

1 **Appendix S1**

2 **Supporting Information for**

3 Optimum growth temperature declines with body size within fish species

4 Max Lindmark^{a,1}, Jan Ohlberger^b, Anna Gårdmark^c

5

6 ^a Swedish University of Agricultural Sciences, Department of Aquatic Resources, Institute of

7 Coastal Research, Skolgatan 6, Öregrund 742 42, Sweden

8 ^b School of Aquatic and Fishery Sciences (SAFS), University of Washington, Box 355020,

9 Seattle, WA 98195-5020, USA

10 ^c Swedish University of Agricultural Sciences, Department of Aquatic Resources, Skolgatan 6,

11 SE-742 42 Öregrund, Sweden

12

13 ¹Author to whom correspondence should be addressed. Current address:

14 Max Lindmark, Swedish University of Agricultural Sciences, Department of Aquatic

15 Resources, Institute of Marine Research, Turistgatan 5, Lysekil 453 30, Sweden, Tel.:

16 +46(0)104784137, email: max.lindmark@slu.se

17

18

19

20

21

22

23

24 **Contents**

25	Literature search, selection process and criteria	3
26	<i>Maximum consumption rate</i>	4
27	<i>Metabolic rate</i>	5
28	<i>Growth rates & optimum temperature for growth over body mass</i>	5
29	Data overview	12
30	<i>Maximum consumption & metabolic rate</i>	12
31	<i>Growth rate</i>	13
32	Supplementary methods and analysis	15
33	Model validation and fit.....	22
34	<i>Maximum consumption rate – below peak temperatures</i>	22
35	<i>Maximum consumption rate – including beyond peak temperatures</i>	26
36	<i>Metabolic rate</i>	30
37	<i>Optimum growth temperature</i>	35
38	References.....	39
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
51		
52		

53 **Literature search, selection process and criteria**

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

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

78 For consumption and growth rate, we determined if each data point within species was
79 below or beyond peak temperature for a size group within a species either by using information
80 provided by the authors (e.g., by deriving a polynomial regression of the rate as a function of
81 temperature to find the temperature of peak rate), by fitting Sharpe Schoolfield equations (see
82 main text, Eq. 4) or visually inspecting data for each species separately. Whether a data point
83 is below or above peak or optimum temperatures is indicated by a separate column in the data
84 (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.

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 (as reported by the original authors),
138 depending on data availability (see Table S1). It is important to control for feeding rations as
139 it affects the temperature optimum for growth (Brett et al., 1969). This was achieved in different
140 ways in the different experimental studies, but commonly involved excess feeding rations once
141 or several times per day. The key description we looked for in the study was that food was not
142 limiting. We treat data as individual-level growth (per fish); however, these were commonly
143 measured as averages for multiple individuals. In the case growth was length-based, we
144 converted it to mass using weight-length relationships from FishBase (Froese et al., 2014;
145 Froese & Pauly, 2019). We compiled two separate data sets: raw growth rates
146 (growth_data.xlsx) and temperature at optimum growth (growth_data_Topt.xlsx). In the latter,
147 we defined optimum temperature for growth as the fitted optimum temperature by size-class
148 (usually estimated in the original study). Therefore, the optimum temperature may not always
149 correspond to an actual experimental temperature but could be an estimation between two
150 temperature treatments. If the optimum temperature (by size group) was not estimated in the

151 original study, we used the temperature where growth rate was maximized. All growth rates
152 were expressed in unit % day⁻¹.

153

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 [°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	G, T _{opt} , C, M

	(Froese & Pauly, 2019).	
<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 (Froese & Pauly, 2019).	G, T _{opt} , C, M
<i>w_maturation_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	G, T _{opt} , C, M

	on the experimental protocol, information on conversion to standard “ <i>unit</i> ”, source of the data (literature search or cited in paper from literature search)	
reference	Source (See Table S2).	G, T _{opt} , C, M

156

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 et al., 2018)
<i>Cyclopterus lumpus</i>	Lumpfish	G, T _{opt}	(Nyrø et al., 2014)
<i>Paralichthys olivaceus</i>	Japanese flounder (alt. bastard halibut, Japanese halibut or Olive flounder)	G, T _{opt} , C	(Iwata et al., 1994)
<i>Salvelinus alpinus</i>	Arctic char	G, T _{opt}	(Siikavuopio et al., 2013)
<i>Salmo salar</i>	Atlantic salmon	G, T _{opt}	(Handeland et al., 2008)
<i>Lates calcarifer</i>	Barramundi	G, T _{opt} , C, M	(Bermudes et al., 2010) (Bermudes et al., 2010) (Bermudes et al., 2010) (Glencross & Felsing, 2006)
<i>Gadus morhua</i>	Atlantic cod	G, T _{opt} , M	(Björnsson et al., 2007)(Tirsgaard et al., 2015)
<i>Hippoglossus hippoglossus</i>	Atlantic halibut	G, T _{opt}	(Björnsson & Tryggvadóttir, 1996)
<i>Scophthalmus maximus</i>	Turbot	G, T _{opt}	(Árnason et al., 2009)
<i>Boreogadus saida</i>	Arctic cod	G, T _{opt}	(Laurel et al., 2017)
<i>Rachycentron canadum</i>	Cobia	G, T _{opt} , C	(Sun & Chen, 2014)
<i>Pelteobagrus fulvidraco</i>	Yellow catfish	G, T _{opt} , C	(Zhang et al., 2017)
<i>Anarhichas minor</i>	Spotted wolffish	G, T _{opt}	(Imsland et al., 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 & Wootten, 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	(Chipp & Wahl, 2004)
<i>Morone saxatilis</i>	Striped bass	C	(Duston et al., 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 et al., 2003)
<i>Channa argus</i>	Chinese snakehead (alt. Northern snakehead or Snakehead)	C, M	(Liu et al., 1998) (Liu et al., 2000)
<i>Siniperca chuatsi</i>	Mandarin fish	C, M	(Liu et al., 1998) (Liu et al., 2000)
<i>Gasterosteus aculeatus</i>	Three-spined stickleback	C	(Wootton et al., 1980)
<i>Salmo trutta</i>	Brown trout	C	(Elliott, 1976)
<i>Epinephelus coioides</i>	Orange-spotted grouper	C	(Lin et al., 2008)
<i>Coregonus albula</i>	Vendace	M	(Ohlberger et al., 2012)
<i>Coregonus fontanae</i>	Stechlin cisco	M	(Ohlberger et al., 2012)
<i>Abramis brama</i>	Common bream	M	(Ohlberger et al., 2012)
<i>Rutilus rutilus</i>	Common roach	M	(Ohlberger et al., 2012)
<i>Salvelinus confluentus</i>	Bull trout	M	(Mesa et al., 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 et al., 1986)
<i>Melanogrammus aeglefinus</i>	Haddock	M	(Peck et al., 2005)
<i>Centropristes striata</i>	Black sea bass	M	(Slesinger et al., 2019)
<i>Anguilla anguilla</i>	European eel	M	(Degani et al., 1989)
<i>Micropterus salmoides</i>	Largemouth bass	M	(Glover et al., 2012)
<i>Cyprinodon macularius</i>	Desert pupfish	M	(Heuton et al., 2018)
<i>Micropogonias undulatus</i>	Atlantic croaker	M	(Horodysky et al., 2011)
<i>Leiostomus xanthurus</i>	Spot	M	(Horodysky et al., 2011)
<i>Coreius guichenoti</i>	Largemouth bronze	M	(Luo & Wang, 2012)

	gudgeon		
<i>Sprattus sprattus</i>	European sprat	M	(Meskendahl et al., 2010)
<i>Plectropomus leopardus</i>	Leopard coral grouper	M	(Messmer et al., 2017)
<i>Galaxias maculatus</i>	Common galaxias	M	(Milano et al., 2016)
<i>Polyodon spathula</i>	American paddlefish (alt. Mississippi paddlefish)	M	(Patterson et al., 2013)
<i>Argyrosomus japonicus</i>	Mulloway	M	(Pirozzi & Booth, 2009)
<i>Lythrypnus dalli</i>	Bluebanded goby	M	(Rangel & Johnson, 2018)
<i>Colossoma macropomum</i>	Tambaqui (alt. Cachama)	M	(Tomala et al., 2014)
<i>Carassius auratus grandoculis</i>	Round crucian carp (alt. Nigorobuna)	M	(Yamanaka et al., 2013)

161

162

163

164

165

166

167

168

169

170

171

172

173

174

175

176

177

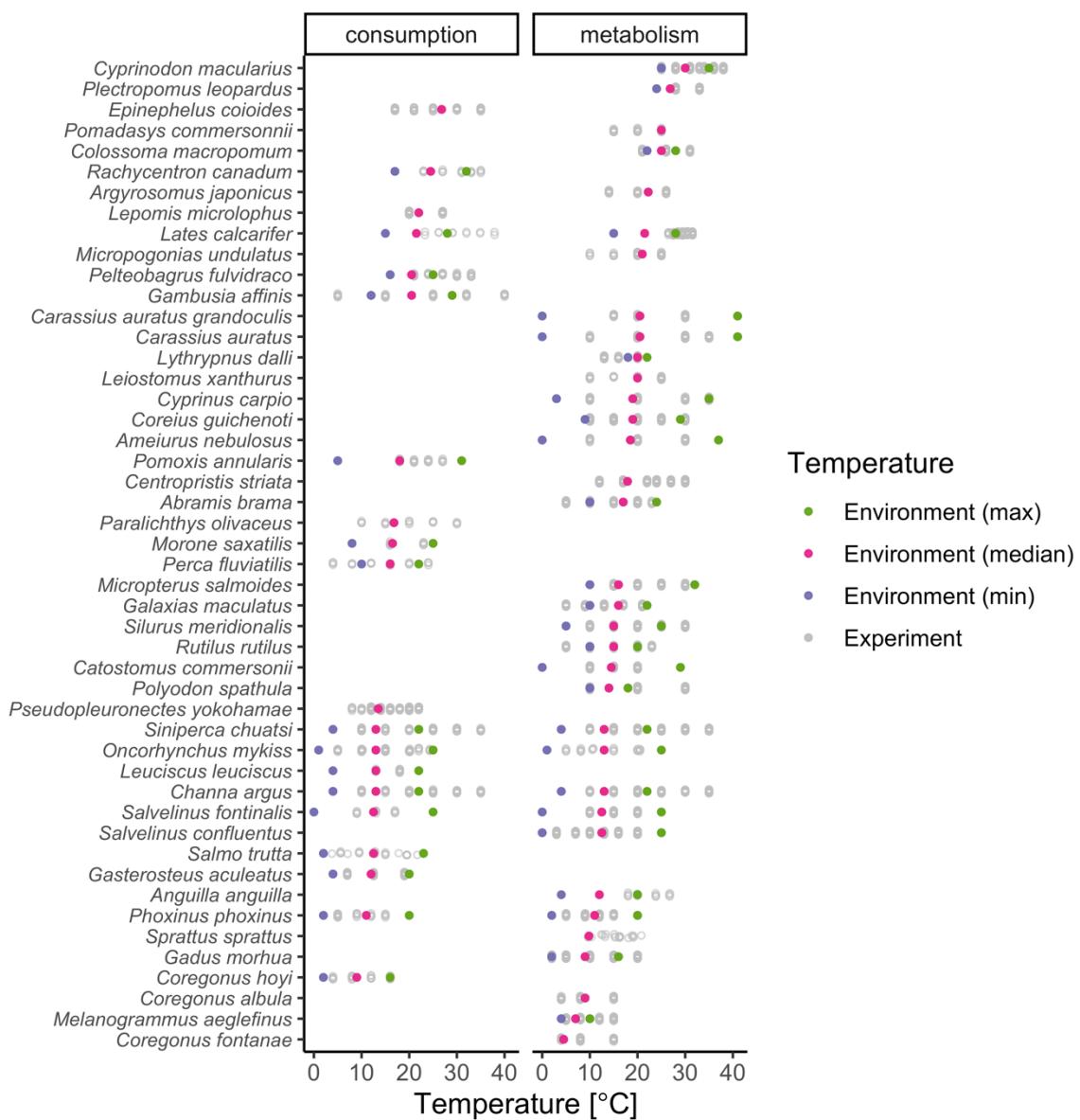
178

179

180

181

182

183 **Data overview**184 ***Maximum consumption & metabolic rate***

185

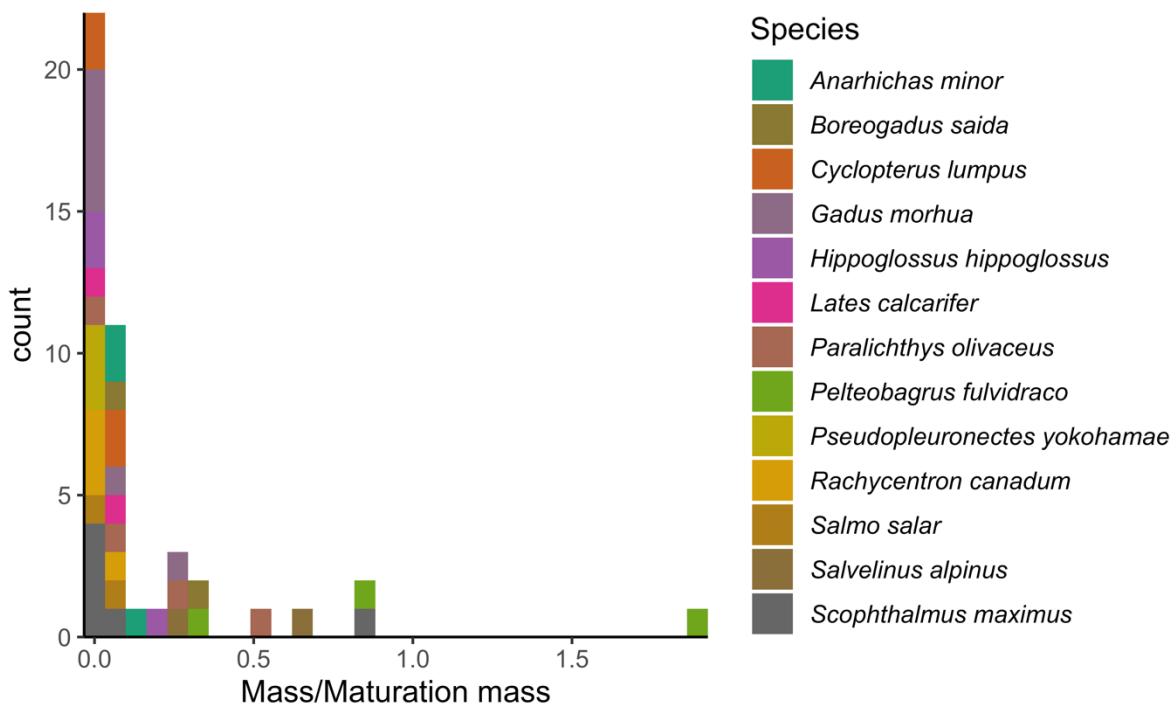
186 *Fig. S1. Experimental temperatures (gray) and environmental (min, median and max)*187 *temperatures (purple, pink and green, respectively) of species represented in the consumption*

188 (left) and metabolism (right) data sets. Missing temperatures means information was not
189 available on FishBase. Experimental temperatures are jittered vertically for visibility.

