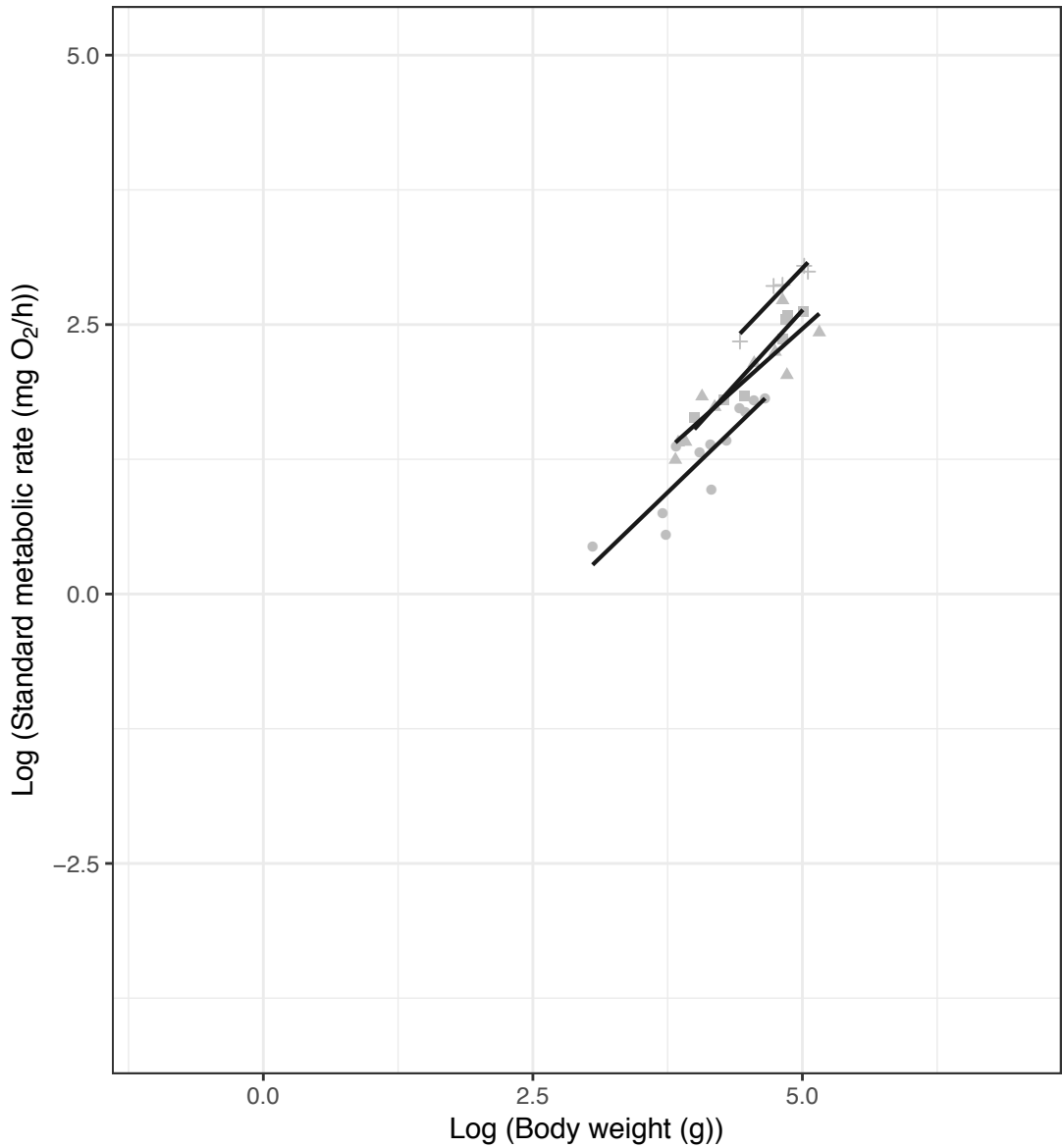


Supplementary material

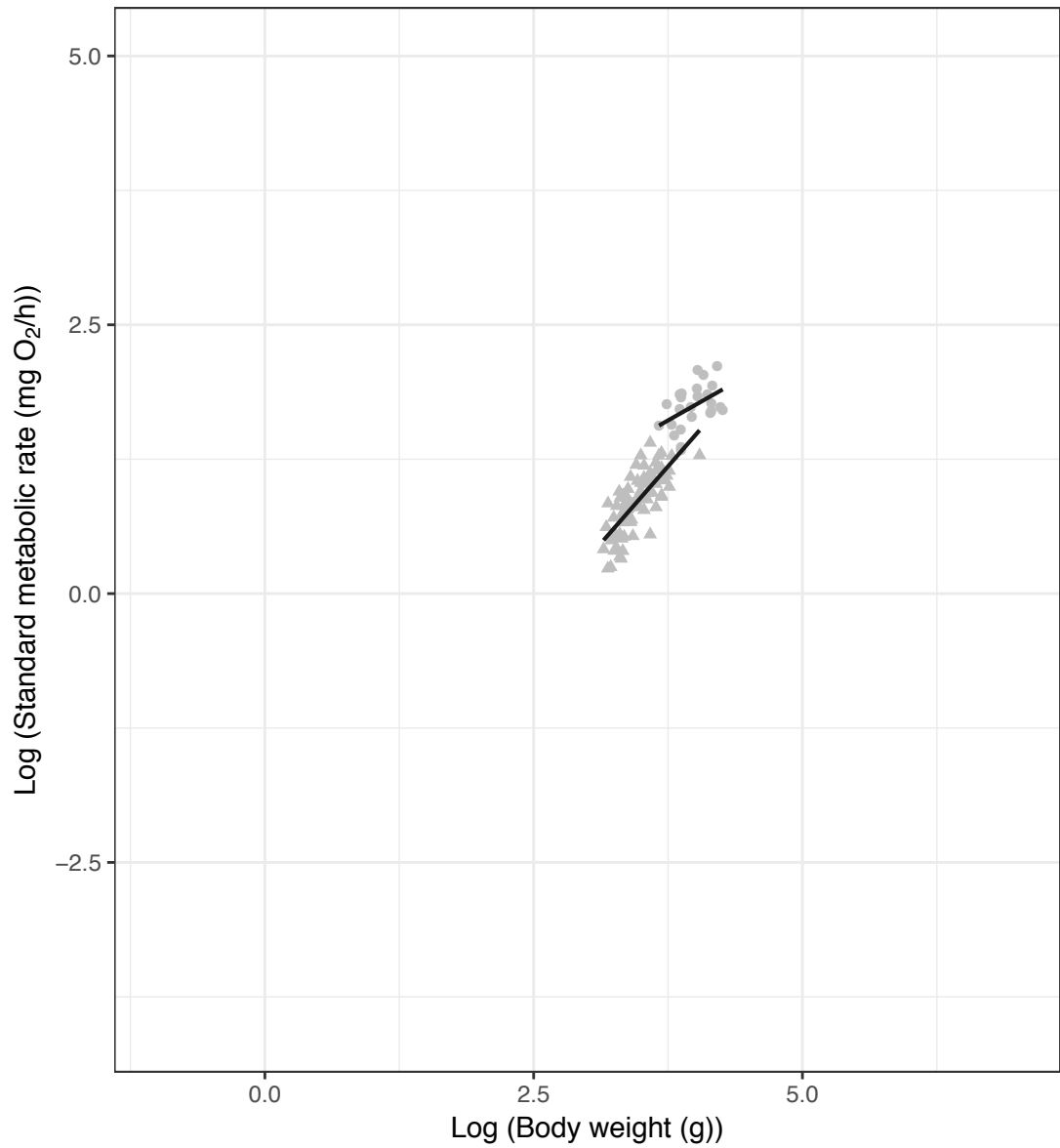
Supplementary material 1: By species regressions

Atlantic Cod (*Gadus morhua*)



