

1 Functional Ecology:

2

3 Ecologically relevant radiation exposure triggers elevated metabolic
4 rate and nectar consumption in bumblebees

5

6 Burrows, Jessica E.*¹; Copplestone, David¹; Raines, Katherine E.¹, Beresford, Nicholas
7 A.²; Tinsley, Matthew C.¹

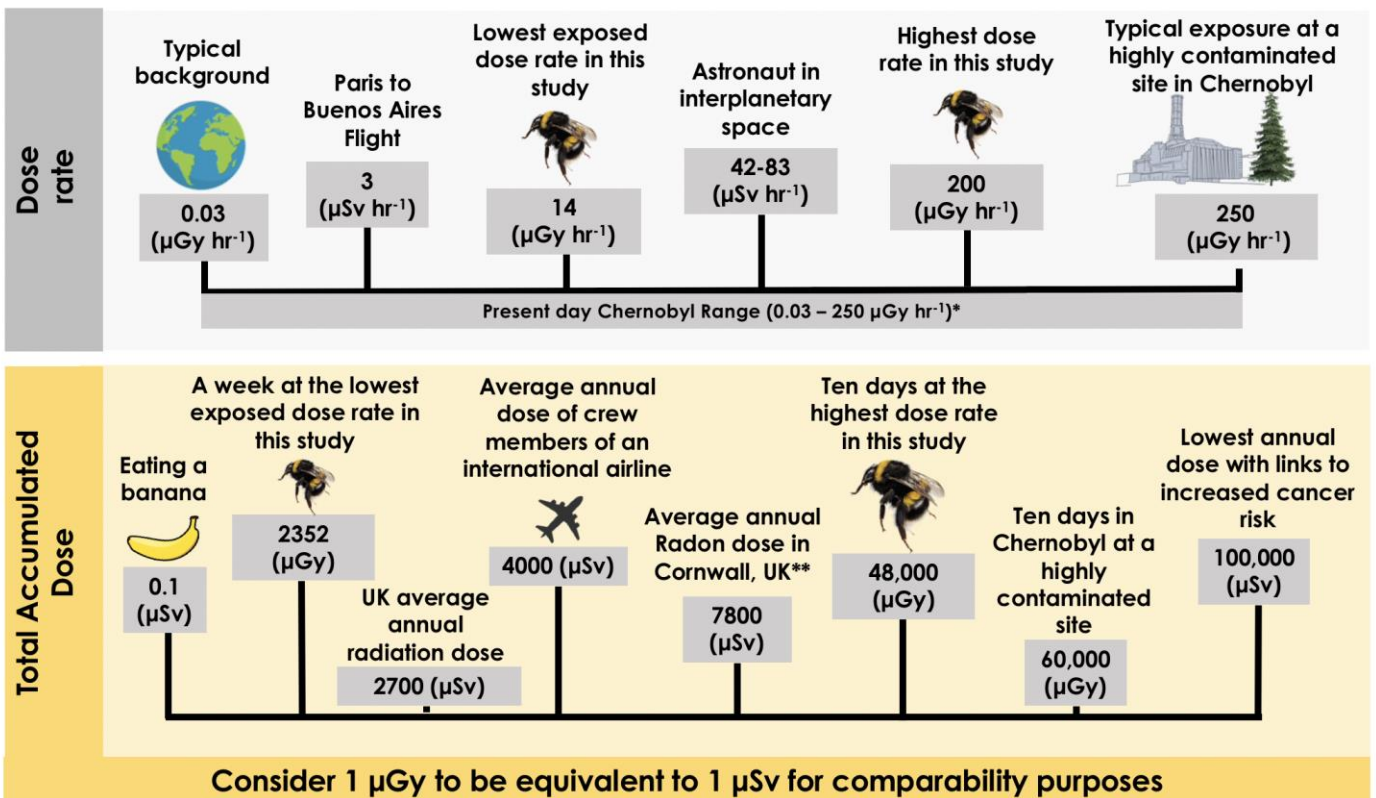
8

9

Supplementary Materials

10

11



* Although most doses fall in between 0.03 and 10 µGy hr⁻¹

** Cornwall has widespread granite bedrock which emits radon more rapidly than other rock types

12

13 **Figure S1:** A diagram of various dose rates experienced in our natural environment in comparison with dose
14 rates used in experiment 1 and 2 (ANSTO., 2022 ; Beresford *et al.*, 2020 ; Chancellor *et al.*, 2018)