190

191

192 **Growth rate**



193
194 Fig. S2. The distribution of rescaled masses for individual observations (mass/mass at
195 maturation), where color indicate species.

196

197

198

199

200

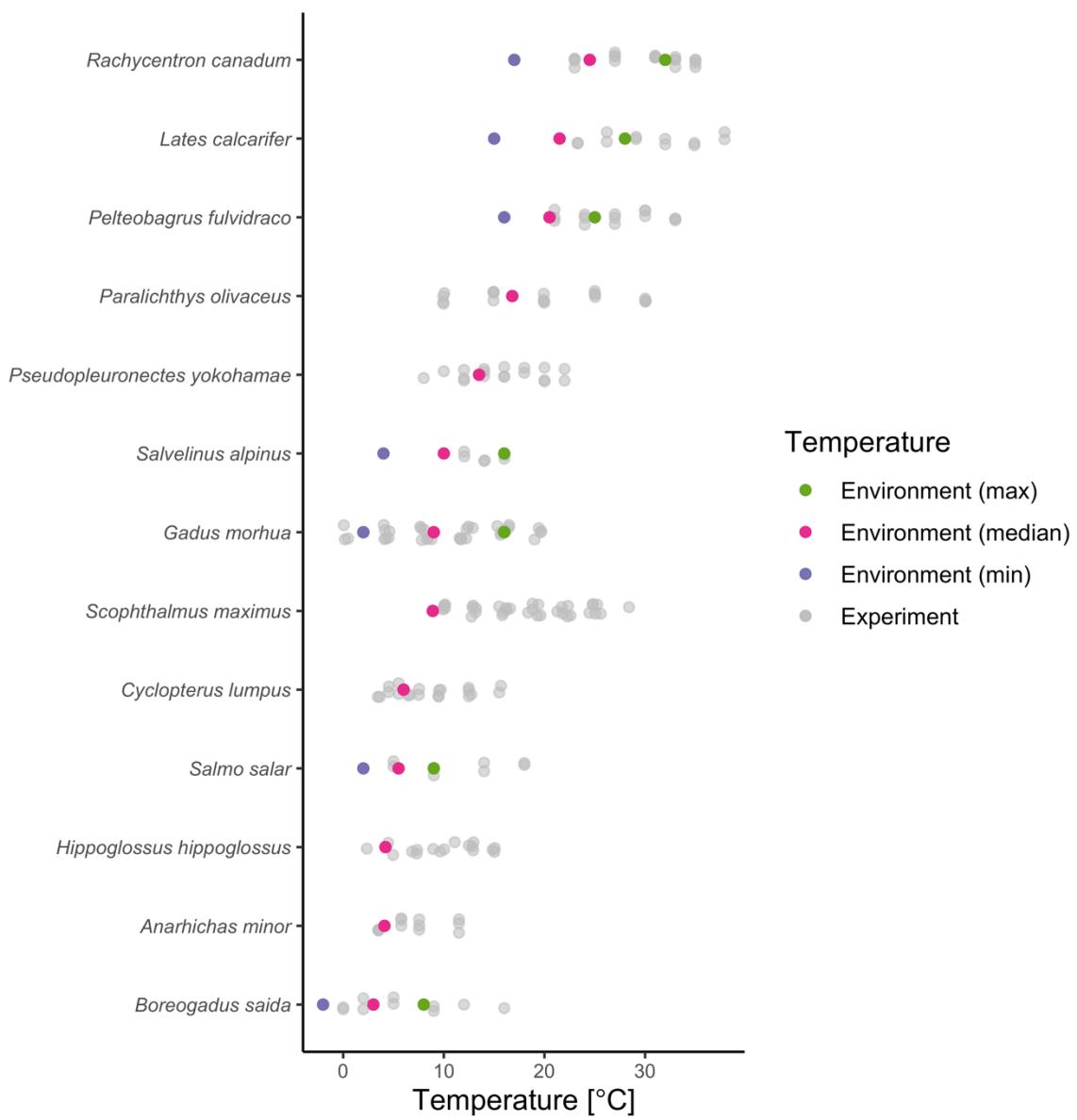
201

202

203

204

205
206
207
208



209
210
211
212
213

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

214 **Supplementary methods and analysis**

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

Model	Parameter	Description	Prior distribution
Log-linear regressions for consumption and metabolism	$\mu_{\beta_{0s}}$	Hyperparameter (average intercept for standard metabolic rate across species). <i>Only for the metabolism models.</i>	$N(-2, 5)$
	$\mu_{\beta_{0r}}$	Hyperparameter (average intercept for routine and resting metabolic rate across species). <i>Only for the metabolism models.</i>	$N(-1, 5)$
	μ_{β_0}	Hyperparameter (average intercept across species). <i>Only for the consumption 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 (unimodal consumption data)	μ_{C_0j}	Hyperparameter (average consumption at reference temperature [-10 on centered scale] across species)	$N(1, 1)$
	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.)	$U(0, 10)$

222

223

224

225

226

227

228

229

230

231

232

233

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

Model	m*t	Species-varying parameter(s)	WAIC metabolism	WAIC consumption
M1	Yes	$\beta_0, \beta_1, \beta_2, \beta_3$	0 (274.6)	3.4 (564.6)
M2		$\beta_0, \beta_1, \beta_2$	1.2 (275.8)	1.87 (563.1)
M3a		β_0, β_1	305.8 (580.4)	147.1 (708.3)
M3b		β_0, β_2	385.3 (659.9)	68.5 (629.7)
M4		β_0	648.6 (923.2)	189.4 (750.6)
M5		$\beta_0, \beta_1, \beta_2$	6.1 (280.6)	0 (561.2)
M6a	No	β_0, β_1	348.2 (622.8)	164.8 (726.0)
M6b		β_0, β_2	386.6 (661.2)	72.5 (633.7)
M7		β_0	681.5 (956.1)	211.9 (773.1)

244
 245
 246
 247
 248
 249
 250
 251

252 **Table S5.** Comparison of the two models fitted to optimum growth temperature data. The
253 WAIC columns shows Δ WAIC and absolute WAIC in brackets, rounded to the nearest decimal,
254 where Δ WAIC is the difference between each models' WAIC and the lowest WAIC across
255 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)

256

257

258

259

260

261

262

263

264

265

266

267

268

269

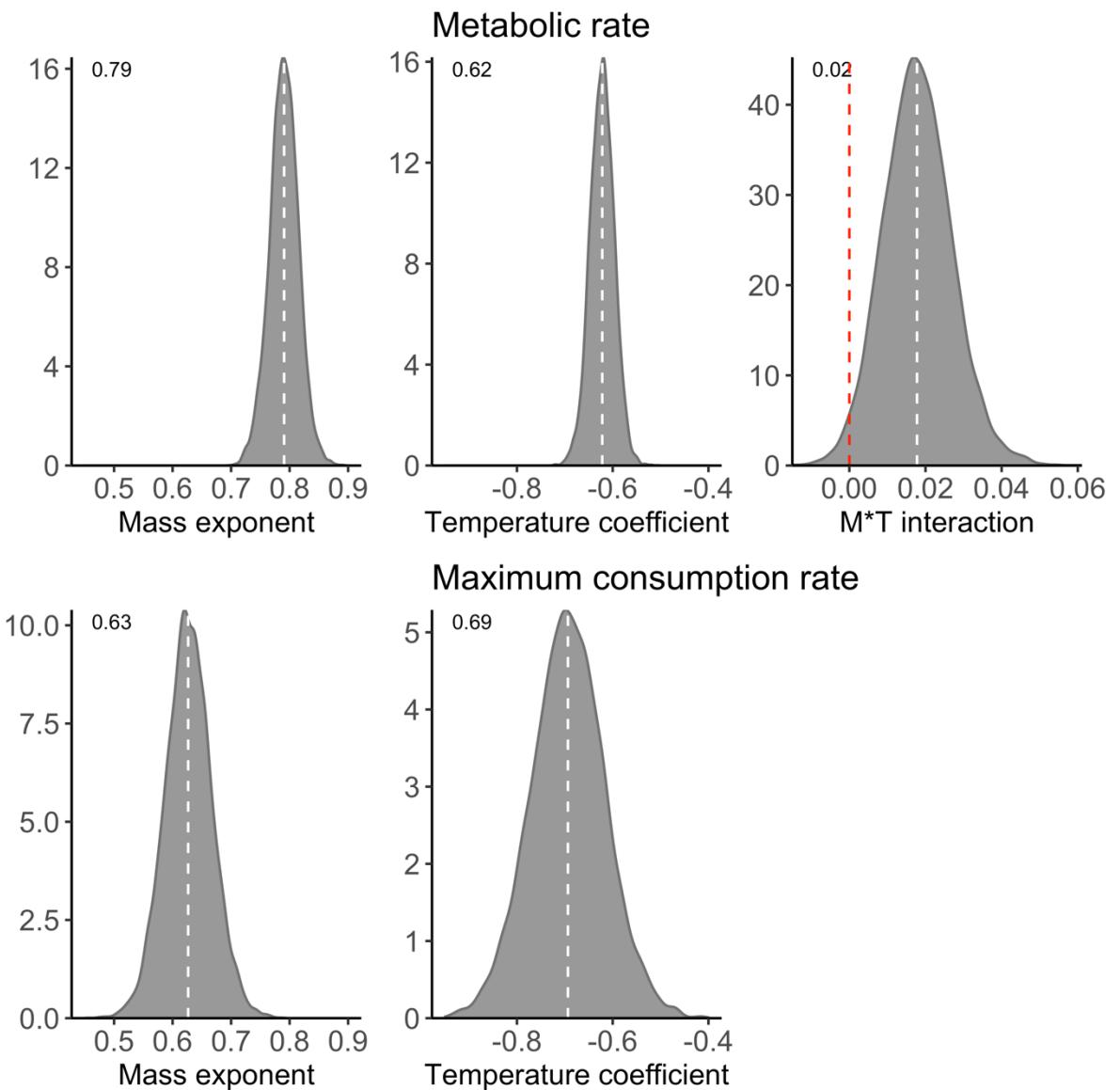
270

271

272

273

274

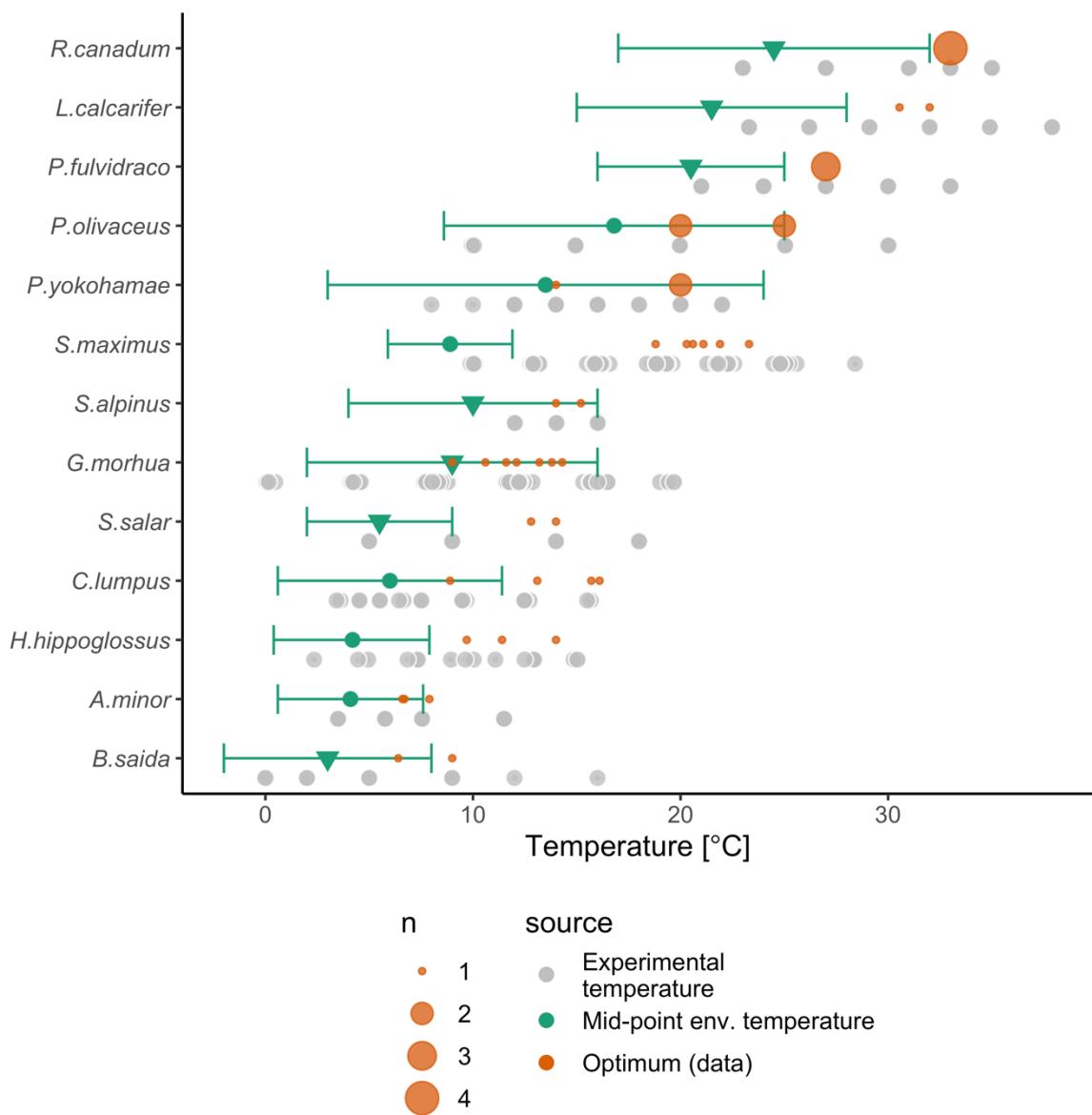


275

276 *Fig. S4. Posterior distributions of the global intraspecific mass exponents (μ_{β_1}) and*
 277 *temperature coefficients (μ_{β_2}) for metabolic rate (top) and maximum consumption rate*
 278 *(bottom). For metabolism, the global interaction coefficient (μ_{β_3}) is also shown (estimated and*
 279 *presented on an Arrhenius temperature scale), but for consumption this term was not included*
 280 *in the selected model. Numbers in the top left corner correspond to the posterior median. The*
 281 *axes are the same for each parameter for comparison between the two rates.*