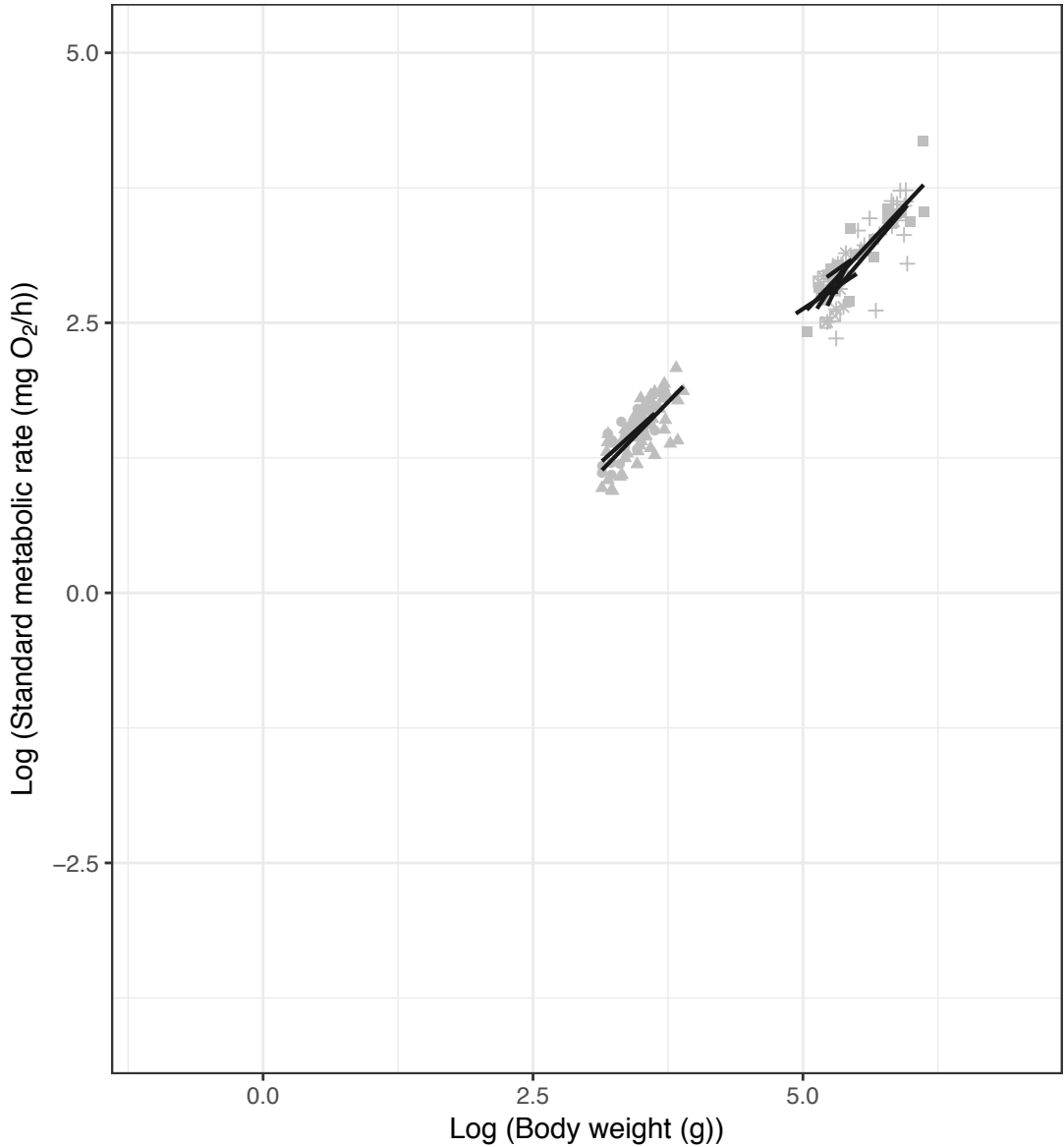
Atlantic Salmon

(Salmo salar)



Barramundi

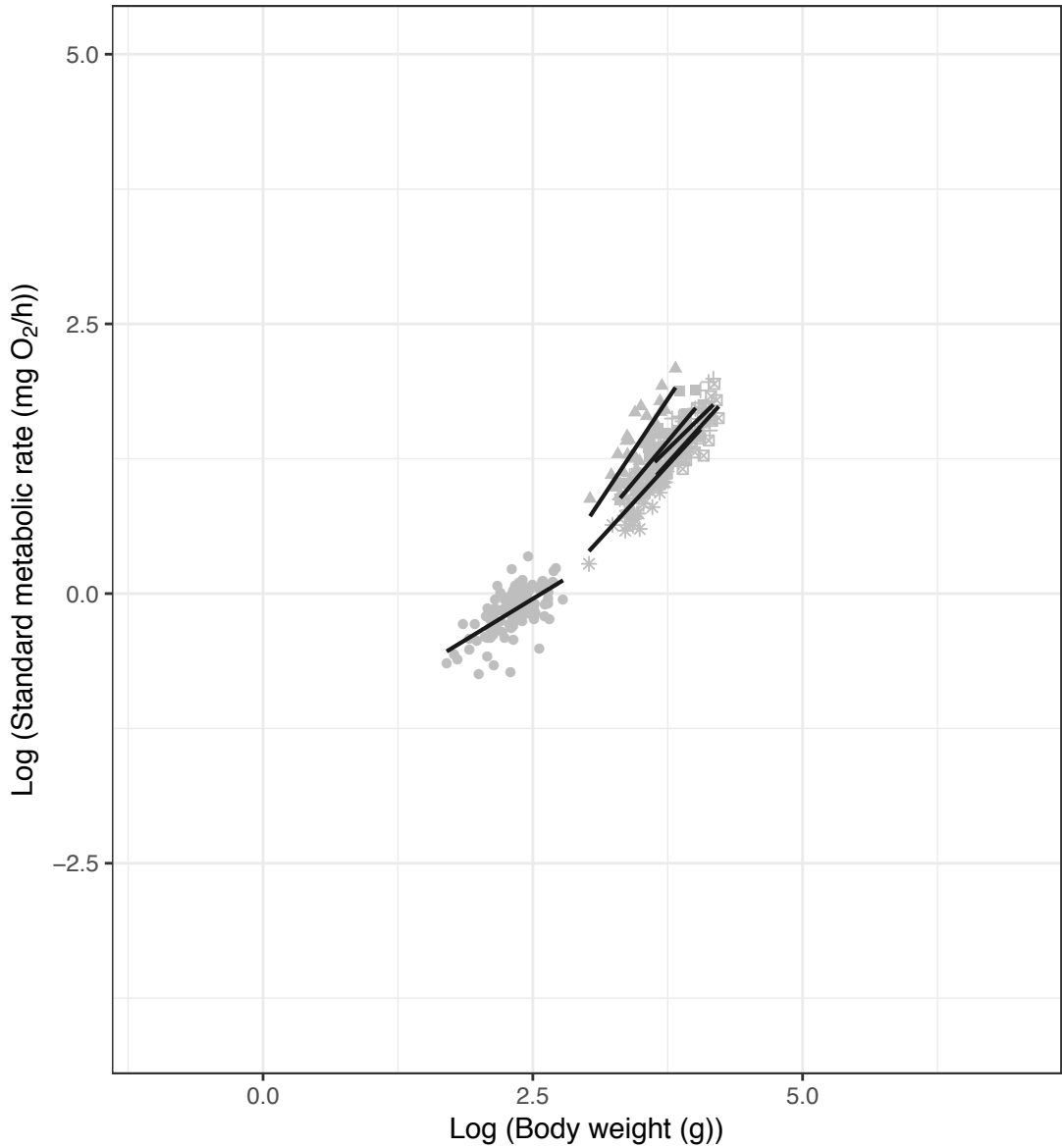
(*Lates calcarifer*)



Trials 11, 23, 24, 25, 49, 50, 51, 52, and 53

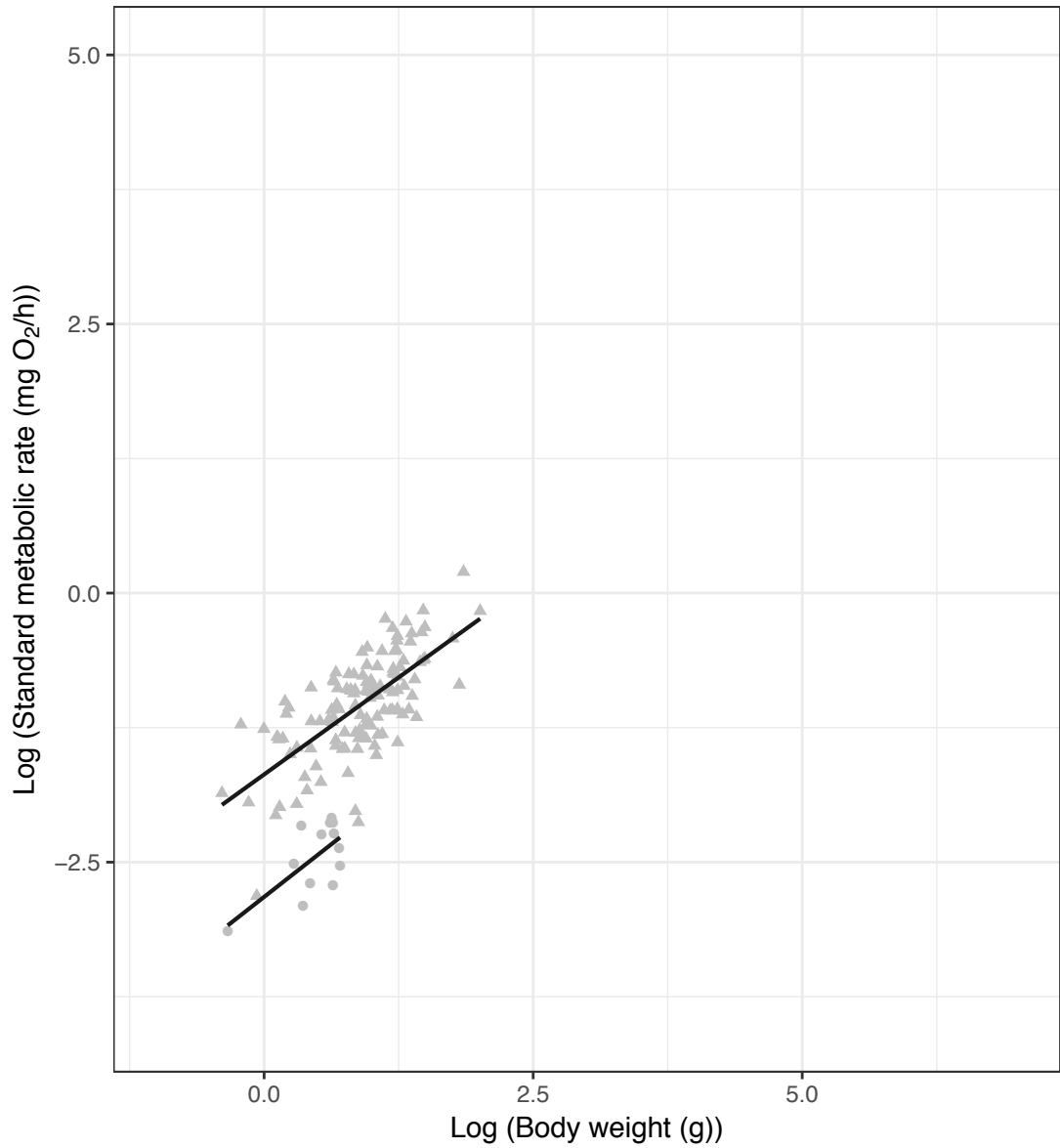
Brown Trout

(*Salmo trutta*)