15

16

17

18

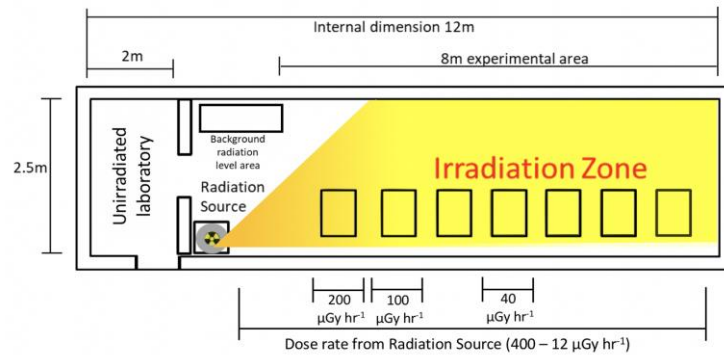
19

20

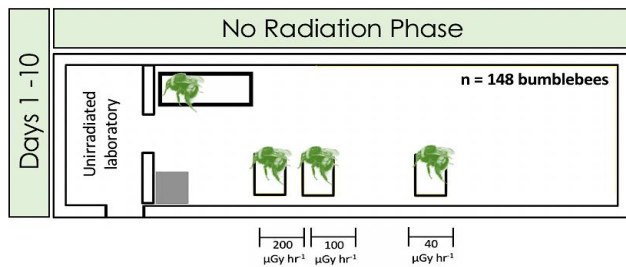
21

22

23
24
25
26
27
28
29
30
31

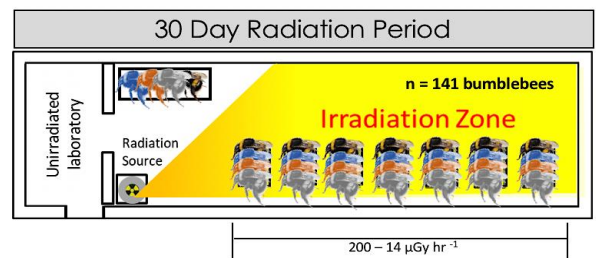


Experiment 1

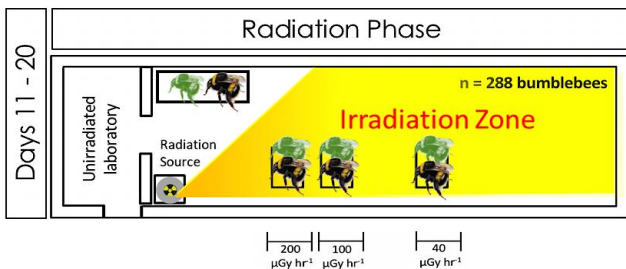


- Radiation source is shielded.
- Nectar consumption was measured every 2 days.

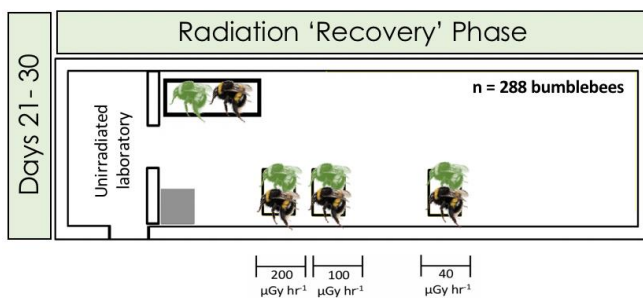
Experiment 2



- Nectar consumption and bumblebee mass was measured every 2 days for 30 days.
- Four bees were placed at each dose rate and assigned a feeder of either 20%, 30%, 40% or 50% sucrose.



- Further 140 bees are added and then radiation source unshielded.
- Nectar consumption was measured every 2 days.
- Metabolic rate and activity were measured on days 7 and 9.