282

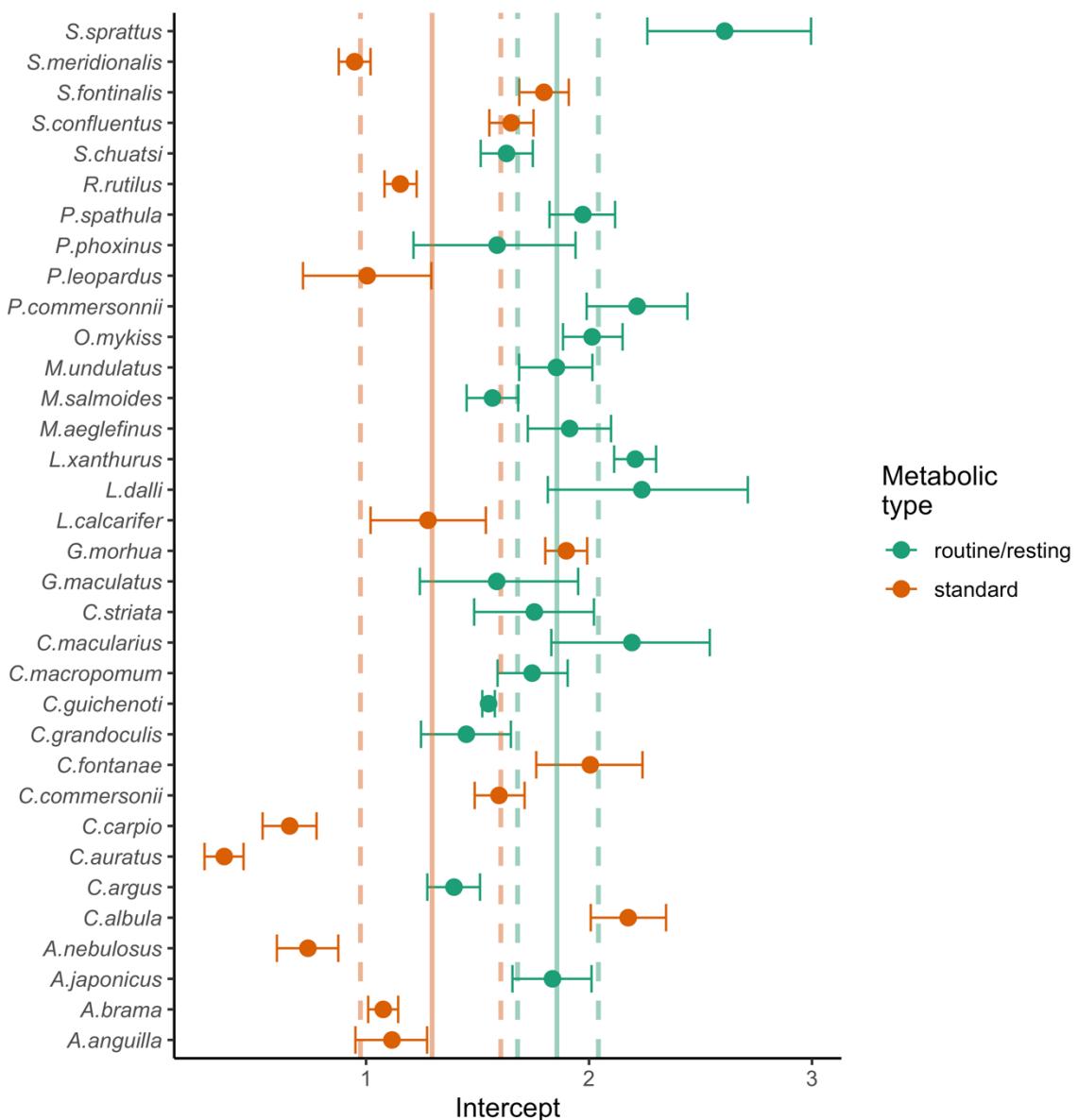
283



284

285 *Fig. S5. Experimental temperatures (grey) overlap environmental temperatures (green), and*
 286 *optimum growth temperatures (orange) are typically at the upper end or above the*
 287 *environmental range. Horizontal green lines show the minimum and maximum environmental*
 288 *temperature based on either temperature in distribution range (triangles) or modelled*
 289 *distribution maps (circles), both taken from FishBase. The optimum growth temperatures are*
 290 *depicted for all size-classes per species, where the circle size is proportional to number of*
 291 *observations at that temperature.*

292



293

294 Fig. S6. Posterior median of species-level intercepts (points) and their 95% credible interval
 295 (horizontal error bars). Colors indicate the type of metabolism measurement for each species.
 296 Vertical solid lines are the posterior medians of the global intercepts (orange for standard
 297 metabolic rate, μ_{β_0s} , and green for routine or resting metabolic rate, μ_{β_0r}), and the dashed
 298 vertical lines show the 95% credible intervals for the global parameters.

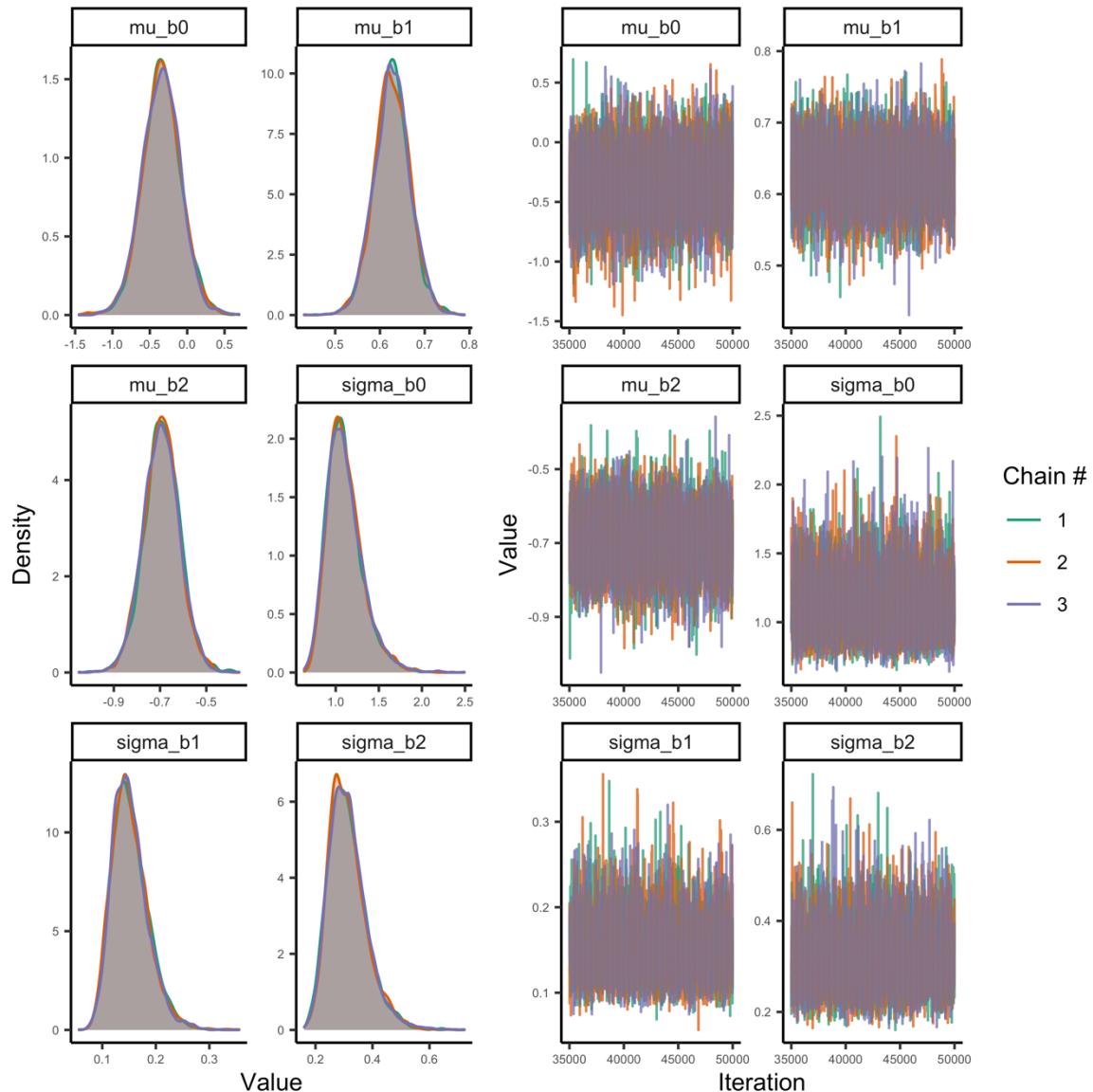
299

300 Model validation and fit

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

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

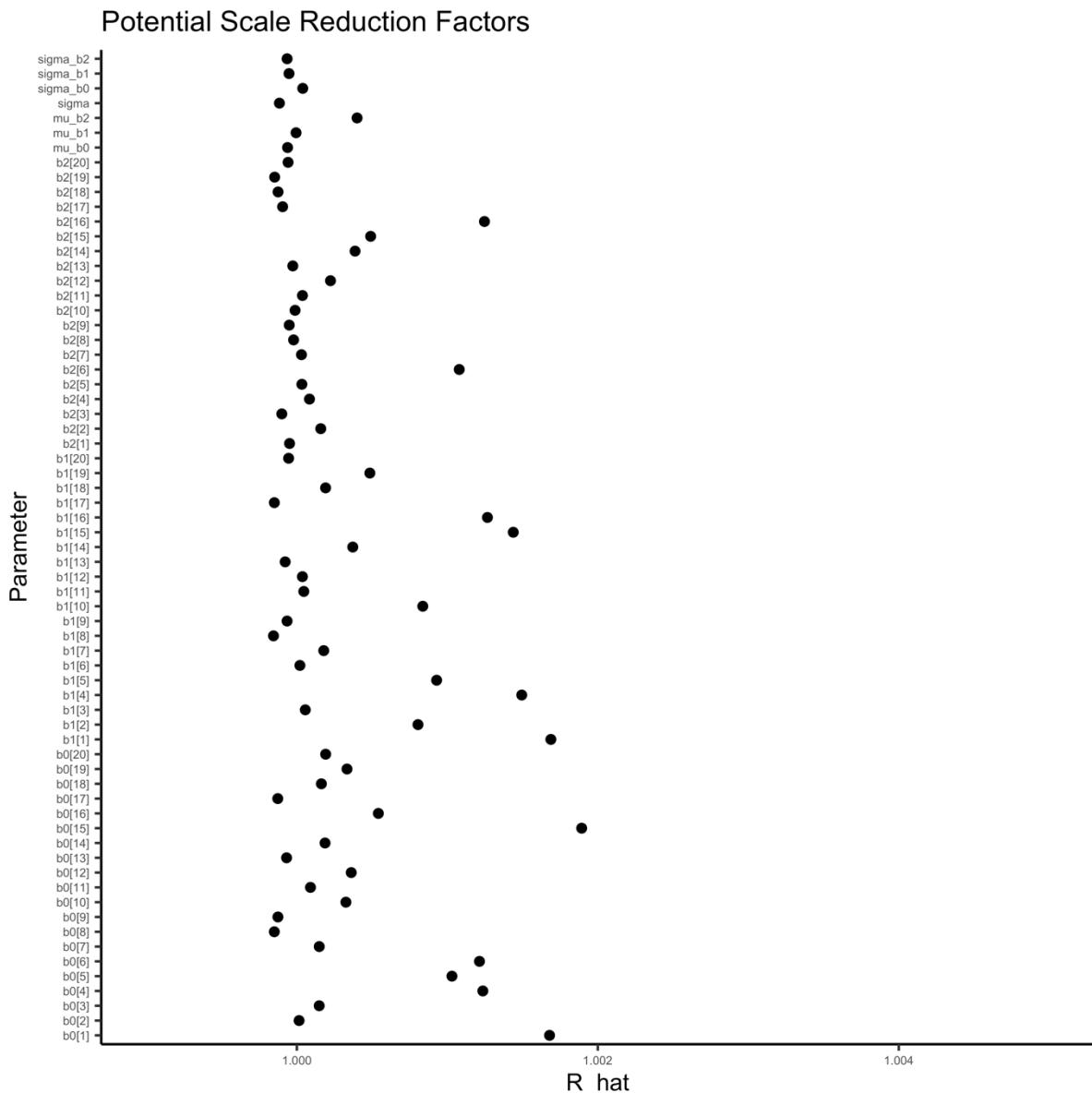
303 Maximum consumption rate – below peak temperatures



304

305 Fig. S7. Posterior densities and trace plots for evaluation of chain convergence (by chain,
306 indicated by color), for the global-level parameters for the log-linear maximum consumption
307 rate model at temperatures below peak temperatures.

308



309

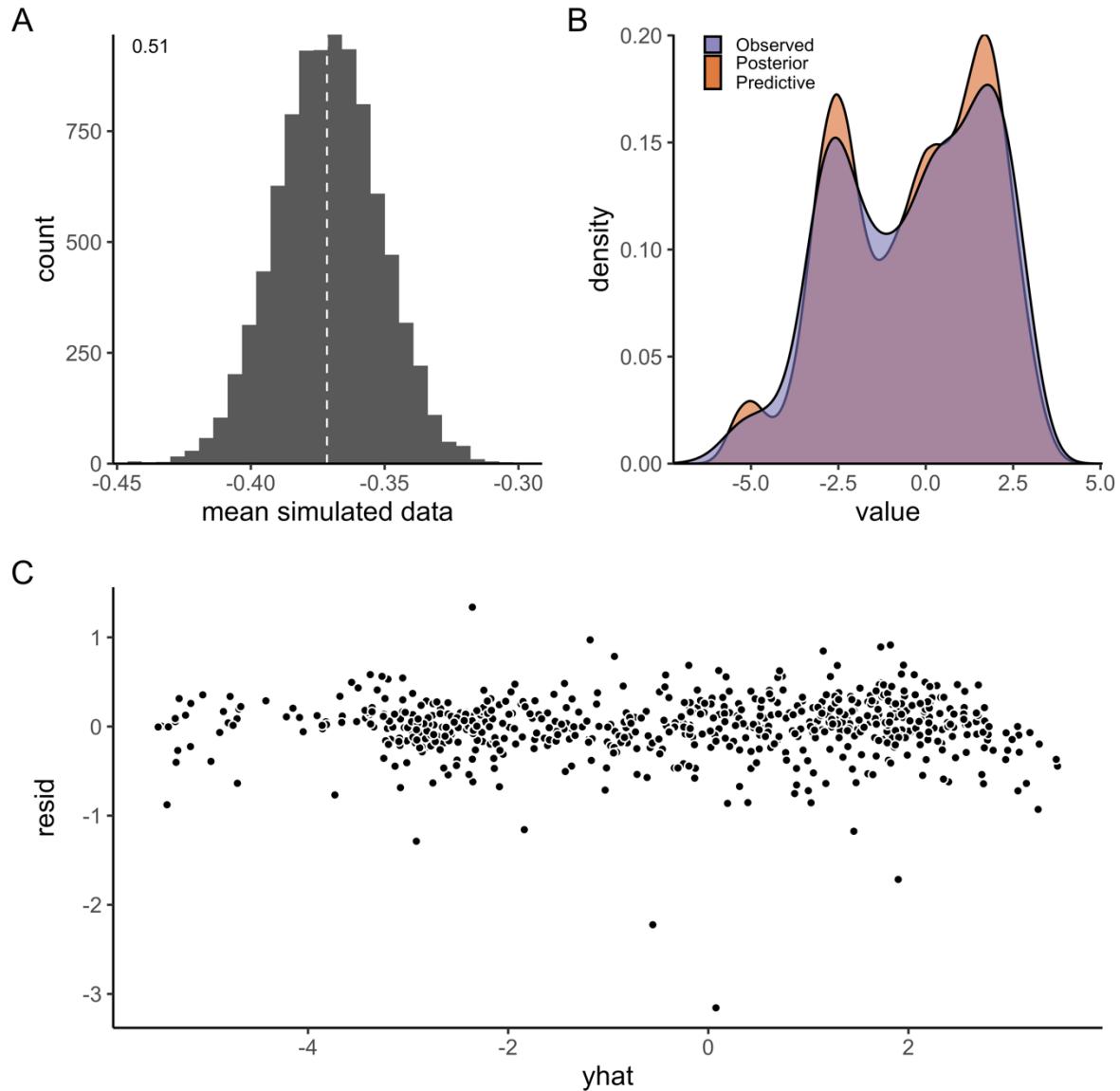
310 *Fig. S8. Potential scale reduction factor (\hat{R}) for the log-linear maximum consumption rate*
 311 *model. This factor is based on the comparison of between and within-chain variation for the*
 312 *same parameter. A value close to one implies chains converged to the same distribution. The*
 313 *index of the parameter corresponds to species in alphabetical order.*