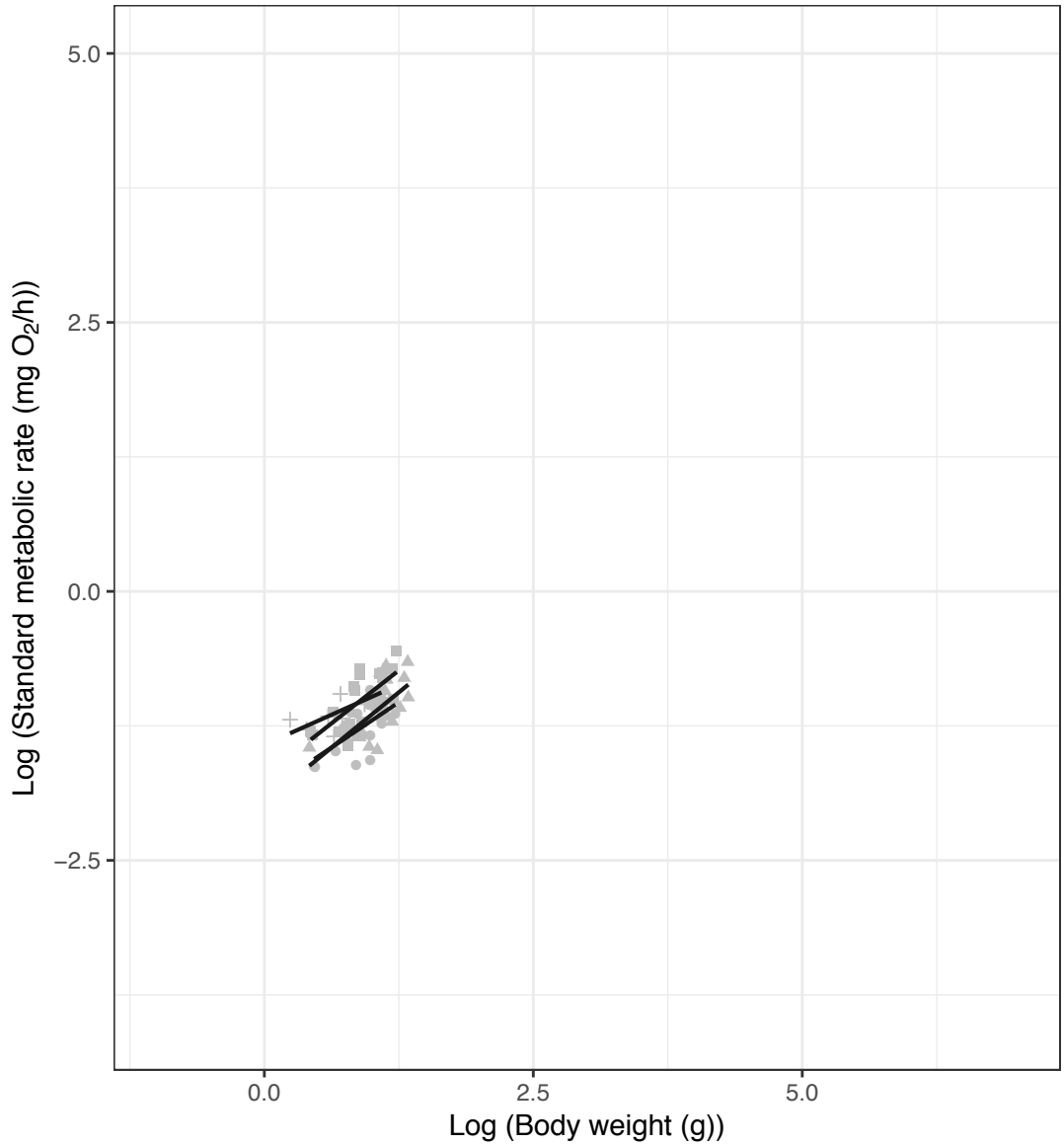
Common Minnow

(Phoxinus phoxinus)



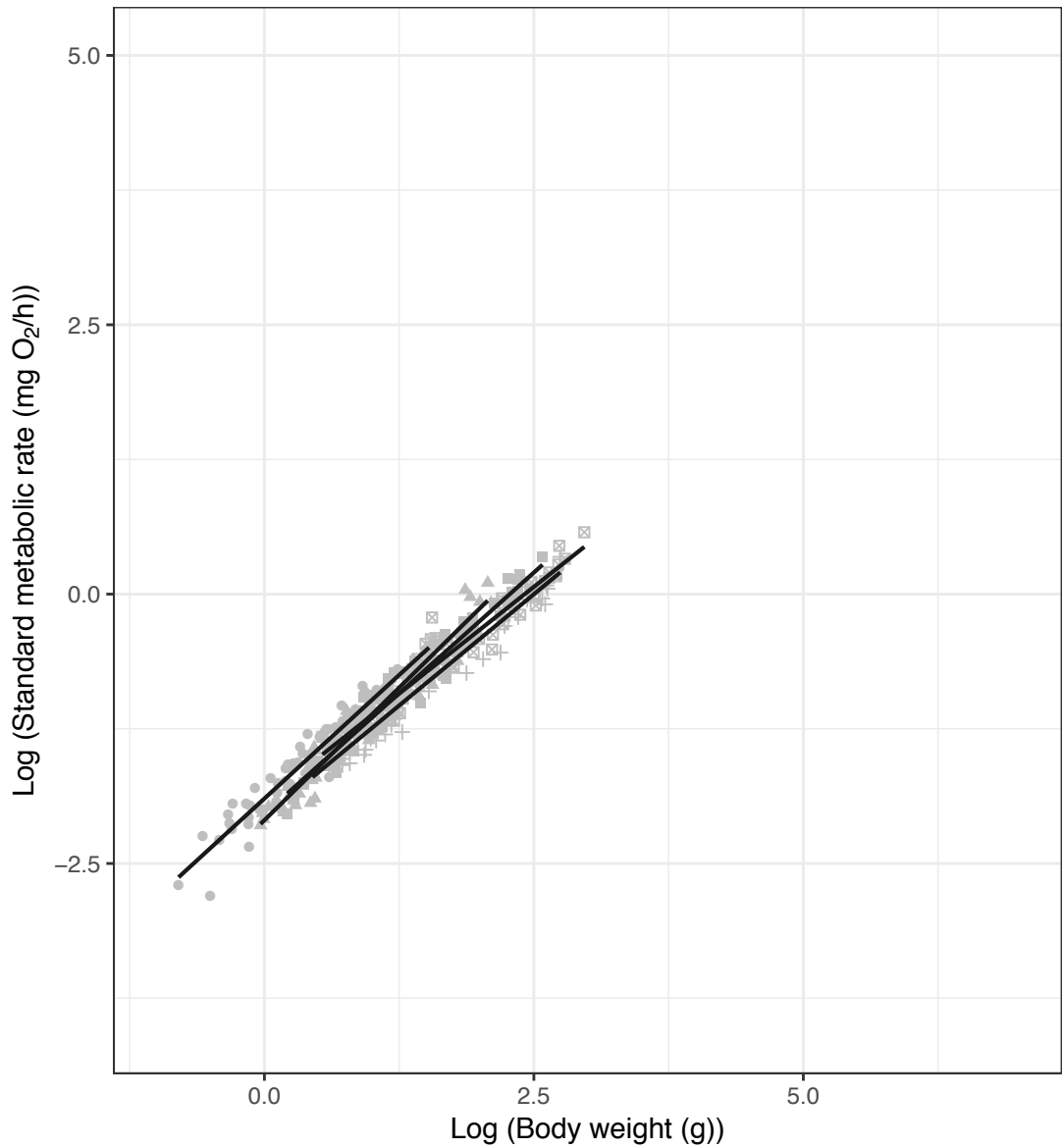
Common Triplefin

(*Forsterygion lapillum*)



Cunner

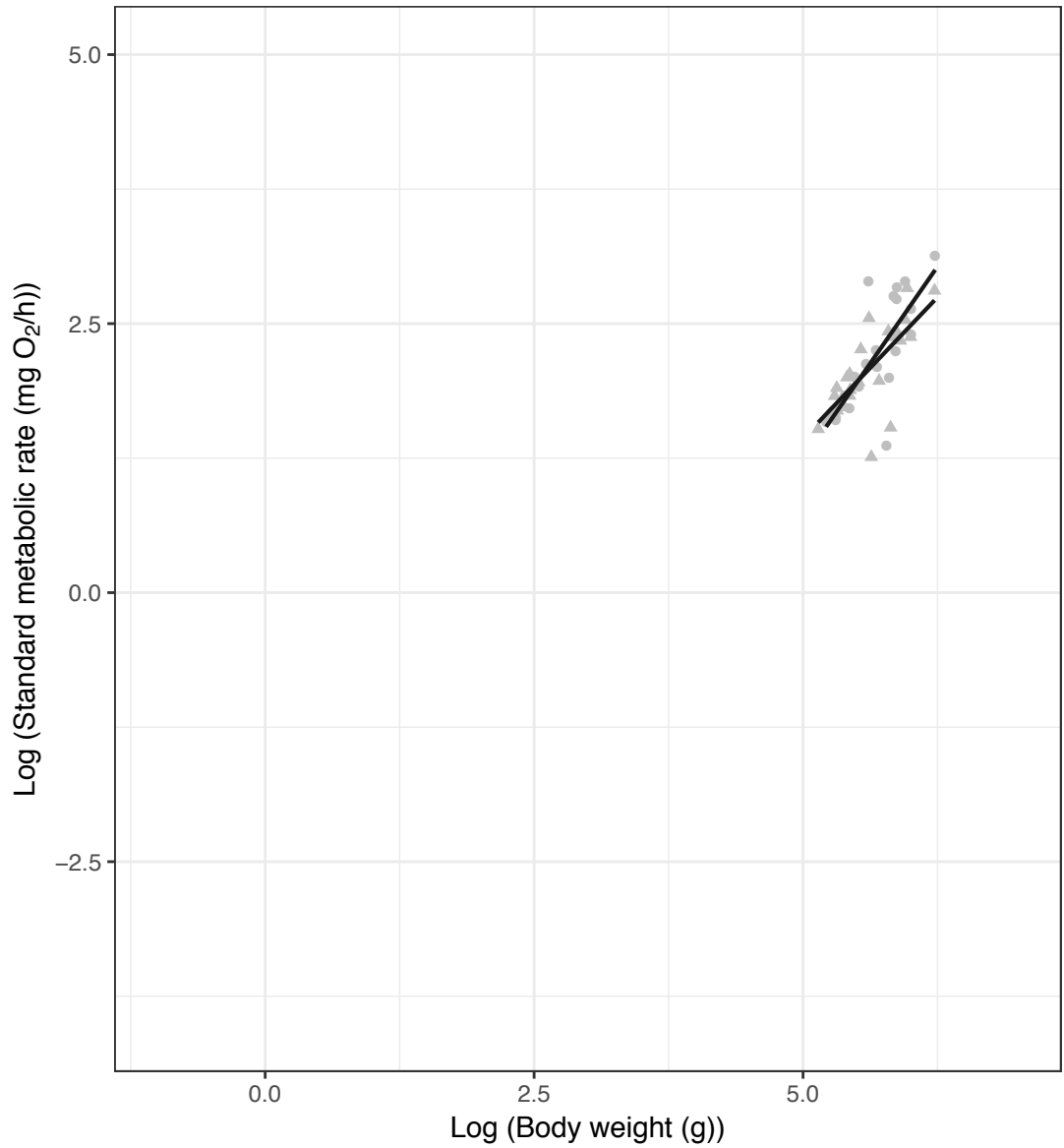
(Tautogoabrus adspersus)