- Radiation source is shielded again.
- Nectar consumption was measured every 2 days.
- Metabolic rate and activity were measured on days 17 and 19.

45
46
47

Figure S2: A diagram of the radiation facility at the University of Stirling. The top image represents the radiation facility with dimensions. The subsequent diagrams represent the two experiments and their design. For experiment 1: black boxes represent shelving units on which bumblebees were placed. Green bumblebees

48 represent those that entered the experiment on day 1 and black bumblebees represent those that entered in
 49 the radiation phase. For experiment 2: the different coloured bees represent each of the four sucrose feeding
 50 treatments of 20%, 30%, 40% and 50%.

51

52 Experiment 1: The effect of radiation on bumblebee nectar consumption

53

54

55 **Table S1.** Parameter estimates for models investigating the effect of the position of a bumblebee in the
 56 experimental facility for 10 days prior to radiation exposure (pre-radiation phase) on consumption of 40%
 57 sucrose nectar solution. Future dose rates were 200, 100, 40 $\mu\text{Gy hr}^{-1}$ and controls. The response variable (ml)
 58 was square root transformed. All variables except dose rate and days were mean centered and scaled by the
 59 standard deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and
 60 bumblebee mass of bee at start of the experiment 1.02 g. Model was linear mixed effects with normally
 61 distributed errors. Multiple measures were made on 148 bumblebees during these observations. Table S1a
 62 describes the minimal model used. Table S1b contains terms removed from the model in reverse order of
 63 deletion during model simplification.

64

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	0.55	0.01	-	-
Days within the experiment	-0.01	1.37x10 ⁻³	21.19	4.17x10 ⁻⁶
Mass of bee at start of experiment (g)	0.02	0.01	4.93	0.03
Average temperature during the days when the nectar measurements were made (°C)	0.28	0.07	14.38	1.50x10 ⁻⁴
Average humidity during the days when the nectar measurements were made (%)	0.01	2.42x10 ⁻³	11.18	8.26x10 ⁻⁴
b. Terms removed from model in reverse order of deletion				
Future dose rate ($\mu\text{Gy hr}^{-1}$)	-1.16x10 ⁻⁴	9.81x10 ⁻⁵	1.44	0.23
Access to a second low nectar concentration feeder	1.23x10 ⁻²	1.38x10 ⁻²	0.82	0.36
Age of bee at start of experiment (days)	3.54x10 ⁻³	6.05x10 ⁻³	0.35	0.55
Average temperature (°C) by humidity (%) during the days when the nectar measurements were made	4.98x10 ⁻²	4.01x10 ⁻²	1.56	0.21
Future dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	8.30x10 ⁻⁵	8.91x10 ⁻⁵	0.91	0.34
Future dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	-1.30x10 ⁻⁴	9.70x10 ⁻⁵	1.89	0.17
Future dose rate ($\mu\text{Gy hr}^{-1}$) by days in the phase	-5.35x10 ⁻⁶	1.80x10 ⁻⁵	0.09	0.77

65

66

67

68

69

70

71

72

73

74

75

76

77

78

79

80

81

82

83 **Table S2.** Parameter estimates for models investigating the effect of radiation dose rate on bumblebee nectar
84 consumption (of 40% sucrose solution) during the 10-day radiation phase of the experiment. Dose rates were
85 200, 100, 40 $\mu\text{Gy hr}^{-1}$ and controls. The response variable (ml) was square root transformed. All variables except
86 dose rate and days were mean centered and scaled by the standard deviation. For this model one standard
87 deviation of temperature is 0.07°C, humidity is 3.41% and bumblebee mass of bee at start of the experiment
88 1.02 g. Model was linear mixed effects with normally distributed errors. Multiple measures were made on 288
89 bumblebees during these observations. Table S2a describes the minimal model used. Table S2b contains terms
90 removed from the model in reverse order of deletion during model simplification.
91
92

