 518 Beamish, F.W.H. & Mookherjii, P.S. (1964). Respiration of fishes with special emphasis on
519 standard oxygen consumption: I. influence of weight and temperature on respiration
520 of goldfish, *Carassius auratus* l. *Can. J. Zool.*, 42, 161–175.
- 521 Bermudes, M., Glencross, B., Austen, K. & Hawkins, W. (2010). The effects of temperature
522 and size on the growth, energy budget and waste outputs of barramundi (*Lates*
523 *calcarifer*). *Aquaculture*, 306, 160–166.
- 524 Binkowski, F.P. & Rudstam, L.G. (1994). Maximum Daily Ration of Great Lakes Bloater.
525 *Transactions of the American Fisheries Society*, 123, 335–343.
- 526 Björnsson, B., Steinarsson, A. & Árnason, T. (2007). Growth model for Atlantic cod (*Gadus*
527 *morhua*): Effects of temperature and body weight on growth rate. *Aquaculture*, 271,
528 216–226.
- 529 Björnsson, B. & Tryggvadóttir, S.V. (1996). Effects of size on optimal temperature for
530 growth and growth efficiency of immature Atlantic halibut (*Hippoglossus*
531 *hippoglossus* L.). *Aquaculture*, 142, 33–42.
- 532 Brett, J.R., Shelbourn, J.E. & Shoop, C.T. (1969). Growth rate and body composition of
533 fingerling sockeye salmon, *Oncorhynchus nerka*, in relation to temperature and ration
534 size. *J. Fish. Res. Bd. Can.*, 26, 2363–2394.
- 535 Chipps, S.R. & Wahl, D.H. (2004). Development and Evaluation of a Western Mosquitofish
536 Bioenergetics Model. *Transactions of the American Fisheries Society*, 133, 1150–
537 1162.
- 538 Cui, Y. & Wootton, R.J. (1988). Bioenergetics of growth of a cyprinid, *Phoxinus phoxinus*:
539 the effect of ration, temperature and body size on food consumption, faecal
540 production and nitrogenous excretion. *J Fish Biology*, 33, 431–443.
- 541 Degani, G., Gallagher, M.L. & Meltzer, A. (1989). The influence of body size and
542 temperature on oxygen consumption of the European eel, *Anguilla anguilla*. *J Fish*
543 *Biology*, 34, 19–24.
- 544 Deslauriers, D., Chipps, S.R., Breck, J.E., Rice, J.A. & Madenjian, C.P. (2017). Fish
545 Bioenergetics 4.0: An R-Based Modeling Application. *Fisheries*, 42, 586–596.
- 546 Du Perez, H., H., McLachlan, A. & Marais, J.F.K. (1986). Oxygen consumption of a shallow
547 water teleost, the spotted grunter, *Pomadasy commersonni* (Lacépède, 1802).
548 *Comparative Biochemistry and Physiology*, 84a, 61–70.
- 549 Duston, J., Astatkie, T. & MacIsaac, P.F. (2004). Effect of body size on growth and food
550 conversion of juvenile striped bass reared at 16–28 °C in freshwater and seawater.
551 *Aquaculture*, 234, 589–600.
- 552 Elliott, J.M. (1976). The Energetics of Feeding, Metabolism and Growth of Brown Trout
553 (*Salmo trutta* L.) in Relation to Body Weight, Water Temperature and Ration Size.
554 *The Journal of Animal Ecology*, 45, 923.
- 555 Froese, R. & Pauly, D. (2019). Editors. *FishBase*. World Wide Web electronic publication.
556 www.fishbase.org, (12/2019).

- 557 Froese, R., Thorson, J.T. & Reyes, R.B. (2014). A Bayesian approach for estimating length-
558 weight relationships in fishes. *Journal of Applied Ichthyology*, 30, 78–85.
- 559 From, J. & Rasmussen, G. (1984). A growth model, gastric evacuation, and body
560 composition in rainbow trout, *Salmo gairdneri* Richardson, 1836. *Dana*, 3, 61–139.
- 561 Glencross, B.D. & Felsing, M. (2006). Influence of fish size and water temperature on the
562 metabolic demand for oxygen by barramundi, *Lates calcarifer* (Bloch), in freshwater.
563 *Aquaculture Res*, 37, 1055–1062.
- 564 Glover, D.C., DeVries, D.R. & Wright, R.A. (2012). Effects of temperature, salinity and
565 body size on routine metabolism of coastal largemouth bass *Micropterus salmoides*.
566 *Journal of Fish Biology*, 81, 1463–1478.
- 567 Handeland, S.O., Imsland, A.K. & Stefansson, S.O. (2008). The effect of temperature and
568 fish size on growth, feed intake, food conversion efficiency and stomach evacuation
569 rate of Atlantic salmon post-smolts. *Aquaculture*, 283, 36–42.