Trials 1, 2, 3, 4, and 5

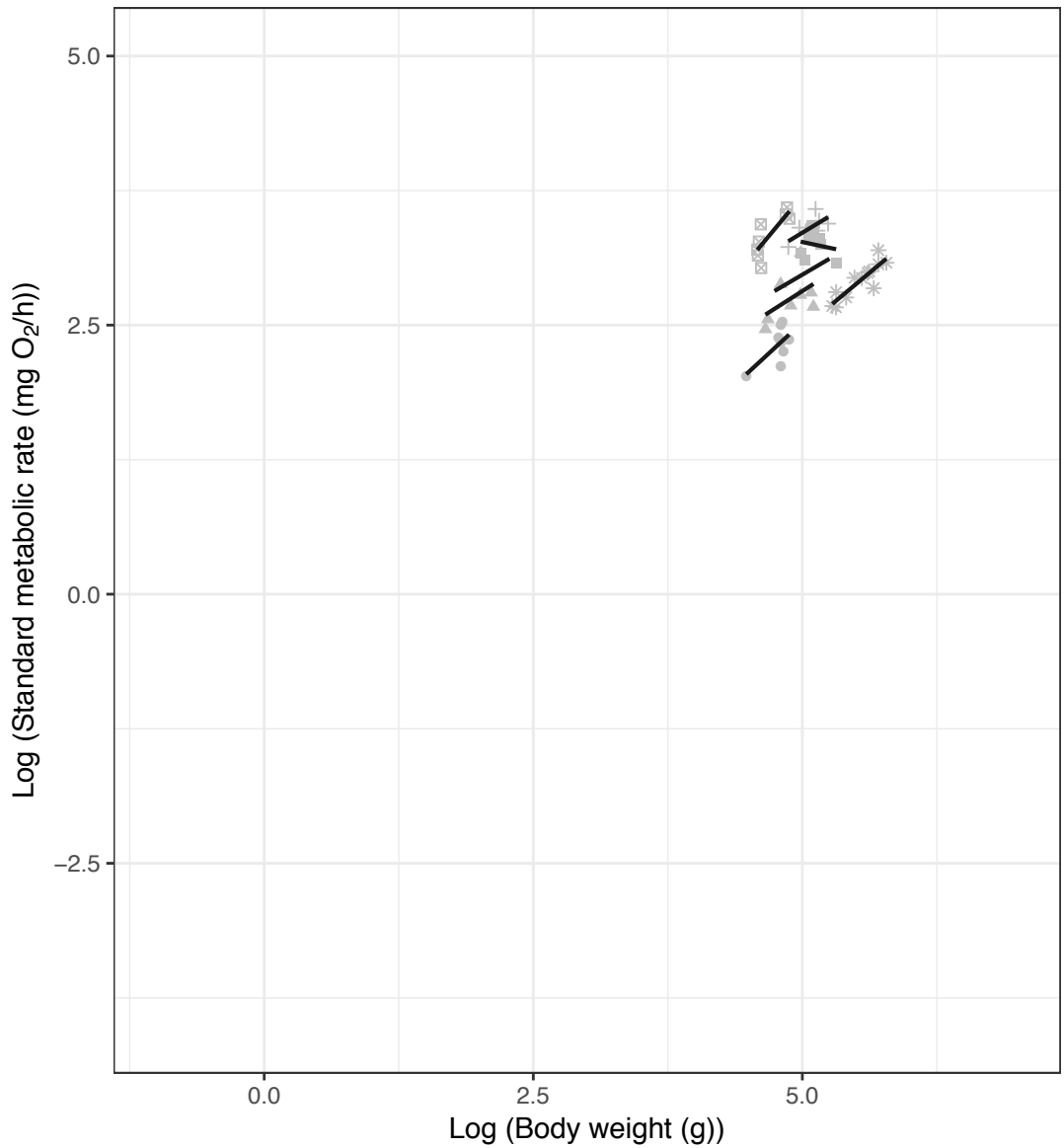
European Eel

(Anguilla anguilla)



Hapuku Wreckfish

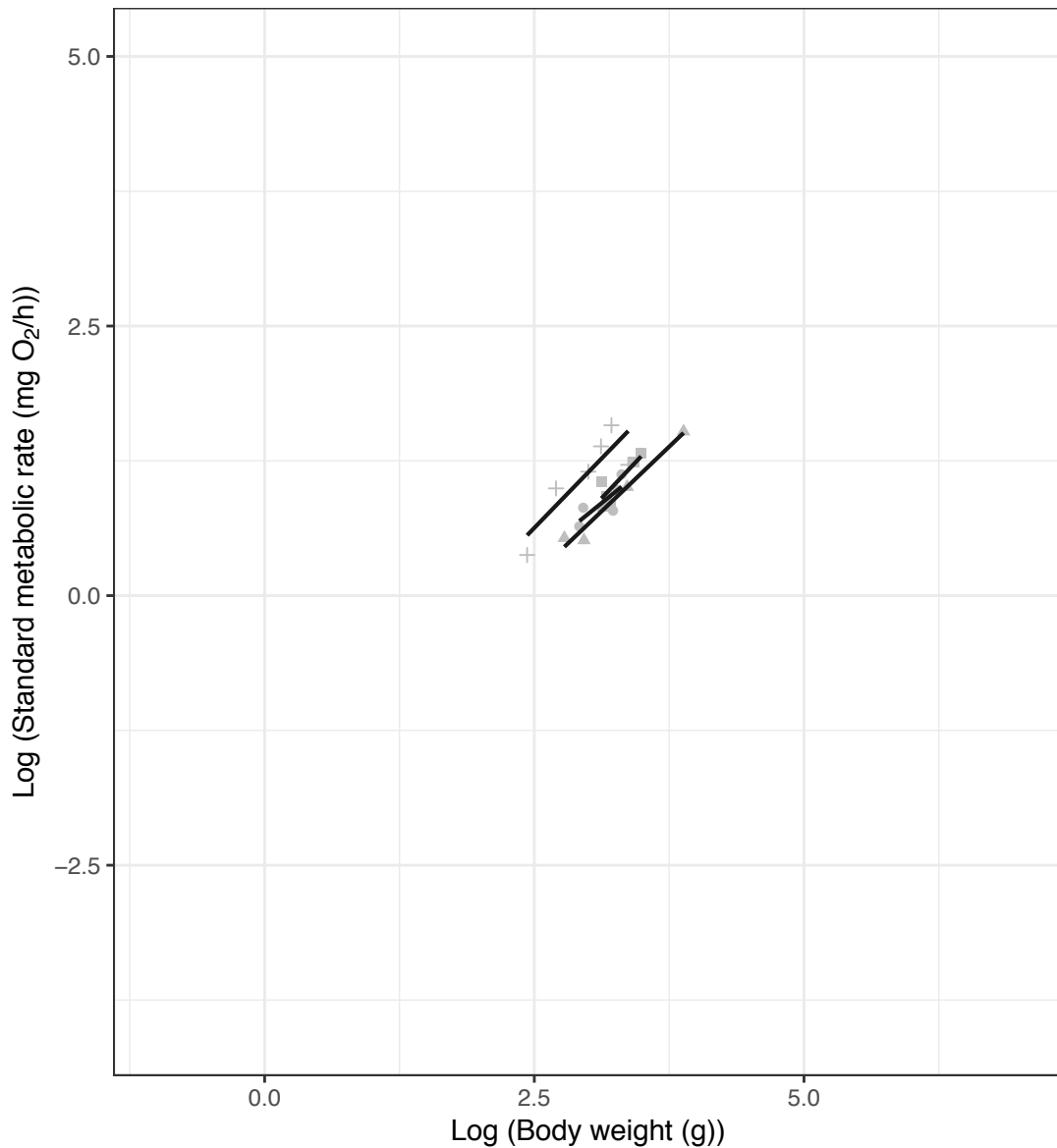
(Polyprion oxygeneios)