314

315

316

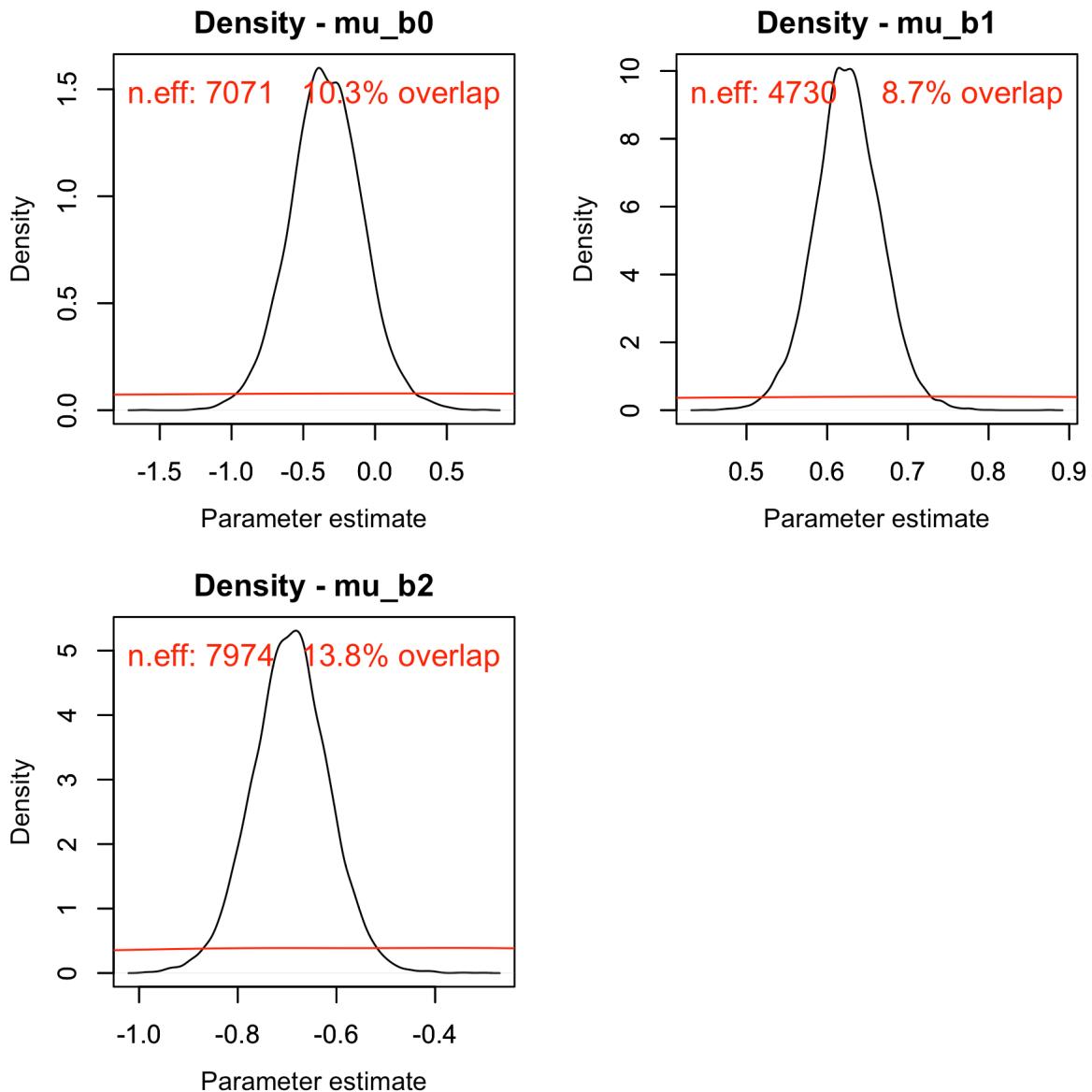
317



318

319 *Fig. S9. A) Model fit (mean) for the log-linear model of maximum consumption rate at*
 320 *temperatures below temperature peak (by species). Fit is evaluated by simulating data from*
 321 *the likelihood (at each iteration of the MCMC chain), to compare how well it matches the*
 322 *original data. Each simulated data point is assigned a 0 or 1 if it is below or above the mean*
 323 *data point (the vertical line corresponds to the mean in data). The number in the plot*
 324 *corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive distribution*
 325 *(orange) and distribution of data (purple). C) Difference between the observed value and the*
 326 *posterior median of the predicted value, plotted against fitted value.*

327



328

329 *Fig. S10. Posterior (black) and prior distribution (red) for the global parameters in the log-*
 330 *linear model for maximum consumption rate, including their % overlap and effective sample*
 331 *size (n.eff).*

332

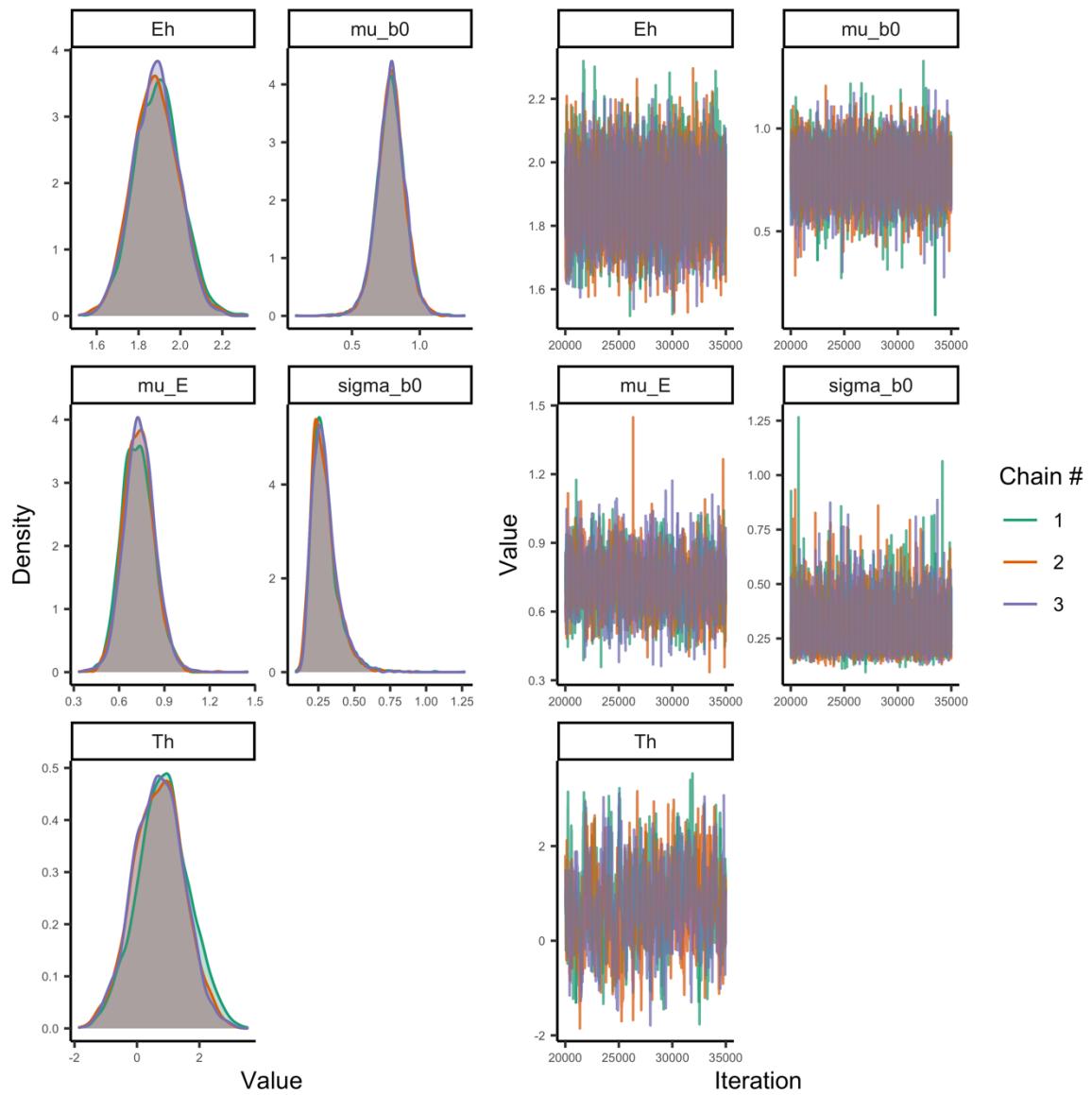
333

334

335

336

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



338

339 *Fig. S11. Posterior densities and trace plots for evaluation of chain convergence (by chain,
 340 indicated by color), for the global-level parameters for the Sharpe-Schoalfeld model fitted to
 341 maximum consumption rate data with temperatures including beyond peak temperatures.*