- 570 Hayward, R.S. & Arnold, E. (1996). Temperature Dependence of Maximum Daily
571 Consumption in White Crappie: Implications for Fisheries Management. *Transactions
572 of the American Fisheries Society*, 125, 132–138.
- 573 Heuton, M., Ayala, L., Morante, A., Dayton, K., Jones, A.C., Hunt, J.R., et al. (2018).
574 Oxygen consumption of desert pupfish at ecologically relevant temperatures suggests
575 a significant role for anaerobic metabolism. *J Comp Physiol B*, 188, 821–830.
- 576 Horodysky, A.Z., Brill, R.W., Bushnell, P.G., Musick, J.A. & Latour, R.J. (2011).
577 Comparative metabolic rates of common western North Atlantic Ocean sciaenid
578 fishes. *Journal of Fish Biology*, 79, 235–255.
- 579 Imsland, A.K., Foss, A., Sparboe, L.O. & Sigurdsson, S. (2006). The effect of temperature
580 and fish size on growth and feed efficiency ratio of juvenile spotted wolffish
581 *Anarhichas minor*. *J Fish Biology*, 68, 1107–1122.
- 582 Iwata, N., Kikuchi, K., Honda, H., Kiyono, M. & Kurokura, H. (1994). Effects of temperature
583 on the growth of Japanese flounder. *Fisheries science*, 60, 527–531.
- 584 Laurel, B.J., Copeman, L.A., Spencer, M. & Iseri, P. (2017). Temperature-dependent growth
585 as a function of size and age in juvenile Arctic cod (*Boreogadus saida*). *ICES Journal
586 of Marine Science*, 74, 1614–1621.
- 587 Lessmark, O. (1983). Competition between perch (*Perca fluviatilis*) and roach (*Rutilus
588 rutilus*) in south Swedish lakes. PhD Thesis. Limnologiska Institutionen, Lunds
589 Universitet (Sweden).
- 590 Lin, X., Xie, S., Su, Y. & Cui, Y. (2008). Optimum temperature for the growth performance
591 of juvenile orange-spotted grouper (*Epinephelus coioides* H.). *Chin. J. Ocean.
592 Limnol.*, 26, 69–75.
- 593 Liu, J., Cui, Y. & Liu, J. (1998). Food consumption and growth of two piscivorous fishes, the
594 mandarin fish and the Chinese snakehead. *Journal of Fish Biology*, 53, 1071–1083.
- 595 Liu, J., Cui, Y. & Liu, J. (2000). Resting metabolism and heat increment of feeding in
596 mandarin fish (*Siniperca chuatsi*) and Chinese snakehead (*Channa argus*).
597 *Comparative Biochemistry and Physiology Part A: Molecular & Integrative
598 Physiology*, 127, 131–138.
- 599 Luo, Y.P. & Wang, Q.Q. (2012). Effects of body mass and temperature on routine metabolic
600 rate of juvenile largemouth bronze gudgeon *Coreius guichenoti*. *Journal of Fish
601 Biology*, 80, 842–851.
- 602 Marmulla, G. & Rosch, R. (1990). Maximum daily ration of juvenile fish fed on living
603 natural zooplankton. *J Fish Biology*, 36, 789–801.
- 604 Mesa, M.G., Weiland, L.K., Christiansen, H.E., Sauter, S.T. & Beauchamp, D.A. (2013).
605 Development and evaluation of a bioenergetics model for bull trout. *Transactions of
606 the American Fisheries Society*, 142, 41–49.

- 607 Meskendahl, L., Herrmann, J.-P. & Temming, A. (2010). Effects of temperature and body
608 mass on metabolic rates of sprat, *Sprattus sprattus* L. *Mar Biol*, 157, 1917–1927.
- 609 Messmer, V., Pratchett, M.S., Hoey, A.S., Tobin, A.J., Coker, D.J., Cooke, S.J., *et al.* (2017).
610 Global warming may disproportionately affect larger adults in a predatory coral reef
611 fish. *Global Change Biology*, 23, 2230–2240.
- 612 Milano, D., Vigliano, P. & Beauchamp, D. (2016). Effect of body size and temperature on
613 respiration of *Galaxias maculatus* (Pisces: Galaxiidae). *New Zealand Journal of
614 Marine and Freshwater Research*, 51, 295–303.
- 615 Nytrø, A.V., Vikingstad, E., Foss, A., Hangstad, T.A., Reynolds, P., Eliassen, G., *et al.*
616 (2014). The effect of temperature and fish size on growth of juvenile lumpfish
617 (*Cyclopterus lumpus* L.). *Aquaculture*, 434, 296–302.
- 618 Ohlberger, J., Mehner, Thomas., Staaks, Georg. & Hölker, Franz. (2012). Intraspecific
619 temperature dependence of the scaling of metabolic rate with body mass in fishes and
620 its ecological implications. *Oikos*, 121, 245–251.