Trials 26, 27, 28, 29, 30, 33, and 34

Polar Cod

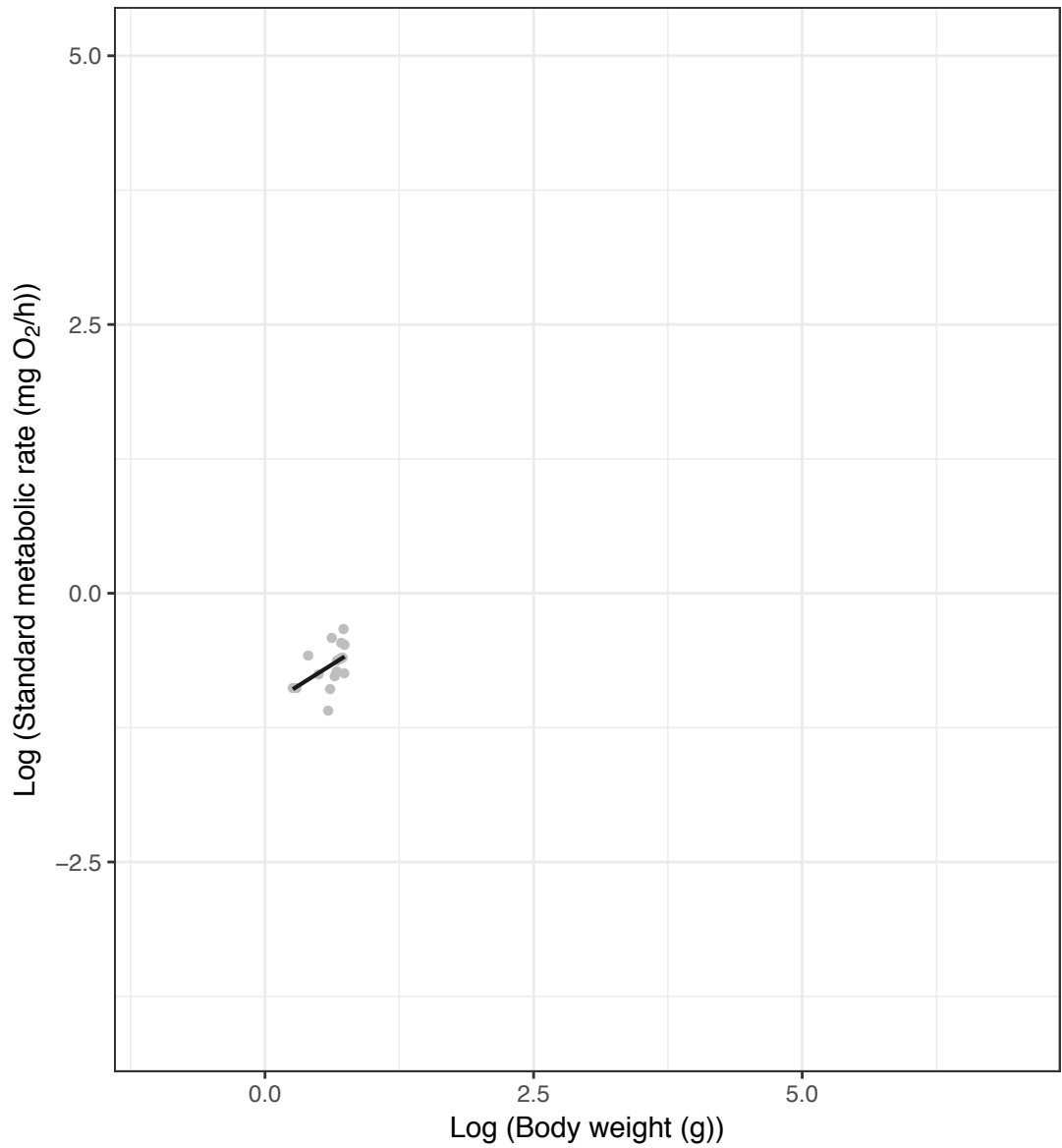
(Boreogadus saida)



Trials 15, 16, 17, and 18

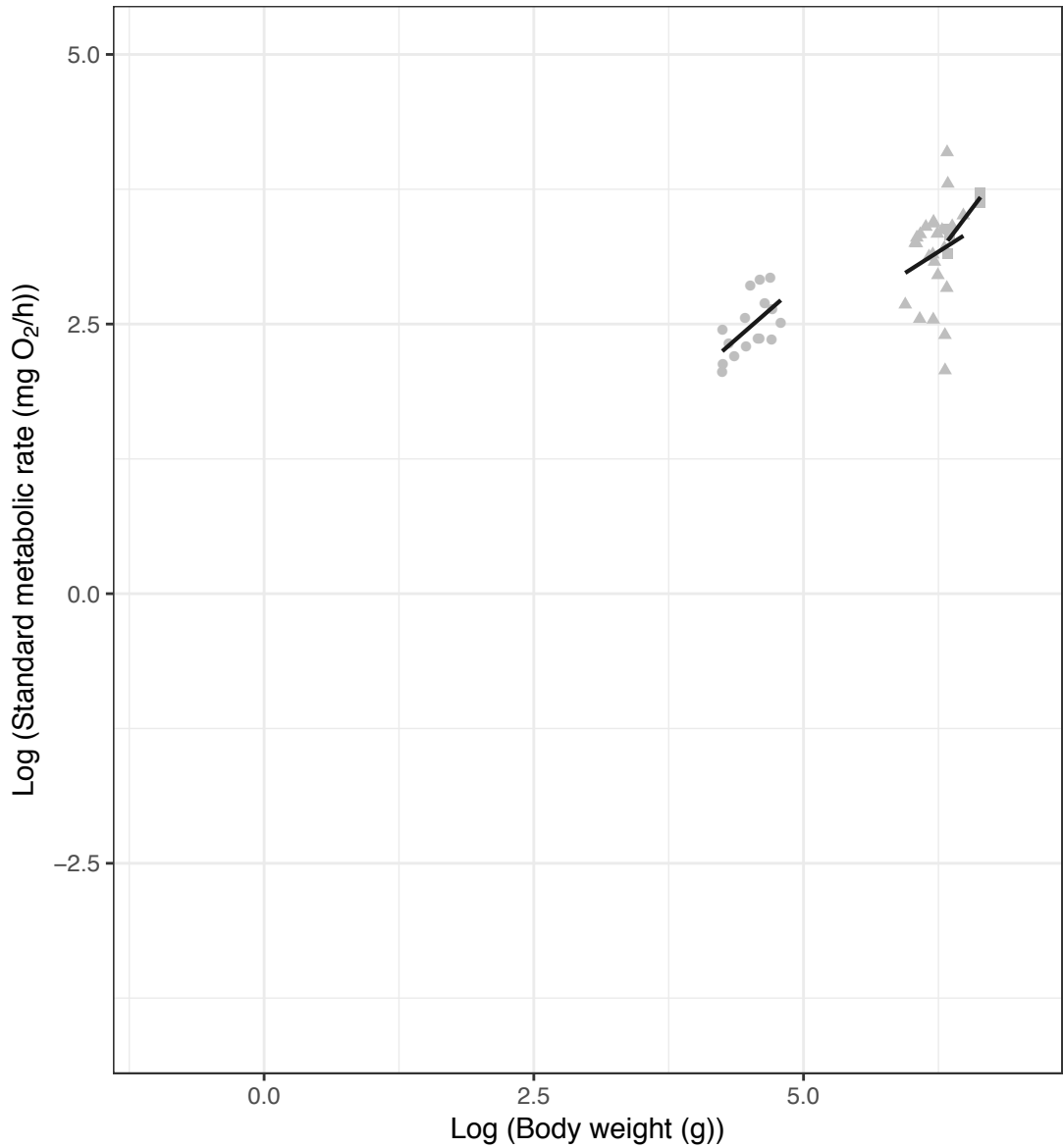
Blue-green Puller

(*Chromis viridis*)



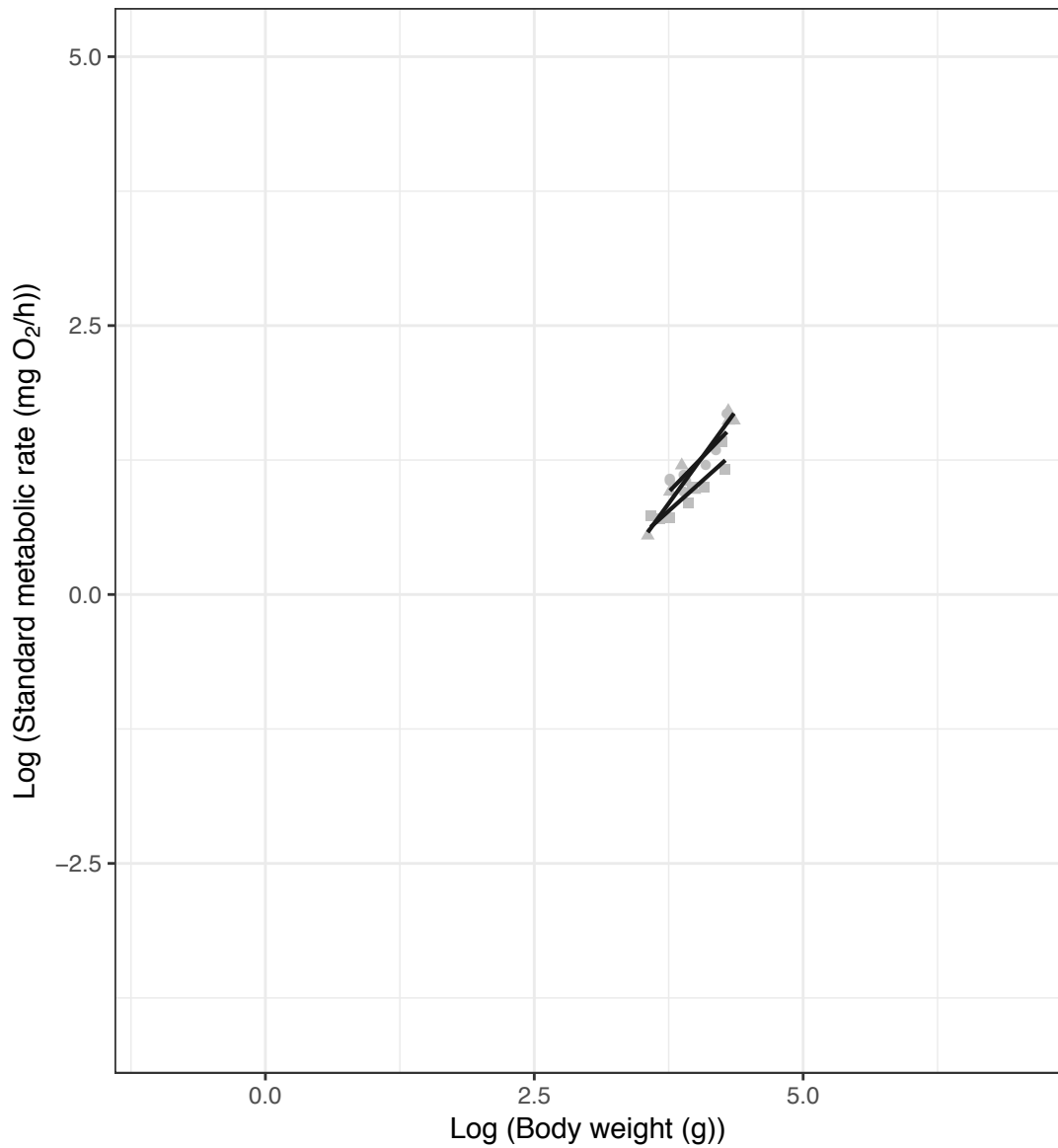
Rainbow Trout

(*Oncorhynchus mykiss*)