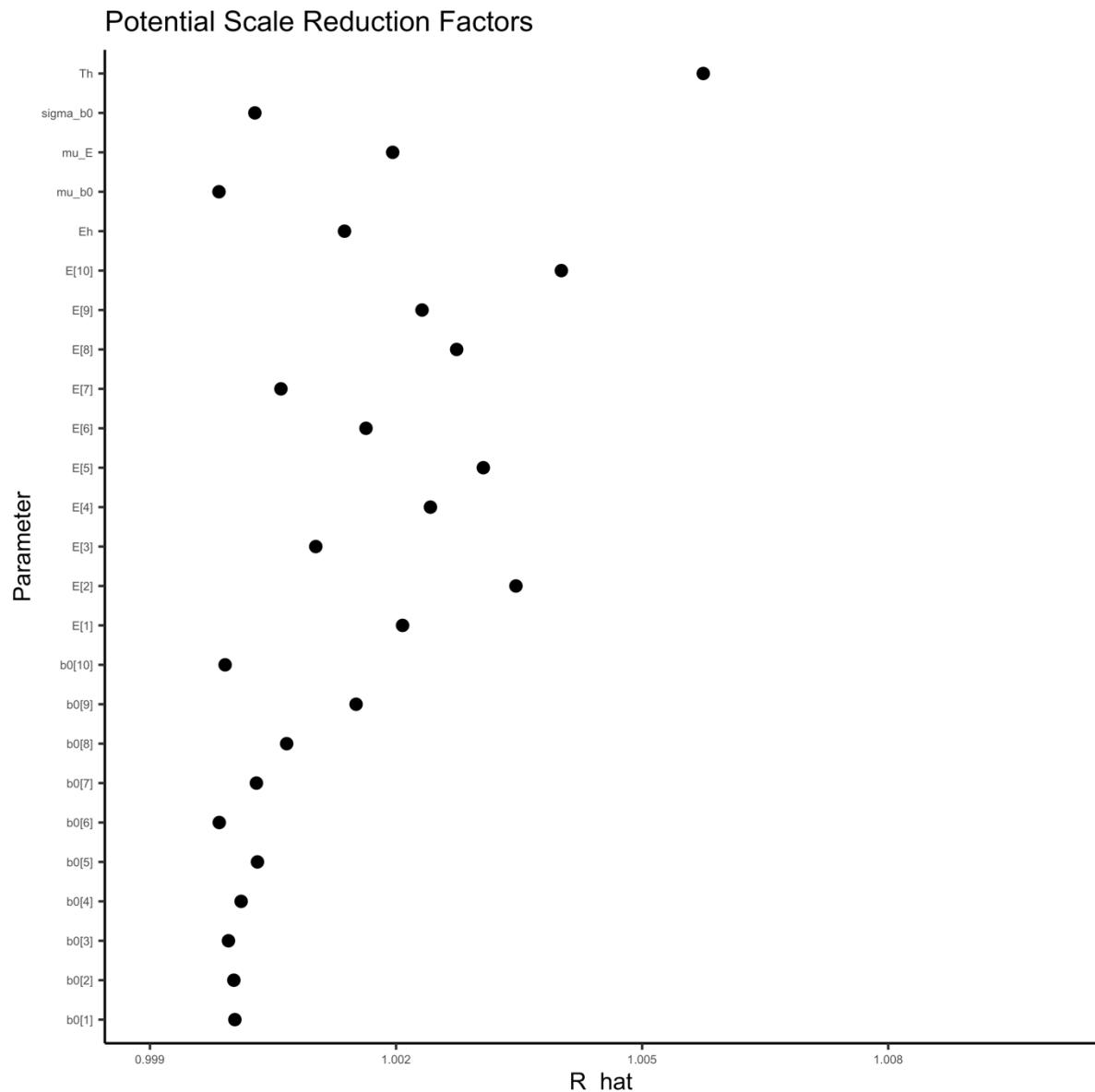
342

343

344

345

346



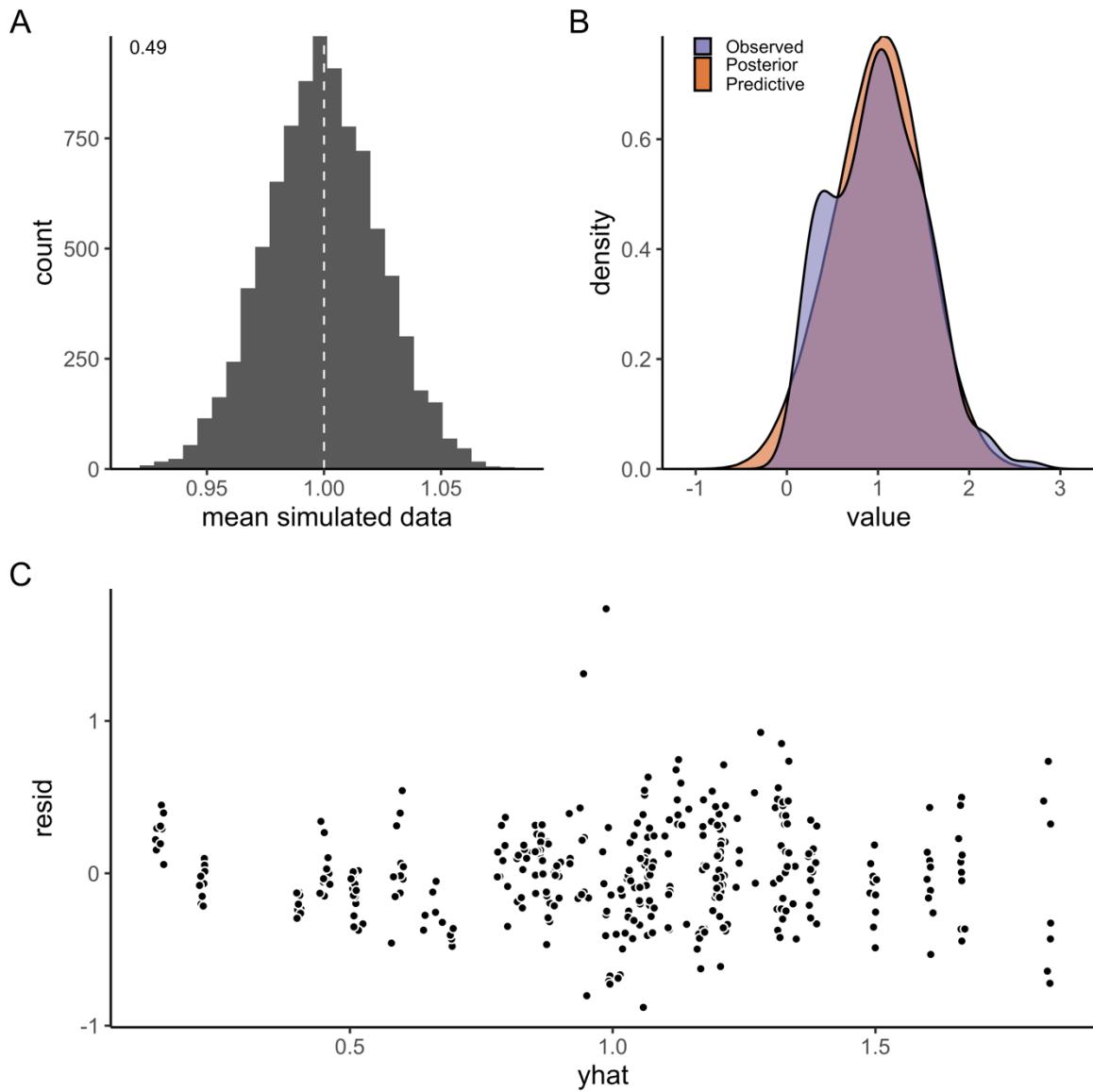
347

348 *Fig. S12. Potential scale reduction factor (\hat{R}) for the Sharpe-Schoolfield model fitted to*
 349 *maximum consumption rate data (including data beyond peak). This factor is based on the*
 350 *comparison of between and within-chain variation for the same parameter. A value close to*
 351 *one implies chains converged to the same distribution. The index of the parameter corresponds*
 352 *to species in alphabetical order.*

353

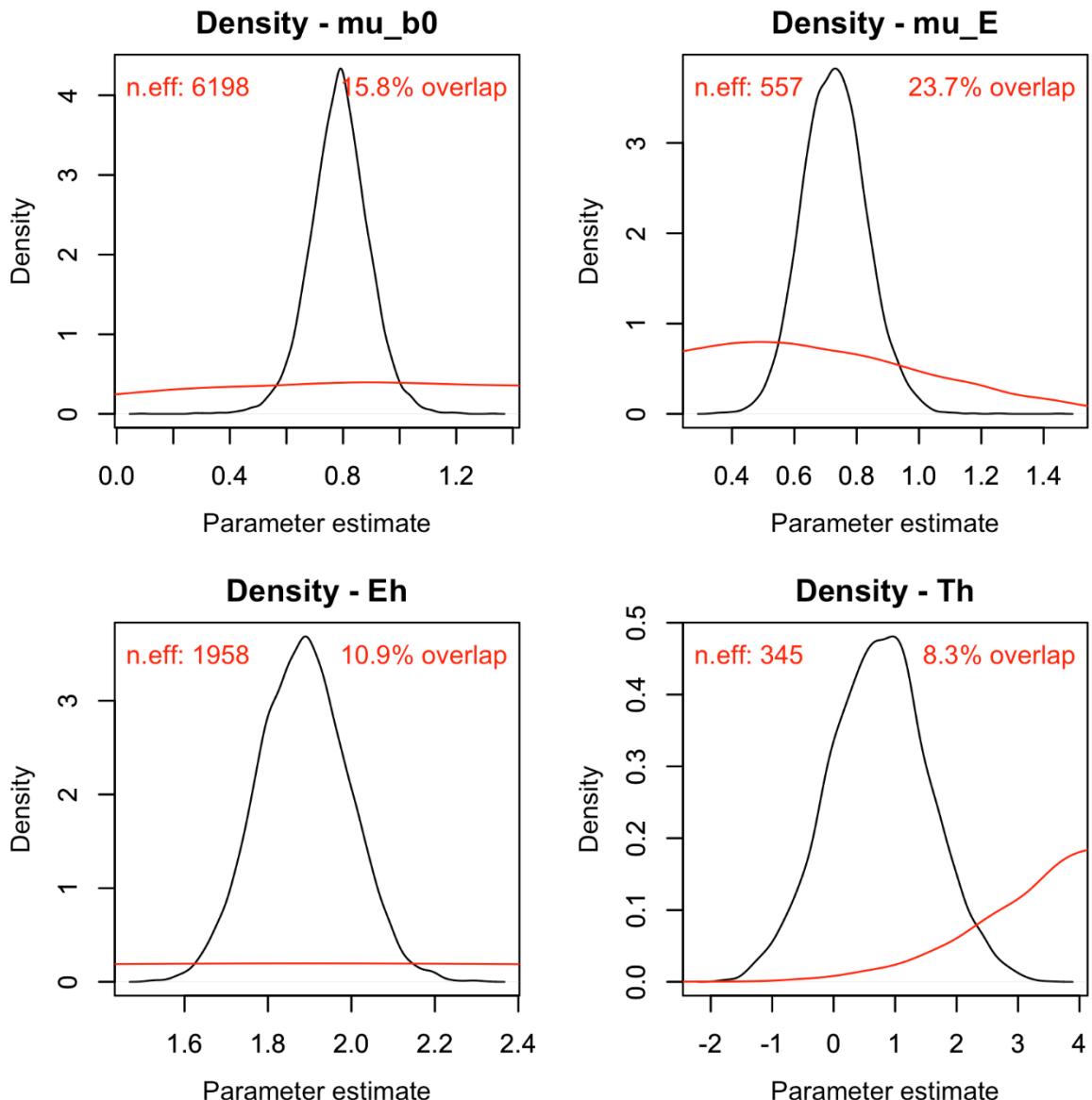
354

355



356

357 *Fig. S13. A) Model fit (mean) for the Sharpe-Schoolfield model fitted to maximum consumption*
 358 *rate data including temperatures beyond peak (by species). Fit is evaluated by simulating data*
 359 *from the likelihood (at each iteration of the MCMC chain), to compare how well it matches the*
 360 *original data. Each simulated data point is assigned a 0 or 1 if it is below or above the mean*
 361 *data point (the vertical line corresponds to the mean in data). The number in the plot*
 362 *corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive distribution*
 363 *(orange) and distribution of data (purple). C) Difference between the observed value and the*
 364 *posterior median of the predicted value, plotted against fitted value.*



365

366 *Fig. S14. Posterior (black) and prior distribution (red) for the global parameters in the Sharpe-*
 367 *Schoolfield model for maximum consumption rate including data beyond peak, including their*
 368 *% overlap (rounded) and effective sample size (n.eff).*

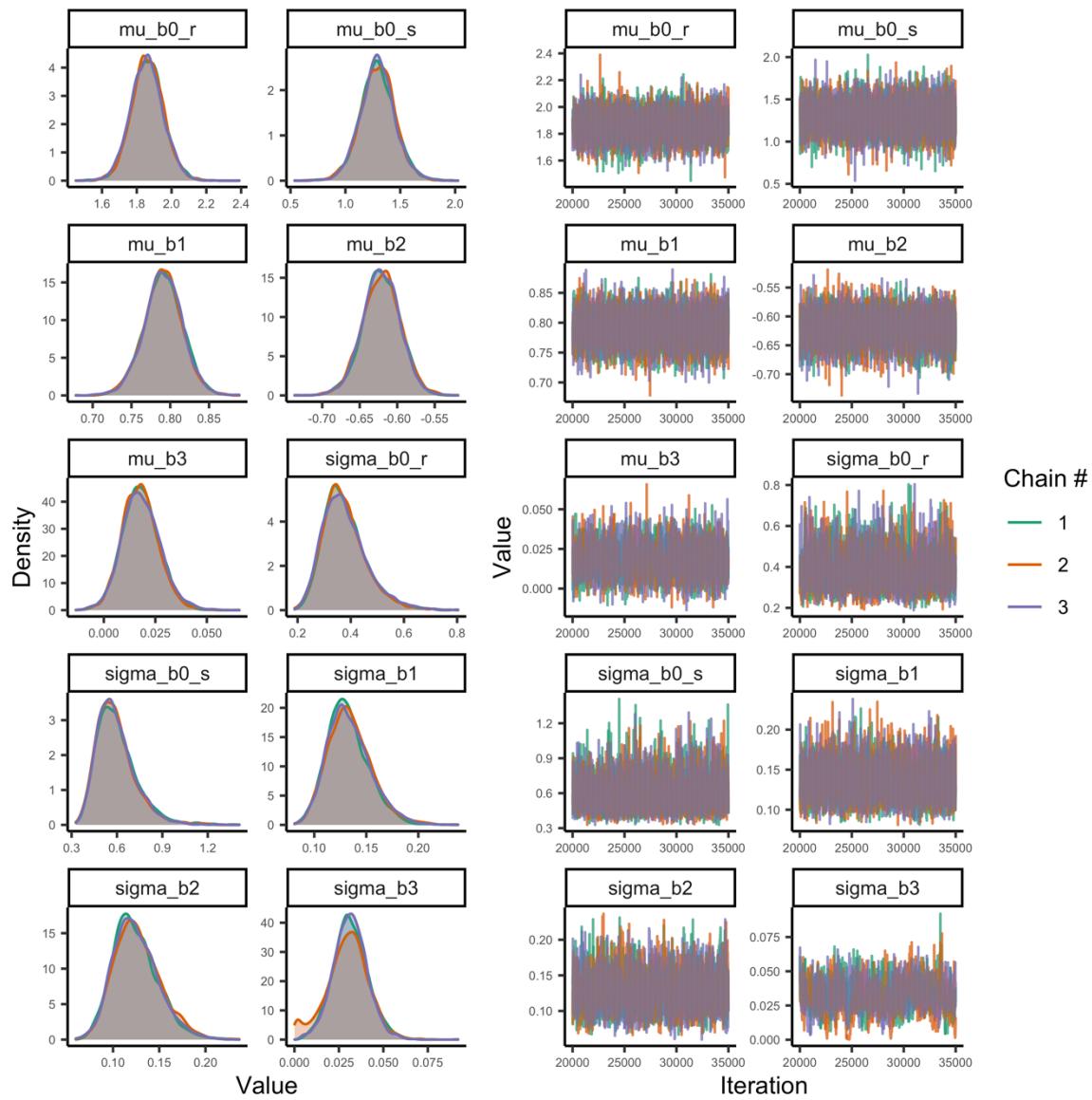
369

370

371

372

373



375

376 *Fig. S15. Posterior densities and trace plots for evaluation of chain convergence (by chain,
 377 indicated by color), for the global-level parameters for the metabolic rate model at
 378 temperatures below peak temperatures.*

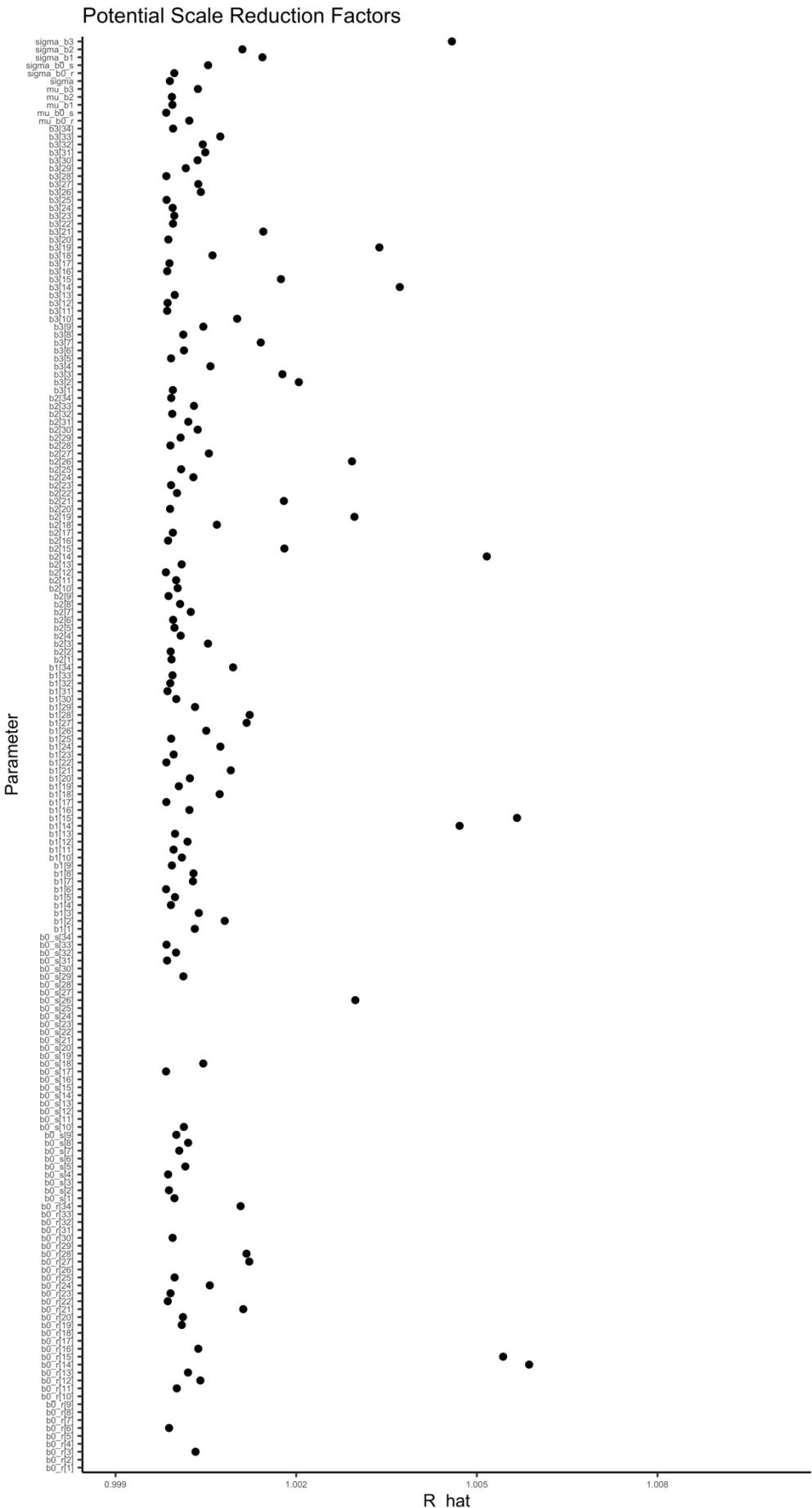
379

380

381

382

383



385 Fig. S16. Potential scale reduction factor (\hat{R}) for the metabolic rate model. This factor is based
386 on the comparison of between and within-chain variation for the same parameter. A value close
387 to one implies chains converged to the same distribution. The index of the parameter
388 corresponds to species in alphabetical order. Note that species with routine metabolism do not
389 have estimates for a standard metabolic rate intercept and vice versa, hence, not all parameters
390 in the graph have \hat{R} values.