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	13.30	0.43	-	-
Days within the experiment	2.20	0.06	23.66	1.15x10 ⁻⁶
Dose rate ($\mu\text{Gy hr}^{-1}$)	0.10	0.15	39.74	2.90x10 ⁻¹⁰
Mass of bee at start of experiment (g)	7.34	1.47	16.94	3.85x10 ⁻⁵
Average temperature during the days when the nectar measurements were made (°C)	118.00	2.16	9.07	2.00x10 ⁻³
Average humidity during the days when the nectar measurements were made (%)	2.38	0.03	7.36	7.00x10 ⁻³
Dose rate ($\mu\text{Gy hr}^{-1}$) by days within the experiment	0.02	0.01	38.25	6.22x10 ⁻¹⁰
Average temperature (°C) by humidity (%) during the days when the nectar measurements were made	45.500	10.02	3.97	0.05
b. Terms removed from model in reverse order of deletion				
Access to a second low nectar concentration feeder	-1.97x10 ⁻²	1.48x10 ⁻²	1.78	0.18
Age of bee at start of experiment (days)	-1.10x10 ⁻³	6.33x10 ⁻³	0.03	0.86
Dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	5.65x10 ⁻⁵	8.62x10 ⁻⁵	0.45	0.50
Dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	-3.84x10 ⁻⁵	1.00x10 ⁻⁴	0.14	0.70
Dose rate ($\mu\text{Gy hr}^{-1}$) by average temperature during the days when the nectar measurements were made (°C)	3.28x10 ⁻³	1.40x10 ⁻³	0.55	0.19
Dose rate ($\mu\text{Gy hr}^{-1}$) by average humidity during the days when the nectar measurements were made (%)	-6.61x10 ⁻⁶	4.32x10 ⁻⁵	0.02	0.89

93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111

112 **Table S3.** Parameter estimates for models investigating the effect of radiation dose rate on bumblebee nectar
 113 consumption (of 40% sucrose solution) during the 10-day radiation phase of the experiment excluding the top
 114 dose rate of 200 $\mu\text{Gy hr}^{-1}$. This model is for dose rates of 100, 40 $\mu\text{Gy hr}^{-1}$ and controls. The response variable
 115 (ml) was square root transformed. All variables except dose rate and days were mean centered and scaled by
 116 the standard deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and
 117 bumblebee mass of bee at start of the experiment 1.02 g. Model was linear mixed effects with normally
 118 distributed errors. Multiple measures were made on 213 bumblebees during these observations. Table S3a
 119 describes the minimal model used. Table S3b contains terms removed from the model in reverse order of
 120 deletion during model simplification.
 121

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	4.93x10 ⁻¹	1.55x10 ⁻²	-	-
Dose rate ($\mu\text{Gy hr}^{-1}$)	7.15x10 ⁻⁴	2.32x10 ⁻⁴	12.27	1.00x10 ⁻³
Mass of bee at start of experiment (g)	3.36x10 ⁻²	9.14x10 ⁻³	13.26	2.00x10 ⁻³
Average humidity during the days when the nectar measurements were made (%)	-1.06x10 ⁻²	2.39x10 ⁻³	19.52	9.93x10 ⁻⁶
b. Terms removed from model in reverse order of deletion				
Access to a second low nectar concentration feeder	-1.76x10 ⁻²	1.80x10 ⁻²	0.97	0.33
Days within the experiment	-9.88x10 ⁻⁴	1.32x10 ⁻³	0.52	0.47
Age of bee at start of experiment (days)	-6.02x10 ⁻³	7.56x10 ⁻³	0.66	0.42
Average temperature during the days when the nectar measurements were made (°C)	6.59x10 ⁻²	1.23x10 ⁻¹	0.30	0.58
Dose rate ($\mu\text{Gy hr}^{-1}$) by days within the experiment	-1.57x10 ⁻⁴	1.20x10 ⁻⁴	0.63	0.43
Average temperature (°C) by humidity (%) during the days when the nectar measurements were made	3.11x10 ⁻²	5.13x10 ⁻²	0.38	0.54
Dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	-1.23x10 ⁻⁴	2.17x10 ⁻⁴	0.34	0.56
Dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	-8.30x10 ⁻⁶	3.34x10 ⁻⁵	0.07	0.79