Round Goby

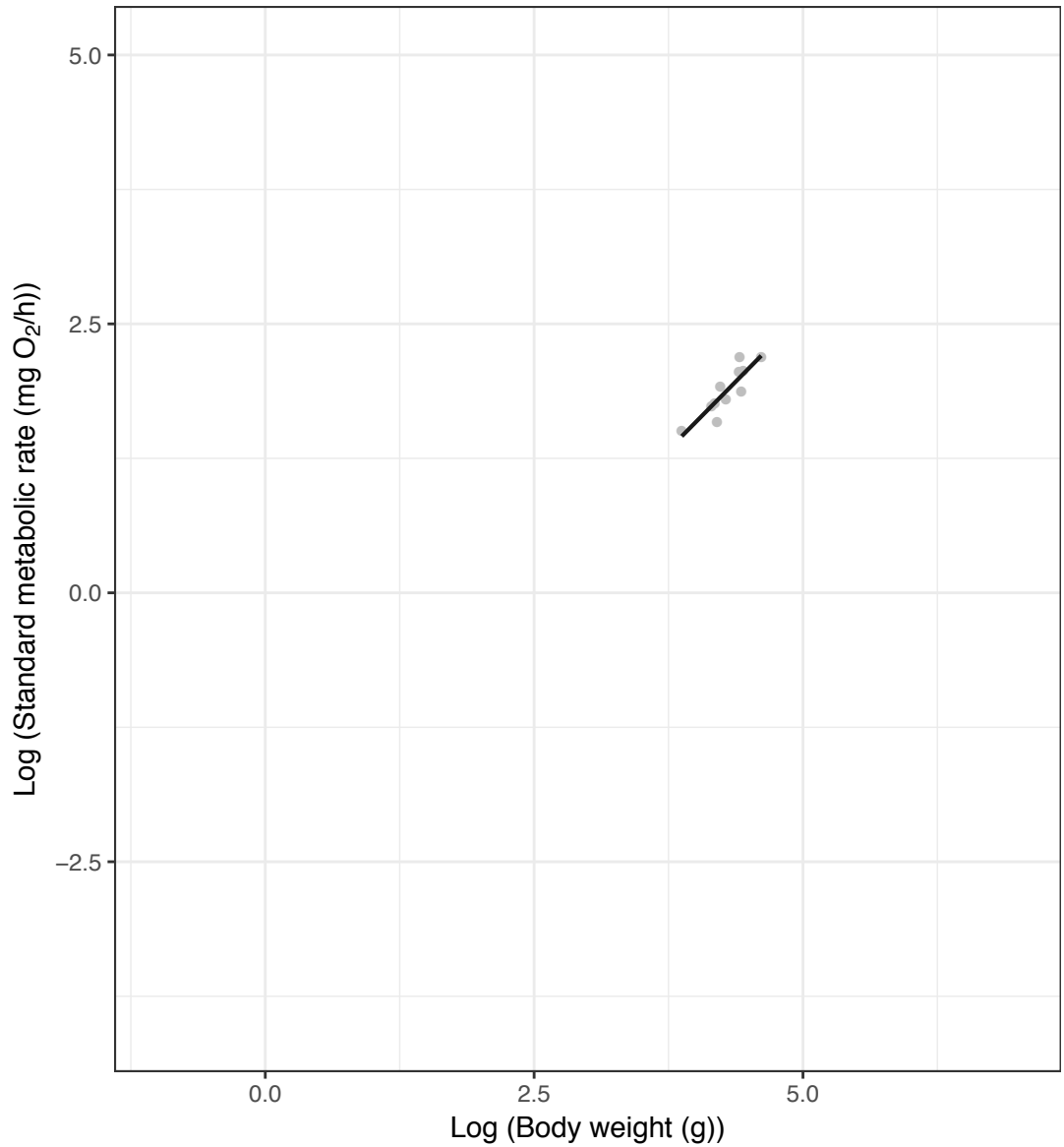
(Neogobius melanostomus)



Trials 7, 8, and 9

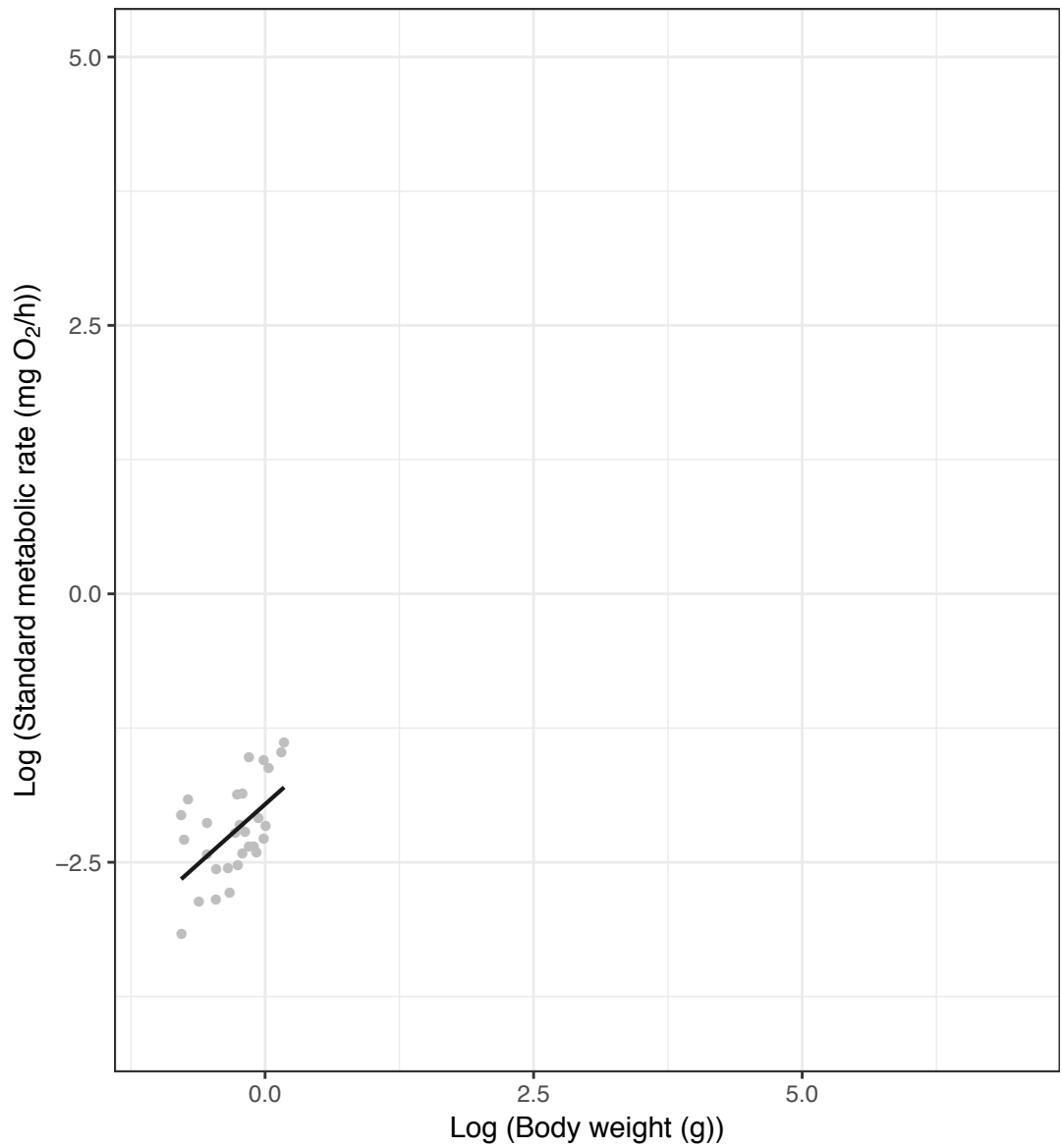
European Sea Bass

(Dicentrarchus labrax)