391

392

393

394

395

396

397

398

399

400

401

402

403

404

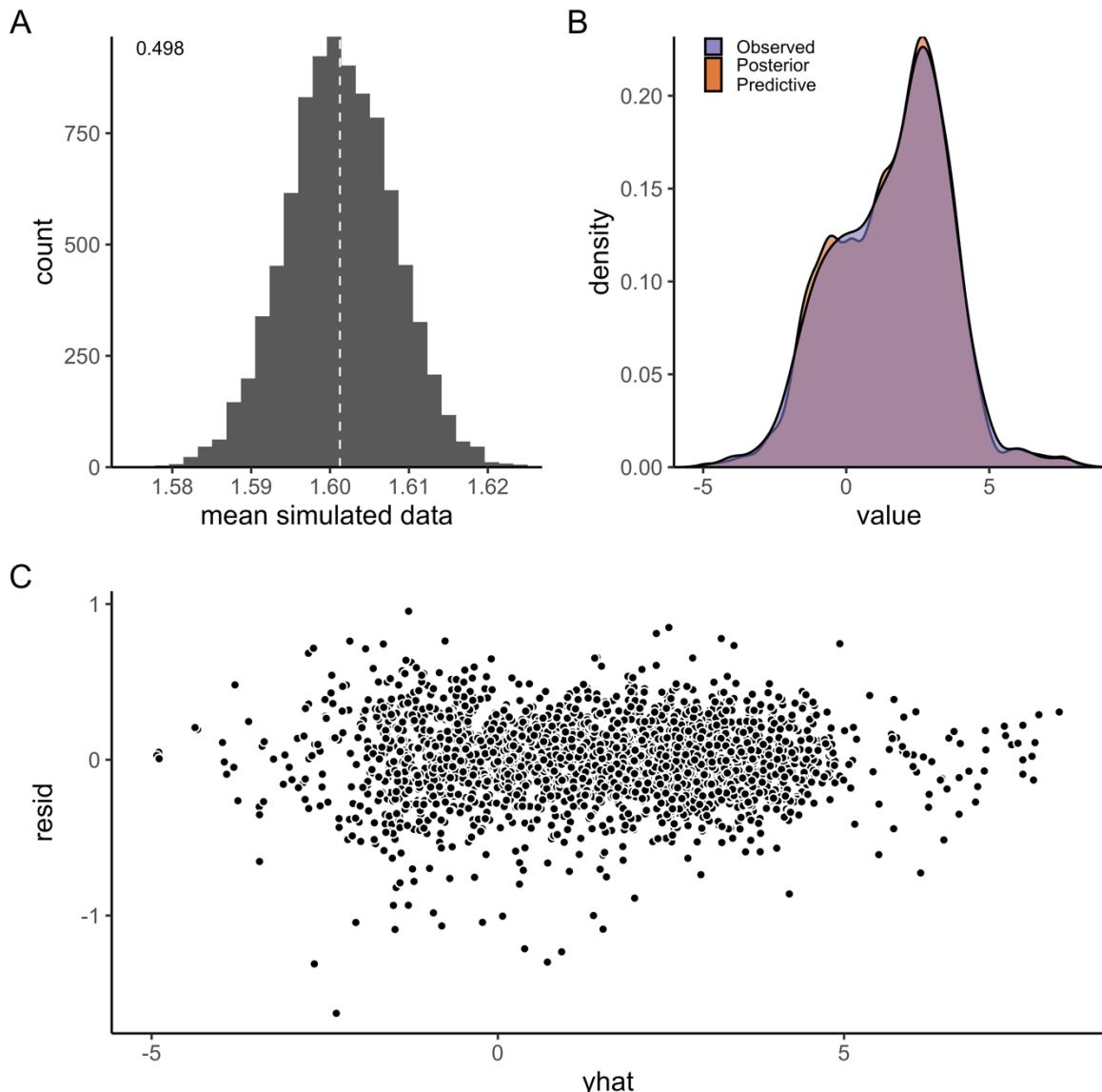
405

406

407

408

409

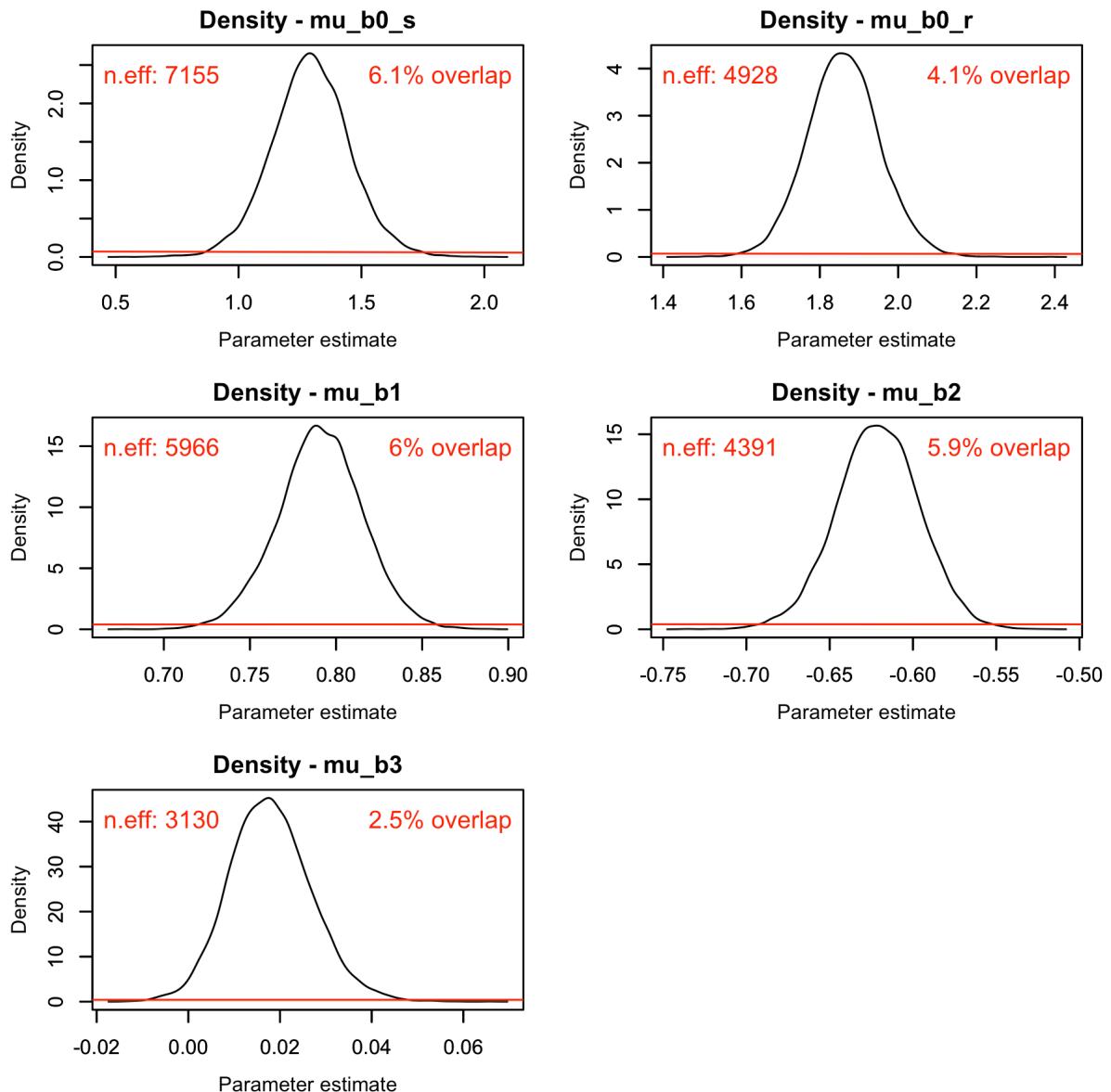


410

411 *Fig. S17. A) Model fit (mean) for the log-linear model of metabolic rate. Fit is evaluated by*
 412 *simulating data from the likelihood (at each iteration of the MCMC chain), to compare how*
 413 *well it matches the original data. Each simulated data point is assigned a 0 or 1 if it is below*
 414 *or above the mean data point (the vertical line corresponds to the mean in data). The number*
 415 *in the plot corresponds to the mean of the vector of 0's and 1's. B) Posterior predictive*
 416 *distribution (orange) and distribution of data (purple). C) Difference between the observed*
 417 *value and the posterior median of the predicted value, plotted against fitted value.*

418

419



420

421 *Fig. S18. Posterior (black) and prior distribution (red) for the global parameters in the model*
 422 *for metabolic rate, including their % overlap and effective sample size (n.eff).*

423

424

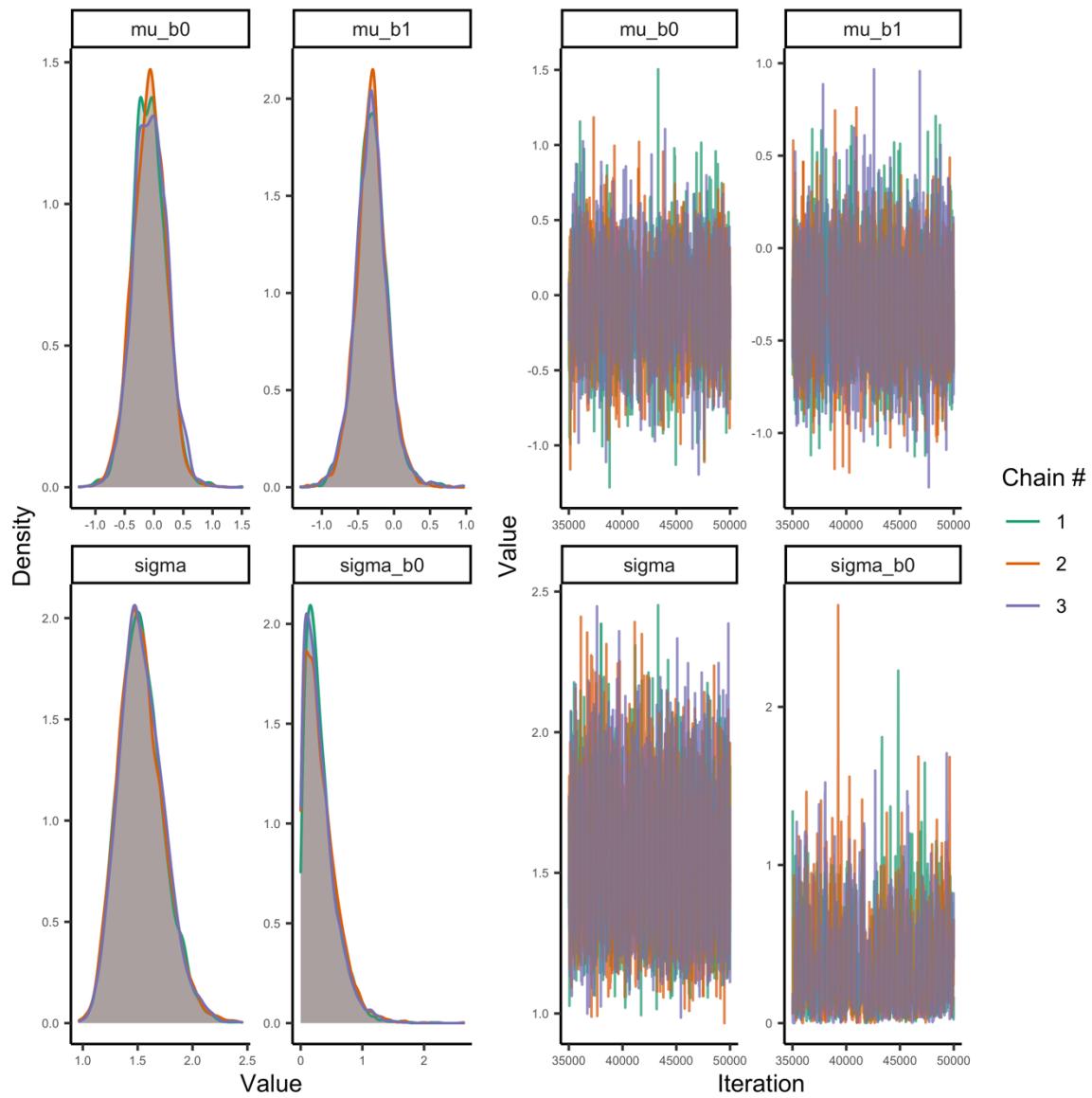
425

426

427

428

429 ***Optimum growth temperature***



430

431 *Fig. S19. Posterior densities and trace plots for evaluation of chain convergence (by chain,*