- 621 Patterson, J.T., Mims, S.D. & Wright, R.A. (2013). Effects of body mass and water
622 temperature on routine metabolism of American paddlefish *Polyodon spathula*:
623 routine metabolism of *Polyodon spathula*. *J Fish Biol*, 82, 1269–1280.
- 624 Peck, M.A., Buckley, L.J. & Bengtson, D.A. (2005). Effects of temperature, body size and
625 feeding on rates of metabolism in young-of-the-year haddock. *Journal of Fish
626 Biology*, 66, 911–923.
- 627 Pirozzi, I. & Booth, M.A. (2009). The effect of temperature and body weight on the routine
628 metabolic rate and postprandial metabolic response in muloway, *Argyrosomus
629 japonicus*. *Comparative Biochemistry and Physiology Part A: Molecular &
630 Integrative Physiology*, 154, 110–118.
- 631 Rangel, R.E. & Johnson, D.W. (2018). Metabolic responses to temperature in a sedentary reef
632 fish, the bluebanded goby (*Lythrypnus dalli*, Gilbert). *Journal of Experimental
633 Marine Biology and Ecology*, 501, 83–89.
- 634 Siikavuopio, S.I., Foss, A., Saether, B.-S., Gunnarsson, S. & Imsland, A.K. (2013).
635 Comparison of the growth performance of offspring from cultured versus wild
636 populations of arctic charr, *Salvelinus alpinus* (L.), kept at three different
637 temperatures. *Aquac Res*, 44, 995–1001.
- 638 Slesinger, E., Andres, A., Young, R., Seibel, B., Saba, V., Phelan, B., *et al.* (2019). The effect
639 of ocean warming on black sea bass (*Centropristes striata*) aerobic scope and hypoxia
640 tolerance. *PLoS ONE*, 14, e0218390.
- 641 Sun, L. & Chen, H. (2014). Effects of water temperature and fish size on growth and
642 bioenergetics of cobia (*Rachycentron canadum*). *Aquaculture*, 426–427, 172–180.
- 643 Tirsgaard, B., Behrens, J.W. & Steffensen, J.F. (2015). The effect of temperature and body
644 size on metabolic scope of activity in juvenile Atlantic cod *Gadus morhua* L.
645 *Comparative Biochemistry and Physiology Part A: Molecular & Integrative
646 Physiology*, 179, 89–94.
- 647 Tomala, D., Chavarria, J. & Angeles, B. (2014). Evaluacion de la tasa de consumo de
648 oxigeno de *Collossoma macropomum* en relacion al peso corporal y temperatura del
649 agua. *lajar*, 42, 971–979.
- 650 Tomiyama, T., Kusakabe, K., Otsuki, N., Yoshida, Y., Takahashi, S., Hata, M., *et al.* (2018).
651 Ontogenetic changes in the optimal temperature for growth of juvenile marbled
652 flounder *Pseudopleuronectes yokohamae*. *Journal of Sea Research*, 141, 14–20.
- 653 Wang, H.P., Hayward, R.S., Whittlege, G.W. & Fischer, S.A. (2003). Prey-size Preference,
654 Maximum Handling Size, and Consumption Rates for Redear Sunfish *Lepomis
655 microlophus* Feeding on Two Gastropods Common to Aquaculture Ponds. *J World
656 Aquaculture Soc*, 34, 379–386.

- 657 Wootton, R.J., Allen, J.R.M. & Cole, S.J. (1980). Effect of body weight and temperature on
658 the maximum daily food consumption of *Gasterosteus aculeatus* L. and *Phoxinus*
659 *phoxinus* (L.): selecting an appropriate model. *J Fish Biology*, 17, 695–705.
- 660 Xie, Xiaojun. & Sun, Ruyung. (1990). The Bioenergetics of the Southern Catfish (*Silurus*
661 *meridionalis* Chen). I. Resting Metabolic Rate as a Function of Body Weight and
662 Temperature. *Physiological Zoology*, 63, 1181–1195.
- 663 Yamanaka, H., Takahara, T., Kohmatsu, Y. & Yuma, M. (2013). Body size and temperature
664 dependence of routine metabolic rate and critical oxygen concentration in larvae and
665 juveniles of the round crucian carp *Carassius auratus grandoculis* Temminck &
666 Schlegel 1846. *J. Appl. Ichthyol.*, 29, 891–895.
- 667 Zhang, L., Zhao, Z.-G. & Fan, Q.-X. (2017). Effects of water temperature and initial weight
668 on growth, digestion and energy budget of yellow catfish *Pelteobagrus fulvidraco*
669 (Richardson, 1846). *J Appl Ichthyol*, 33, 1108–1117.
- 670