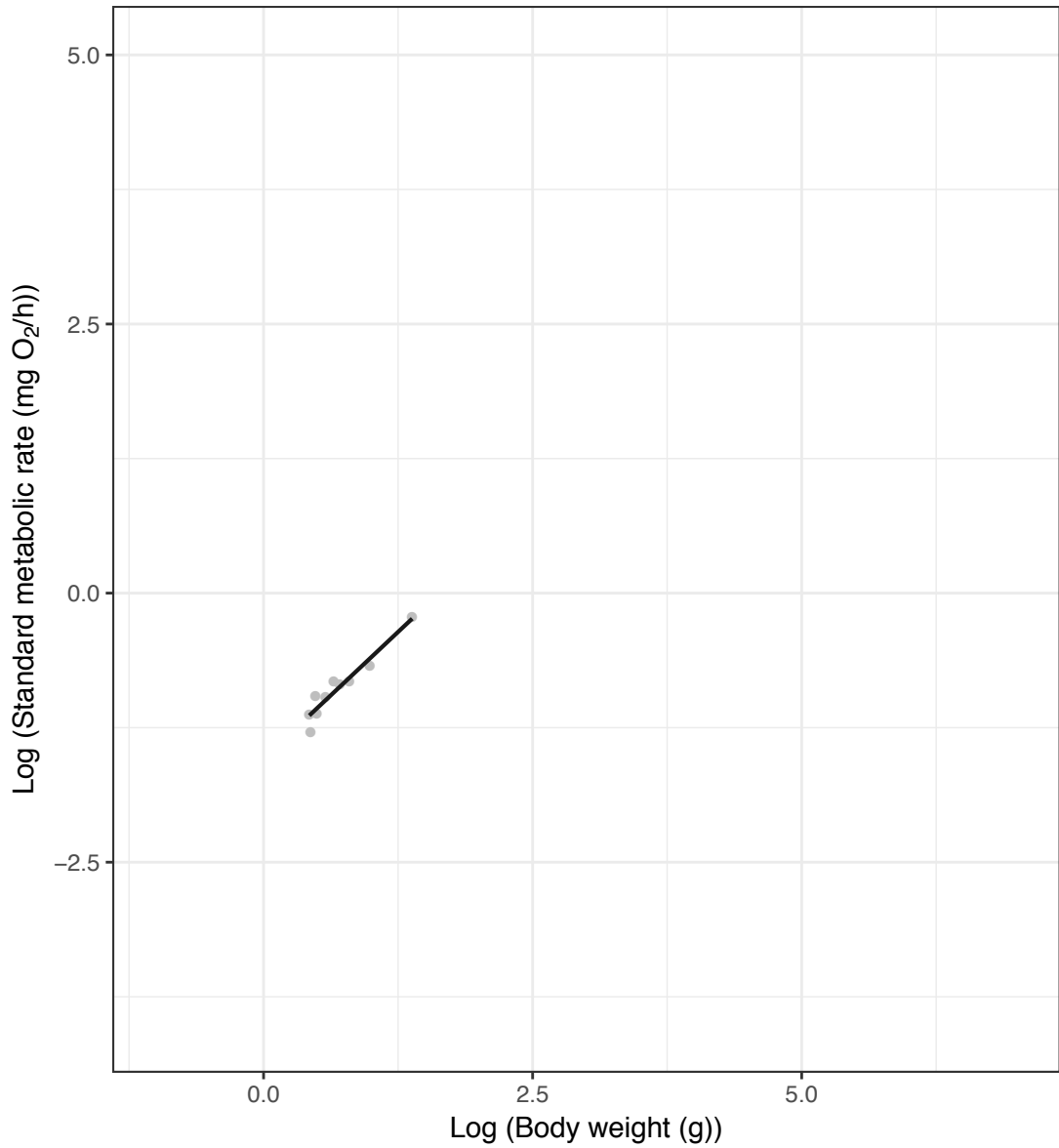
Three-spined Stickleback

(Gasterosteus aculeatus)



Twister

(Bellapiscis medius)



1 **Supplementary material 2: R output of each model with a free parameter for the slope**

2 **Model Suite 1: Random Intercept models**

3 **Fixed effect: Weight, Temp; Random effect: Species; Nested effect: Trial**

4

5 Formula: $\log(\text{smr}) \sim \log(\text{bw_g}) + \text{temp} + (1 | \text{species}) + (1 | \text{species}:\text{trial})$

6

7 AIC BIC logLik deviance
8 -135.8 -104.1 73.9 -147.8

9

10 Random effects:

Groups	Name	Variance	Std.Dev.
species:trial	(Intercept)	0.02729	0.1652
species	(Intercept)	0.19473	0.4413
Residual		0.04673	0.2162

15

16 Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	-2.976927	0.189428	-15.715
log(bw_g)	0.868078	0.014608	59.423
temp	0.065893	0.008853	7.443

21

22

23 **Model Suite 2: Estimated species intercept models**

24 **Fixed effect: Weight, Temp & Species, Nested effect: Trial**

25

26 Formula: $\log(\text{smr}) \sim \log(\text{bw_g}) + \text{temp} + \text{species} + (1 | \text{species}:\text{trial}) - 1$

27

28 AIC BIC logLik deviance
29 -175.5 -69.8 107.7 -215.5

30 Random effects:

Groups	Name	Variance	Std.Dev.
species:trial	(Intercept)	0.01764	0.1328
Residual		0.04672	0.2161

34

35 Fixed effects:

	Estimate	Std. Error	t value
log(bw_g)	0.866399	0.014747	58.749
temp	0.079591	0.008419	9.453
speciesAtlantic_Cod	-2.595677	0.128265	-20.237
speciesAtlantic_Salmon	-2.967810	0.156093	-19.013
speciesBarramundi	-3.845463	0.248164	-15.496
speciesBlue_green_puller	-3.506407	0.283329	-12.376
speciesBrown_Trout	-3.088307	0.143155	-21.573
speciesCommon_Minnow	-3.221242	0.139432	-23.103
speciesCommon_Tripelfin	-3.383674	0.173440	-19.509
speciesCunner	-3.201778	0.141166	-22.681
speciesE_sea_bass	-3.152090	0.212755	-14.816
speciesEuropean_Eel	-4.347451	0.212546	-20.454
speciesHapuku_Wreckfish	-2.793287	0.178356	-15.661
speciesPolar_Cod	-2.087451	0.100664	-20.737
speciesRainbow_Trout	-2.974013	0.163135	-18.230
speciesRound_Goby	-3.768955	0.185149	-20.356
speciesThree_Spine_Stickleback	-3.050021	0.171394	-17.795
speciesTwister	-3.156603	0.231724	-13.622

54

55

56 **Model Suite 3: Random intercepts with random slopes**
 57 **Fixed Effect: Weight & Temp; Random: Species & Slope; Nested effect: Trial**

58
 59 Formula: $\log(\text{smr}) \sim \log(\text{bw_g}) + (1 + \log(\text{bw_g}) \mid \text{species}:\text{trial}) + \text{temp} + (1 \mid \text{species})$
 60

61	AIC	BIC	logLik	deviance
62	-147.8	-105.6	81.9	-163.8

63
 64 Random effects:

65	Groups	Name	Variance	Std.Dev.
66	species:trial	(Intercept)	0.070458	0.2654
67	log(bw_g)		0.004998	0.0707
68	species	(Intercept)	0.231253	0.4809
69	Residual		0.045650	0.2137

70
 71 Fixed effects:

72	Estimate	Std. Error	t value
73 (Intercept)	-3.019453	0.206274	-14.638
74 log(bw_g)	0.892427	0.021353	41.794
75 temp	0.064432	0.009122	7.063

76
 77 **Model Suite 4: Estimated species intercept models with random slopes**
 78 **Fixed Effect: Weight, Temp & Species; Random: Slope; Nested effect: Trial**

79
 80 Formula: $\log(\text{smr}) \sim \log(\text{bw_g}) + (0 + \log(\text{bw_g}) \mid \text{species}:\text{trial}) + \text{temp} +$
 81 $\text{species} + (1 \mid \text{species}:\text{trial}) - 1$
 82

83	AIC	BIC	logLik	deviance
84	-173.6	-62.6	107.8	-215.6

85 Random effects:

86	Groups	Name	Variance	Std.Dev.
87	species.trial	log(bw_g)	9.646e-05	0.009821
88	species.trial.1	(Intercept)	1.690e-02	0.130014
89	Residual		4.664e-02	0.215967

90 Fixed effects:

91	Estimate	Std. Error	t value
92 log(bw_g)	0.86787	0.01503	57.737
93 temp	0.07951	0.00860	9.245
94 speciesAtlantic_Cod	-2.60234	0.13075	-19.904
95 speciesAtlantic_Salmon	-2.97524	0.15883	-18.732
96 speciesBarramundi	-3.85023	0.25339	-15.195
97 speciesBlue_green_puller	-3.50494	0.28662	-12.229
98 speciesBrown_Trout	-3.09260	0.14562	-21.238
99 speciesCommon_Minnow	-3.21739	0.13966	-23.037
100 speciesCommon_Triplesfin	-3.38329	0.17603	-19.220
101 speciesCunner	-3.20142	0.14308	-22.374
102 speciesE_sea_bass	-3.15763	0.21737	-14.527
103 speciesEuropean_Eel	-4.36195	0.21847	-19.966
104 speciesHapuku_Wreckfish	-2.79732	0.18231	-15.344
105 speciesPolar_Cod	-2.09188	0.10157	-20.596
106 speciesRainbow_Trout	-2.97451	0.16811	-17.694
107 speciesRound_Goby	-3.77453	0.18875	-19.998
108 speciesThree_Spine_Stickleback	-3.04785	0.17055	-17.871
109 speciesTwister	-3.15609	0.23313	-13.538

110 **Supplementary material 3: Lobster repeated body mass (grams) measurement data used in Box**
 111 **1 (NC=Not conducted)**

ID	weight1 (g)	weight2 (g)	weight3 (g)	Weight double dry time (g)
1	930	937	938	932
2	2725	2739	2744	2725
3	818	820	822	NC
4	1214	1222	1226	NC
5	2430	2432	2437	2426
6	231	233	230	227
7	240	243	242	NC
8	179	178	178	175
9	184	184	185	NC
10	1859	1865	1859	NC
11	915	917	919	912
12	242	243	242	NC
13	539	539	539	535
14	385	382	392	380
15	491	492	492	NC
16	436	435	439	NC
17	616	618	618	NC
22	599	601	602	NC
23	432	432	432	NC
24	497	496	499	NC
25	532	534	533	NC
26	195	195	195	NC
27	288	289	288	NC
28	1382	1391	1388	NC
29	188	188	189	NC
31	433	433	435	NC
36	386	387	388	NC
37	334	333	335	NC
38	189	189	189	NC
39	716	715	717	NC
40	466	465	468	NC
41	1112	1116	1119	NC