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

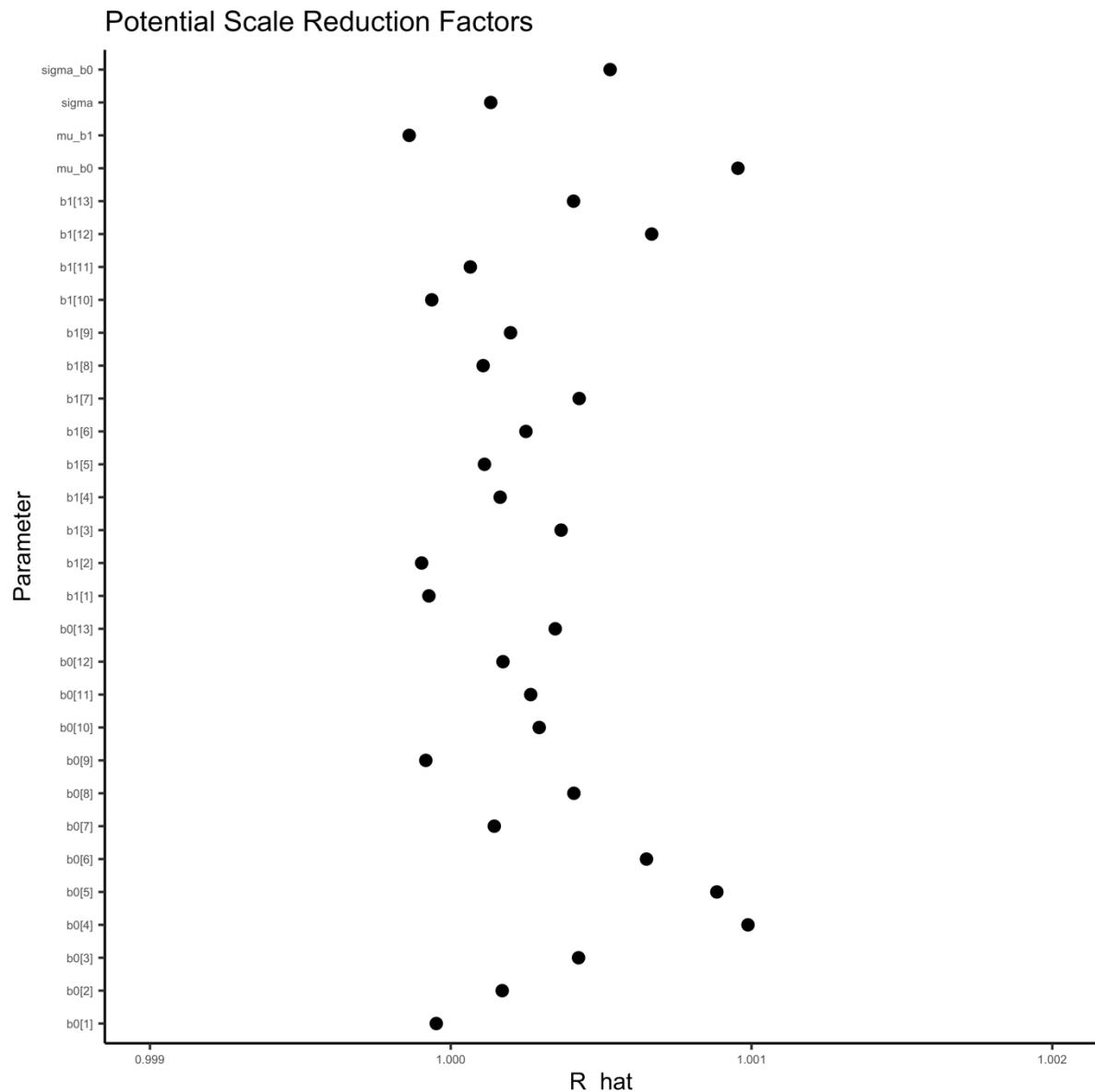
433

434

435

436

437



438

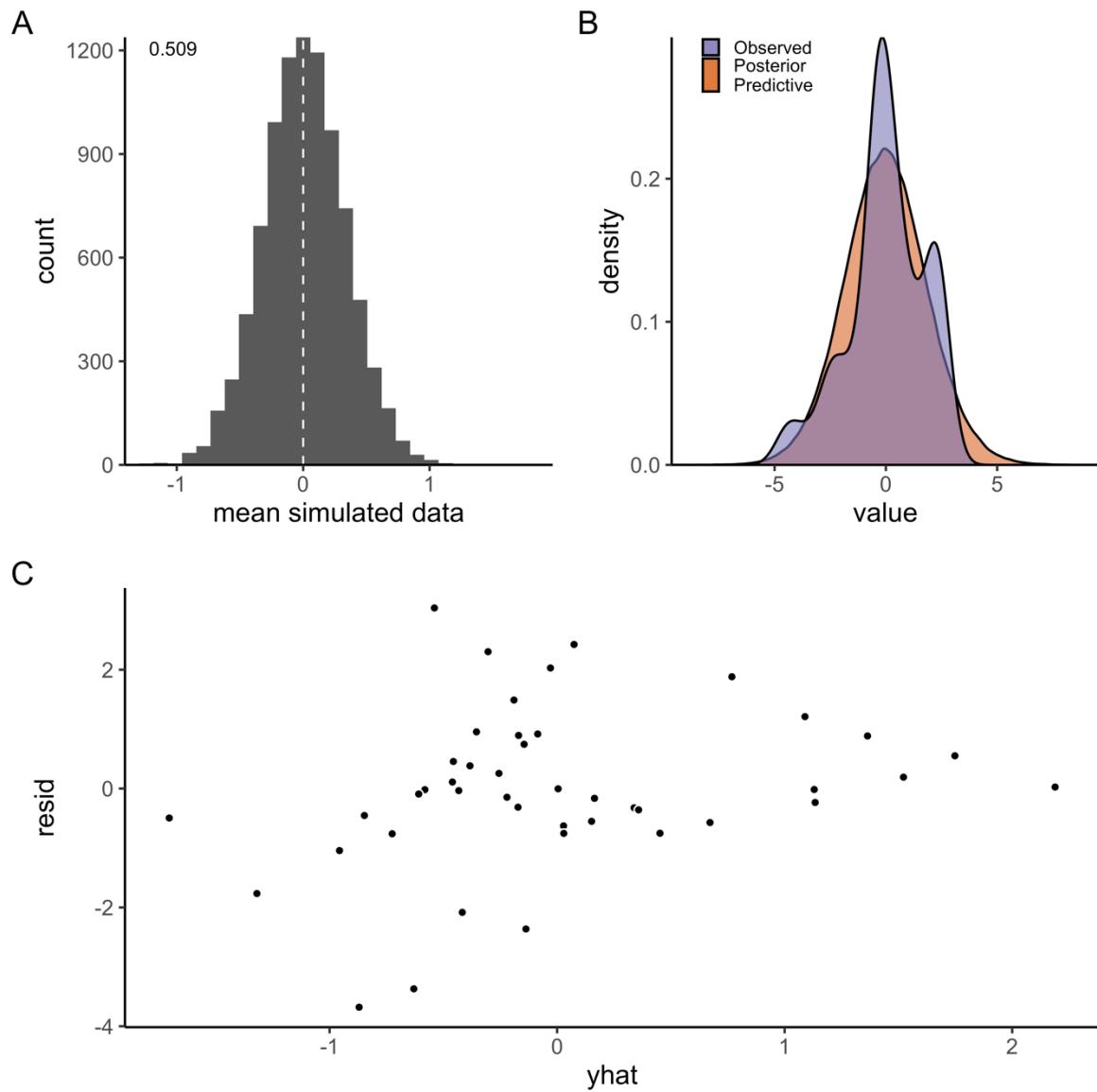
439 Fig. S20. Potential scale reduction factor (\hat{R}) for the T_{opt} model. This factor is based on the
 440 comparison of between and within-chain variation for the same parameter. A value close to
 441 one implies chains converged to the same distribution. The index of the parameter corresponds
 442 to species in alphabetical order.

443

444

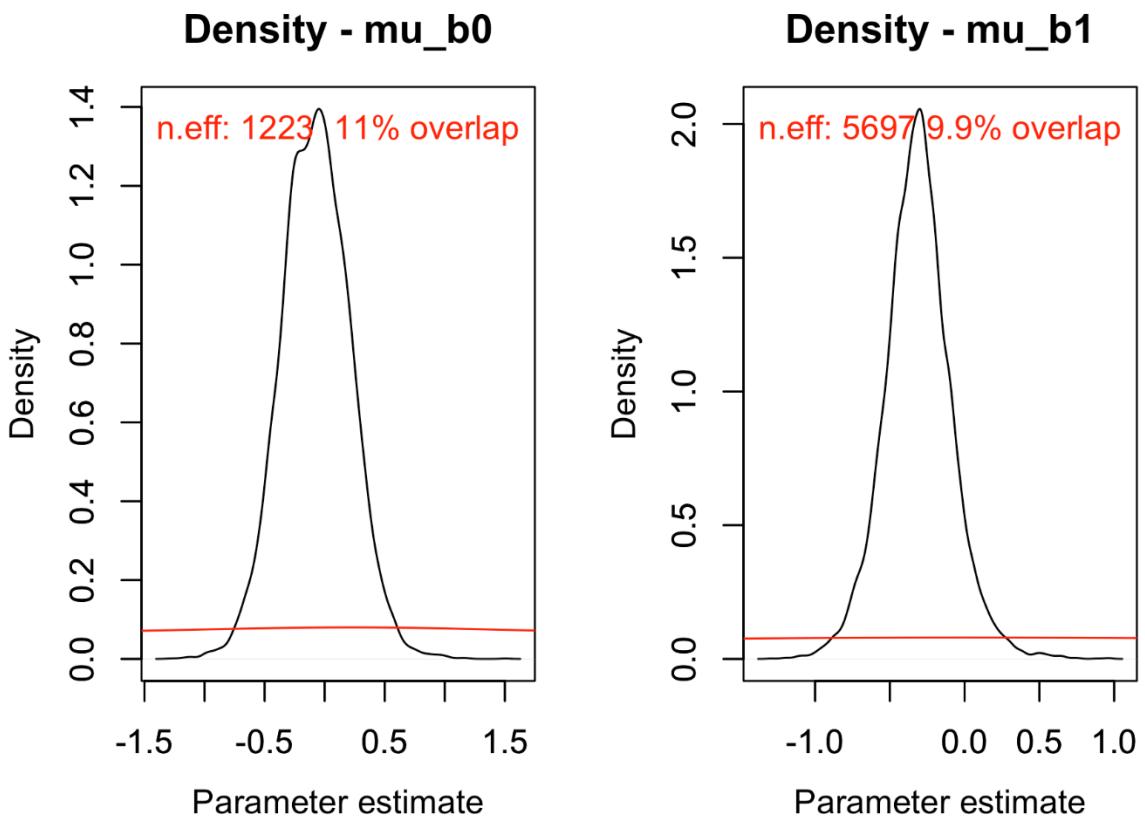
445

446



447

448 Fig. S21. A) Model fit (mean) for the model of optimum growth temperature as a function of
 449 body mass. Fit is evaluated by simulating data from the likelihood (at each iteration of the
 450 MCMC chain), to compare how well it matches the original data. Each simulated data point is
 451 assigned a 0 or 1 if it is below or above the mean data point (the vertical line corresponds to
 452 the mean in data). The number in the plot corresponds to the mean of the vector of 0's and 1's.
 453 B) Posterior predictive distribution (orange) and distribution of data (purple). C) Difference
 454 between the observed value and the posterior median of the predicted value, plotted against
 455 fitted value.



456

457 *Fig. S22. Posterior (black) and prior distribution (red) for the global parameters in the model*
 458 *for T_{opt} , including their % overlap and effective sample size (n.eff).*

459

460

461

462

463

464

465

466

467

468

469 **References**

- 470 Árnason, T., Björnsson, B., Steinarsson, A., & Oddgeirsson, M. (2009). Effects of
471 temperature and body weight on growth rate and feed conversion ratio in turbot
472 (*Scophthalmus maximus*). *Aquaculture*, 295(3–4), 218–225.
473 <https://doi.org/10.1016/j.aquaculture.2009.07.004>
- 474 Baldwin, N. S. (1957). Food Consumption and Growth of Brook Trout at Different
475 Temperatures. *Transactions of the American Fisheries Society*, 86(1), 323–328.
476 [https://doi.org/10.1577/1548-8659\(1956\)86\[323:FCAGOB\]2.0.CO;2](https://doi.org/10.1577/1548-8659(1956)86[323:FCAGOB]2.0.CO;2)
- 477 Beamish, F. W. H. (1964). Respiration of fishes with special emphasis on standard oxygen
478 consumption II. Influence of weight and temperature on respiration of several
479 species'. *Canadian Journal of Zoology/Revue Canadienne de Zoologie*, 42(2), 177–
480 188.
- 481 Beamish, F. W. H., & Mookherjii, P. S. (1964). Respiration of fishes with special emphasis
482 on standard oxygen consumption: I. influence of weight and temperature on
483 respiration of goldfish, *Carassius auratus* l. *Canadian Journal of Zoology*, 42(2),
484 161–175. <https://doi.org/10.1139/z64-015>
- 485 Bermudes, M., Glencross, B., Austen, K., & Hawkins, W. (2010). The effects of temperature
486 and size on the growth, energy budget and waste outputs of barramundi (*Lates*
487 *calcarifer*). *Aquaculture*, 306(1–4), 160–166.
488 <https://doi.org/10.1016/j.aquaculture.2010.05.031>
- 489 Binkowski, F. P., & Rudstam, L. G. (1994). Maximum Daily Ration of Great Lakes Bloater.
490 *Transactions of the American Fisheries Society*, 123, 335–343.
- 491 Björnsson, B., Steinarsson, A., & Árnason, T. (2007). Growth model for Atlantic cod (*Gadus*
492 *morhua*): Effects of temperature and body weight on growth rate. *Aquaculture*,
493 271(1–4), 216–226. <https://doi.org/10.1016/j.aquaculture.2007.06.026>
- 494 Björnsson, B., & Tryggvadóttir, S. V. (1996). Effects of size on optimal temperature for
495 growth and growth efficiency of immature Atlantic halibut (*Hippoglossus*
496 *hippoglossus* L.). *Aquaculture*, 142(1–2), 33–42. [https://doi.org/10.1016/0044-8486\(95\)01240-0](https://doi.org/10.1016/0044-8486(95)01240-0)
- 497 Brett, J. R., Shelbourn, J. E., & Shoop, C. T. (1969). Growth rate and body composition of
498 fingerling sockeye salmon, *Oncorhynchus nerka*, in relation to temperature and ration
499 size. *Journal of the Fisheries Research Board of Canada*, 26(9), 2363–2394.
500 <https://doi.org/10.1139/f69-230>
- 501 Chipp, S. R., & Wahl, D. H. (2004). Development and Evaluation of a Western
502 Mosquitofish Bioenergetics Model. *Transactions of the American Fisheries Society*,
503 133(5), 1150–1162. <https://doi.org/10.1577/T03-118.1>
- 504 Cui, Y., & Wootton, R. J. (1988). Bioenergetics of growth of a cyprinid, *Phoxinus phoxinus*:
505 The effect of ration, temperature and body size on food consumption, faecal
506 production and nitrogenous excretion. *Journal of Fish Biology*, 33(3), 431–443.
507 <https://doi.org/10.1111/j.1095-8649.1988.tb05484.x>
- 508 Degani, G., Gallagher, M. L., & Meltzer, A. (1989). The influence of body size and
509 temperature on oxygen consumption of the European eel, *Anguilla anguilla*. *Journal*
510 *of Fish Biology*, 34(1), 19–24. <https://doi.org/10.1111/j.1095-8649.1989.tb02953.x>
- 511 Deslauriers, D., Chipp, S. R., Breck, J. E., Rice, J. A., & Madenjian, C. P. (2017). Fish
512 Bioenergetics 4.0: An R-Based Modeling Application. *Fisheries*, 42(11), 586–596.
513 <https://doi.org/10.1080/03632415.2017.1377558>
- 514