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42	1167	1171	1171	NC
43	767	767	767	NC
44	328	328	329	NC
45	411	412	412	NC
46	420	419	418	NC
47	210	209	211	NC
48	291	290	290	NC
49	1578	1577	1578	NC
50	1212	1214	1214	NC
51	368	368	367	NC
52	411	413	413	NC
53	2575	2575	2576	NC
54	1289	1297	1293	NC

112
113

114 **Supplementary material 4: Output of models described in Box 5 used to evaluate temperature**

115

116 In the body of this paper (Box 5), for conceptual clarity, we have written the joint effects of
 117 $\log(\text{weight})$ and the $\log(\text{weight}) \times \text{Temp}$ interaction as a temperature sensitive coefficient for
 118 $\log(\text{weight})$, $\hat{\beta}(\text{temp})$. $\hat{\beta}(\text{temp})$ is a linear combination of $\hat{\beta}_{\log(\text{weight})}$ and $\hat{\beta}_{\log(\text{weight}) * \text{temp}}$, with a
 119 combination weight vector of (1 T). When estimated, $\hat{\beta}_{\log(\text{weight})}$ and $\hat{\beta}_{\log(\text{weight}) * \text{temp}}$ are random
 120 variables—they are estimated with error. The variance of any linear combination of a random vector
 121 is given by a quadratic form of the variance/covariance matrix for the random vector (see Searle
 122 1971, p 40).

123

124 In this case, the standard error for the temperature sensitive scaling is

125 $SE \hat{\beta}(\text{Temp})$

$$126 = \sqrt{\text{var}(\hat{\beta}_{\log(\text{weight})}) + \text{var}(\hat{\beta}_{\log(\text{weight}) * \text{temp}}) * \text{temp}^2 + 2 * \text{covar}(\log(\text{weight}) * \text{temp})}$$

127 where,

128 $\text{var}(\hat{\beta}_{\log(\text{weight})})$ is the variance of the $\log(\text{weight})$ parameter,129 $\text{var}(\hat{\beta}_{\log(\text{weight}) * \text{temp}})$ is the variance of the $\log(\text{weight}) * \text{temp}$ interaction parameter,

130 and,

131 $\text{covar}(\hat{\beta}_{\log(\text{weight}) * \text{temp}})$ is the covariance of $\hat{\beta}_{\log(\text{weight})}$ and $\hat{\beta}_{\log(\text{weight}) * \text{temp}}$. Values of
 132 parameter variance and covariance can be extracted from the lme4 package using the
 133 `covar(model)` command.

134

135 **Temp interaction on the fixed slope model**

136

137 No temp

138 M17: $\log(\text{smr}) \sim \log(\text{bw_g}) + (1 | \text{species}) + (1 | \text{species}:\text{trial})$

139

140 Fixed factor temp

141 M1: $\log(\text{smr}) \sim \log(\text{bw_g}) + \text{temp} + (1 | \text{species}) + (1 | \text{species}:\text{trial})$

142

143 Fixed factor temp with interaction

144 M18: $\log(\text{smr}) \sim \log(\text{bw_g}) + \text{temp} + \text{temp} * (\log(\text{bw_g})) + (1 | \text{species})$

145

146 **Temp interaction on the random slope model**

147 No temp

148 M19: $\log(\text{smr}) \sim \log(\text{bw_g}) + (1 + \log(\text{bw_g}) | \text{species}:\text{trial}) + (1 | \text{species})$

149

150 Fixed factor temp

151 M9: $\log(\text{smr}) \sim \log(\text{bw_g}) + (1 + \log(\text{bw_g}) | \text{species}:\text{trial}) + \text{temp} + (1 | \text{species})$

152

153 Fixed factor temp with interaction

154 M20: $\log(\text{smr}) \sim \log(\text{bw_g}) + (1 + \log(\text{bw_g}) | \text{species}:\text{trial}) + \text{temp} + \text{temp} * (\log(\text{bw_g})) + (1$
 155 $| \text{species}) + (1 | \text{species}:\text{trial})$

156

157

158

159

160 **OUTPUT**

161
 162 **M17: Formula: log(smr) ~ log(bw_g) + (1 | species) + (1 | species:trial)**
 163

164	AIC	BIC	logLik	deviance	df.resid
165	-107.2	-80.7	58.6	-117.2	1451
166	Random effects:				
167	Groups	Name	Variance	Std.Dev.	
168	species:trial	(Intercept)	0.07578	0.2753	
169	species	(Intercept)	0.09193	0.3032	
170	Residual		0.04679	0.2163	

171	Fixed effects:				
172		Estimate	Std. Error	t value	
173	(Intercept)	-1.91897	0.09988	-19.21	
174	log(bw_g)	0.87241	0.01475	59.14	

175
 176
 177
 178
 179 **M1: Formula: log(smr) ~ log(bw_g) + temp + (1 | species) + (1 | species:trial)**
 180

181	AIC	BIC	logLik	deviance	df.resid
182	-135.9	-104.2	74.0	-147.9	1450
183	Random effects:				
184	Groups	Name	Variance	Std.Dev.	
185	species:trial	(Intercept)	0.02732	0.1653	
186	species	(Intercept)	0.19460	0.4411	
187	Residual		0.04673	0.2162	

188	Fixed effects:				
189		Estimate	Std. Error	t value	
190	(Intercept)	-2.976252	0.189430	-15.712	
191	Log(bw_g)	0.868000	0.014608	59.420	
192	temp	0.065868	0.008854	7.439	

193
 194
 195
 196
 197 **M18: Formula: log(smr) ~ log(bw_g) + temp + temp * (log(bw_g)) + (1 | species) + (1 | species:trial)**
 198

199	AIC	BIC	logLik	deviance	df.resid
200	-134.6	-97.7	74.3	-148.6	1449
201	Random effects:				
202	Groups	Name	Variance	Std.Dev.	
203	species:trial	(Intercept)	0.02800	0.1673	
204	species	(Intercept)	0.19842	0.4454	
205	Residual		0.04666	0.2160	

206	Fixed effects:				
207		Estimate	Std. Error	t value	
208	(Intercept)	-2.830956	0.254823	-11.110	
209	log(bw_g)	0.828807	0.047818	17.333	
210	temp	0.056580	0.013960	4.053	
211	log(bw_g):temp	0.002536	0.002931	0.865	

212	Variance-Covariance Matrix				
213		(Intercept)	log(bw_g)	temp	log(bw_g):temp
214	(Intercept)	0.0649346847	-0.0083274299	-3.110329e-03	4.935793e-04

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218 log(bw_g) -0.0083274299 0.0022865299 4.885162e-04 -1.334289e-04
 219 temp -0.0031103293 0.0004885162 1.948952e-04 -3.141428e-05
 220 log(bw_g):temp 0.0004935793 -0.0001334289 -3.141428e-05 8.589476e-06

221

222 **M19: Formula: log(smr) ~ log(bw_g) + (1 + log(bw_g) | species:trial) + (1 | species)**

223

224	AIC	BIC	logLik	deviance	df.resid	
225	-123.1	-86.1	68.5	-137.1	1449	
226	Random effects:					
227	Groups		Name	Variance	Std.Dev.	Corr
228			species:trial (Intercept)	0.11710	0.3422	
229			log(bw_g)	0.01064	0.1031	-0.80
230			species (Intercept)	0.13715	0.3703	
231			Residual	0.04538	0.2130	

232

233 Fixed effects:

234		Estimate	Std. Error	t value
235	(Intercept)	-2.03282	0.13165	-15.44
236	log(bw_g)	0.90837	0.02582	35.18

237

238 **M9: Formula: log(smr) ~ log(bw_g) + (1 + log(bw_g) | species:trial) + temp + (1 | species)**

239

240	AIC	BIC	logLik	deviance	df.resid	
241	-147.8	-105.6	81.9	-163.8	1448	
242	Random effects:					
243	Groups		Name	Variance	Std.Dev.	Corr
244			species:trial (Intercept)	0.070458	0.2654	
245			log(bw_g)	0.004998	0.0707	-0.86
246			species (Intercept)	0.231253	0.4809	
247			Residual	0.045650	0.2137	

248

249 Fixed effects:

250		Estimate	Std. Error	t value
251	(Intercept)	-3.019453	0.206274	-14.638
252	log(bw_g)	0.892427	0.021353	41.794
253	temp	0.064432	0.009122	7.063

254

255 **M20: Formula: log(smr) ~ log(bw_g) + (1 + log(bw_g) | species:trial) + temp + temp * (log(bw_g)) + (1 | species)**

256

257	AIC	BIC	logLik	deviance	df.resid	
258	-145.9	-98.4	82.0	-163.9	1447	
259	Random effects:					
260	Groups		Name	Variance	Std.Dev.	Corr
261			species:trial (Intercept)	0.070663	0.2658	
262			log(bw_g)	0.004901	0.0700	-0.86
263			species (Intercept)	0.232109	0.4818	
264			Residual	0.045649	0.2137	

265

266 Fixed effects:

267		Estimate	Std. Error	t value
268	(Intercept)	-2.958265	0.281762	-10.499
269	log(bw_g)	0.874656	0.057701	15.158
270	temp	0.060812	0.014717	4.132
271	log(bw_g):temp	0.001061	0.003270	0.324

272

273 Variance-Covariance Matrix

274	(Intercept)	log(bw_g)	temp	log(bw_g):temp
-----	-------------	-----------	------	----------------

275

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276	(Intercept)	0.0793900196	-0.0117618489	-3.573021e-03	6.271892e-04
277	log(bw_g)	-0.0117618489	0.0033294100	6.198137e-04	-1.753920e-04
278	temp	-0.0035730207	0.0006198137	2.165976e-04	-3.776815e-05
279	log(bw_g):temp	0.0006271892	-0.0001753920	-3.776815e-05	1.069525e-05
280					
281					