- 515 Du Perez, H., H., McLachlan, A., & Marais, J. F. K. (1986). Oxygen consumption of a
516 shallow water teleost, the spotted grunter, *Pomadys commersonni* (Lacépède, 1802).
517 *Comparative Biochemistry and Physiology*, 84a(1), 61–70.
- 518 Duston, J., Astatkie, T., & MacIsaac, P. F. (2004). Effect of body size on growth and food
519 conversion of juvenile striped bass reared at 16–28 °C in freshwater and seawater.
520 *Aquaculture*, 234(1–4), 589–600. <https://doi.org/10.1016/j.aquaculture.2004.01.005>
- 521 Elliott, J. M. (1976). The Energetics of Feeding, Metabolism and Growth of Brown Trout
522 (*Salmo trutta* L.) in Relation to Body Weight, Water Temperature and Ration Size.
523 *The Journal of Animal Ecology*, 45(3), 923. <https://doi.org/10.2307/3590>
- 524 Froese, R., & Pauly, D. (2019). Editors. *FishBase*.
- 525 Froese, R., Thorson, J. T., & Reyes, R. B. (2014). A Bayesian approach for estimating length-
526 weight relationships in fishes. *Journal of Applied Ichthyology*, 30(1), 78–85.
- 527 From, J., & Rasmussen, G. (1984). A growth model, gastric evacuation, and body
528 composition in rainbow trout, *Salmo gairdneri* Richardson, 1836. *Dana*, 3, 61–139.
- 529 Glencross, B. D., & Felsing, M. (2006). Influence of fish size and water temperature on the
530 metabolic demand for oxygen by barramundi, *Lates calcarifer* (Bloch), in freshwater.
531 *Aquaculture Research*, 37(11), 1055–1062. <https://doi.org/10.1111/j.1365-2109.2006.01526.x>
- 532 Glover, D. C., DeVries, D. R., & Wright, R. A. (2012). Effects of temperature, salinity and
533 body size on routine metabolism of coastal largemouth bass *Micropterus salmoides*.
534 *Journal of Fish Biology*, 81(5), 1463–1478. <https://doi.org/10.1111/j.1095-8649.2012.03385.x>
- 535 Handeland, S. O., Imsland, A. K., & Stefansson, S. O. (2008). The effect of temperature and
536 fish size on growth, feed intake, food conversion efficiency and stomach evacuation
537 rate of Atlantic salmon post-smolts. *Aquaculture*, 283(1), 36–42.
<https://doi.org/10.1016/j.aquaculture.2008.06.042>
- 538 Hayward, R. S., & Arnold, E. (1996). Temperature Dependence of Maximum Daily
539 Consumption in White Crappie: Implications for Fisheries Management. *Transactions
540 of the American Fisheries Society*, 125, 132–138.
- 541 Heuton, M., Ayala, L., Morante, A., Dayton, K., Jones, A. C., Hunt, J. R., McKenna, A., van
542 Breukelen, F., & Hillyard, S. (2018). Oxygen consumption of desert pupfish at
543 ecologically relevant temperatures suggests a significant role for anaerobic
544 metabolism. *Journal of Comparative Physiology B*, 188(5), 821–830.
<https://doi.org/10.1007/s00360-018-1174-1>
- 545 Horodsky, A. Z., Brill, R. W., Bushnell, P. G., Musick, J. A., & Latour, R. J. (2011).
546 Comparative metabolic rates of common western North Atlantic Ocean sciaenid
547 fishes. *Journal of Fish Biology*, 79(1), 235–255. <https://doi.org/10.1111/j.1095-8649.2011.03017.x>
- 548 Imsland, A. K., Foss, A., Sparboe, L. O., & Sigurdsson, S. (2006). The effect of temperature
549 and fish size on growth and feed efficiency ratio of juvenile spotted wolffish
550 (*Anarhichas minor*). *Journal of Fish Biology*, 68(4), 1107–1122.
<https://doi.org/10.1111/j.0022-1112.2006.00989.x>
- 551 Iwata, N., Kikuchi, K., Honda, H., Kiyono, M., & Kurokura, H. (1994). Effects of
552 temperature on the growth of Japanese flounder. *Fisheries Science*, 60(5), 527–531.
<https://doi.org/10.2331/fishsci.60.527>
- 553 Laurel, B. J., Copeman, L. A., Spencer, M., & Iseri, P. (2017). Temperature-dependent
554 growth as a function of size and age in juvenile Arctic cod (*Boreogadus saida*). *ICES
555 Journal of Marine Science*, 74(6), 1614–1621. <https://doi.org/10.1093/icesjms/fsx028>

- 563 Lessmark, O. (1983). *Competition between perch (Perca fluviatilis) and roach (Rutilus*
564 *rutilus) in south Swedish lakes* [PhD Thesis]. Limnologiska Institutionen, Lunds
565 Universitet (Sweden).
- 566 Lin, X., Xie, S., Su, Y., & Cui, Y. (2008). Optimum temperature for the growth performance
567 of juvenile orange-spotted grouper (*Epinephelus coioides* H.). *Chinese Journal of*
568 *Oceanology and Limnology*, 26(1), 69–75. <https://doi.org/10.1007/s00343-008-0069-5>
- 570 Liu, J., Cui, Y., & Liu, J. (1998). Food consumption and growth of two piscivorous fishes,
571 the mandarin fish and the Chinese snakehead. *Journal of Fish Biology*, 53(5), 1071–
572 1083. <https://doi.org/10.1111/j.1095-8649.1998.tb00464.x>
- 573 Liu, J., Cui, Y., & Liu, J. (2000). Resting metabolism and heat increment of feeding in
574 mandarin fish (*Siniperca chuatsi*) and Chinese snakehead (*Channa argus*).
575 *Comparative Biochemistry and Physiology Part A: Molecular & Integrative*
576 *Physiology*, 127(2), 131–138. [https://doi.org/10.1016/S1095-6433\(00\)00246-4](https://doi.org/10.1016/S1095-6433(00)00246-4)
- 577 Luo, Y. P., & Wang, Q. Q. (2012). Effects of body mass and temperature on routine
578 metabolic rate of juvenile largemouth bronze gudgeon *Coreius guichenoti*. *Journal of*
579 *Fish Biology*, 80(4), 842–851. <https://doi.org/10.1111/j.1095-8649.2012.03229.x>
- 580 Marmulla, G., & Rosch, R. (1990). Maximum daily ration of juvenile fish fed on living
581 natural zooplankton. *Journal of Fish Biology*, 36(6), 789–801.
582 <https://doi.org/10.1111/j.1095-8649.1990.tb05628.x>
- 583 Mesa, M. G., Weiland, L. K., Christiansen, H. E., Sauter, S. T., & Beauchamp, D. A. (2013).
584 Development and evaluation of a bioenergetics model for bull trout. *Transactions of*
585 *the American Fisheries Society*, 142(1), 41–49.
586 <https://doi.org/10.1080/00028487.2012.720628>
- 587 Meskendahl, L., Herrmann, J.-P., & Temming, A. (2010). Effects of temperature and body
588 mass on metabolic rates of sprat, *Sprattus sprattus* L. *Marine Biology*, 157(9), 1917–
589 1927. <https://doi.org/10.1007/s00227-010-1461-1>
- 590 Messmer, V., Pratchett, M. S., Hoey, A. S., Tobin, A. J., Coker, D. J., Cooke, S. J., & Clark,
591 T. D. (2017). Global warming may disproportionately affect larger adults in a
592 predatory coral reef fish. *Global Change Biology*, 23(6), 2230–2240.
- 593 Milano, D., Vigliano, P., & Beauchamp, D. (2016). Effect of body size and temperature on
594 respiration of *Galaxias maculatus* (Pisces: Galaxiidae). *New Zealand Journal of*
595 *Marine and Freshwater Research*, 51(2), 295–303.
596 <https://doi.org/10.1080/00288330.2016.1231127>
- 597 Nytrø, A. V., Vikingstad, E., Foss, A., Hangstad, T. A., Reynolds, P., Eliassen, G., Elvegård,
598 T. A., Falk-Petersen, I.-B., & Imsland, A. K. (2014). The effect of temperature and
599 fish size on growth of juvenile lumpfish (*Cyclopterus lumpus* L.). *Aquaculture*, 434,
600 296–302. <https://doi.org/10.1016/j.aquaculture.2014.07.028>
- 601 Ohlberger, J., Mehner, Thomas., Staaks, Georg., & Höller, Franz. (2012). Intraspecific
602 temperature dependence of the scaling of metabolic rate with body mass in fishes and
603 its ecological implications. *Oikos*, 121(2), 245–251. <https://doi.org/10.1111/j.1600-0706.2011.19882.x>
- 605 Patterson, J. T., Mims, S. D., & Wright, R. A. (2013). Effects of body mass and water
606 temperature on routine metabolism of American paddlefish *Polyodon spathula*:
607 Routine metabolism of *Polyodon spathula*. *Journal of Fish Biology*, 82(4), 1269–
608 1280. <https://doi.org/10.1111/jfb.12066>
- 609 Peck, M. A., Buckley, L. J., & Bengtson, D. A. (2005). Effects of temperature, body size and
610 feeding on rates of metabolism in young-of-the-year haddock. *Journal of Fish*
611 *Biology*, 66(4), 911–923. <https://doi.org/10.1111/j.0022-1112.2005.00633.x>

- 612 Pirozzi, I., & Booth, M. A. (2009). The effect of temperature and body weight on the routine
613 metabolic rate and postprandial metabolic response in mulloway, *Argyrosomus*
614 *japonicus*. *Comparative Biochemistry and Physiology Part A: Molecular &*
615 *Integrative Physiology*, 154(1), 110–118. <https://doi.org/10.1016/j.cbpa.2009.05.010>
- 616 Rangel, R. E., & Johnson, D. W. (2018). Metabolic responses to temperature in a sedentary
617 reef fish, the bluebanded goby (*Lythrypnus dalli*, Gilbert). *Journal of Experimental*
618 *Marine Biology and Ecology*, 501, 83–89.
619 <https://doi.org/10.1016/j.jembe.2018.01.011>
- 620 Siikavuopio, S. I., Foss, A., Saether, B.-S., Gunnarsson, S., & Imsland, A. K. (2013).
621 Comparison of the growth performance of offspring from cultured versus wild
622 populations of arctic charr, *Salvelinus alpinus* (L.), kept at three different
623 temperatures. *Aquaculture Research*, 44(6), 995–1001. <https://doi.org/10.1111/j.1365-2109.2012.03112.x>
- 625 Slesinger, E., Andres, A., Young, R., Seibel, B., Saba, V., Phelan, B., Rosendale, J.,
626 Wieczorek, D., & Saba, G. (2019). The effect of ocean warming on black sea bass
627 (*Centropristes striata*) aerobic scope and hypoxia tolerance. *PLOS ONE*, 14(6),
628 e0218390. <https://doi.org/10.1371/journal.pone.0218390>
- 629 Sun, L., & Chen, H. (2014). Effects of water temperature and fish size on growth and
630 bioenergetics of cobia (*Rachycentron canadum*). *Aquaculture*, 426–427, 172–180.
631 <https://doi.org/10.1016/j.aquaculture.2014.02.001>
- 632 Tirsgaard, B., Behrens, J. W., & Steffensen, J. F. (2015). The effect of temperature and body
633 size on metabolic scope of activity in juvenile Atlantic cod *Gadus morhua* L.
634 *Comparative Biochemistry and Physiology Part A: Molecular & Integrative*
635 *Physiology*, 179, 89–94. <https://doi.org/10.1016/j.cbpa.2014.09.033>
- 636 Tomala, D., Chavarria, J., & Angeles, B. (2014). Evaluacion de la tasa de consumo de
637 oxigeno de *Collossoma macropomum* en relacion al peso corporal y temperatura del
638 agua. *Latin American Journal of Aquatic Research*, 42(5), 971–979.
639 <https://doi.org/10.3856/vol42-issue5-fulltext-4>
- 640 Tomiyama, T., Kusakabe, K., Otsuki, N., Yoshida, Y., Takahashi, S., Hata, M., Shoji, J., &
641 Hori, M. (2018). Ontogenetic changes in the optimal temperature for growth of
642 juvenile marbled flounder *Pseudopleuronectes yokohamae*. *Journal of Sea Research*,
643 141, 14–20. <https://doi.org/10.1016/j.seares.2018.07.010>
- 644 Wang, H. P., Hayward, R. S., Whitledge, G. W., & Fischer, S. A. (2003). Prey-size
645 Preference, Maximum Handling Size, and Consumption Rates for Redear Sunfish
646 *Lepomis microlophus* Feeding on Two Gastropods Common to Aquaculture Ponds.
647 *Journal of the World Aquaculture Society*, 34(3), 379–386.
648 <https://doi.org/10.1111/j.1749-7345.2003.tb00075.x>
- 649 Wootton, R. J., Allen, J. R. M., & Cole, S. J. (1980). Effect of body weight and temperature
650 on the maximum daily food consumption of *Gasterosteus aculeatus* L. and *Phoxinus*
651 *phoxinus* (L.): Selecting an appropriate model. *Journal of Fish Biology*, 17(6), 695–
652 705. <https://doi.org/10.1111/j.1095-8649.1980.tb02803.x>
- 653 Xie, Xiaojun., & Sun, Ruyung. (1990). The Bioenergetics of the Southern Catfish (*Silurus*
654 *meridionalis* Chen). I. Resting Metabolic Rate as a Function of Body Weight and
655 Temperature. *Physiological Zoology*, 63(6), 1181–1195.
- 656 Yamanaka, H., Takahara, T., Kohmatsu, Y., & Yuma, M. (2013). Body size and temperature
657 dependence of routine metabolic rate and critical oxygen concentration in larvae and
658 juveniles of the round crucian carp *Carassius auratus grandoculis* Temminck &
659 Schlegel 1846. *Journal of Applied Ichthyology*, 29(4), 891–895.
660 <https://doi.org/10.1111/jai.12126>

661 Zhang, L., Zhao, Z.-G., & Fan, Q.-X. (2017). Effects of water temperature and initial weight
662 on growth, digestion and energy budget of yellow catfish *Pelteobagrus fulvidraco*
663 (Richardson, 1846). *Journal of Applied Ichthyology*, 33(6), 1108–1117.
664 <https://doi.org/10.1111/jai.13465>
665