122
 123
 124
 125
 126
 127
 128
 129
 130
 131
 132
 133
 134
 135
 136
 137
 138
 139
 140
 141
 142
 143
 144
 145
 146
 147
 148

149 **Table S4.** Parameter estimates for models investigating the effect of radiation dose rate on bumblebee nectar
 150 consumption (of 40% sucrose solution) during the 10-day radiation phase of the experiment at a doses rate of
 151 40 $\mu\text{Gy hr}^{-1}$ and controls. Dose rates of 200 and 100 $\mu\text{Gy hr}^{-1}$ were removed. The response variable (ml) was
 152 square root transformed. All variables except dose rate and days were mean centered and scaled by the
 153 standard deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and
 154 bumblebee mass of bee at start of the experiment 1.02 g. Model was linear mixed effects with normally
 155 distributed errors. Multiple measures were made on 146 bumblebees during these observations. Table S4a
 156 describes the minimal model used. Table S4b contains terms removed from the model in reverse order of
 157 deletion during model simplification.

158

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	0.51	0.01	-	-
Days within the experiment	-3.00×10^{-3}	1.00×10^{-3}	4.93	0.03
Mass of bee at start of experiment (g)	0.03	0.01	6.51	0.01
Average humidity during the days when the nectar measurements were made (%)	-0.01	3.00×10^{-3}	4.23	3.00×10^{-3}
b. Terms removed from model in reverse order of deletion				
Average temperature during the days when the nectar measurements were made (°C)	-0.24	0.14	2.76	0.10
Dose rate ($\mu\text{Gy hr}^{-1}$)	0.03	0.02	1.51	0.22
Age of bee at start of experiment (days)	-6.00×10^{-3}	8.00×10^{-3}	0.57	0.45
Access to a second low nectar concentration feeder	-7.00×10^{-3}	0.02	0.13	0.72
Dose rate ($\mu\text{Gy hr}^{-1}$) by days within the experiment	-0.03	0.02	2.81	0.09
Dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	-0.02	0.02	0.49	0.48
Average temperature (°C) by humidity (%) during the days when the nectar measurements were made	0.03	0.07	0.18	0.67
Dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	-5.94×10^{-4}	3.55×10^{-3}	0.009	0.92

159

160

161 **Table S5.** Paired t-tests conducted to assess changes in bumblebee nectar consumption (40% sucrose) between
 162 day 10 at the end of the no radiation phase and two days later, after two days of exposure during the radiation
 163 phase. A total of 295 bees were measured on day 10 and 12.

164

Dose rate ($\mu\text{Gy hr}^{-1}$) group	Mean difference	df	T	P value
200	-4.00×10^{-3}	74	-0.18	0.86
100	-0.03	73	-1.24	0.23
40	0.04	71	1.89	0.07
0.11	0.03	73	1.44	0.16

165

166

167

168

169

170

171

172

173

174

175

176

177 **Table S6.** Parameter estimates for models investigating the effect of radiation dose rate on bumblebee nectar
 178 consumption from the 5% nectar solution during the 10-day radiation phase of the experiment. Dose rates were
 179 200, 100, 40 $\mu\text{Gy hr}^{-1}$ and controls. The response variable (ml) was square root transformed. All variables except
 180 dose rate and days were mean centered and scaled by the standard deviation. For this model one standard
 181 deviation of temperature is 0.07°C, humidity is 3.41% and bumblebee mass of bee at start of the experiment
 182 1.02 g. Model was linear mixed effects with normally distributed errors. Multiple measures were made on 144
 183 bumblebees during these observations. Table 6a describes the minimal model used. Table S6b contains terms
 184 removed from the model in reverse order of deletion during model simplification.
 185

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	0.60	0.04	-	-
b. Terms removed from model in reverse order of deletion				
Days within the experiment	0.02	0.01	1.61	0.21
Average temperature during the days when the nectar measurements were made (°C)	-1.54	0.96	1.61	0.20
Mass of bee at start of experiment (g)	0.04	0.04	0.86	0.35
Dose rate ($\mu\text{Gy hr}^{-1}$)	-2.23×10^{-4}	3.98×10^{-4}	0.37	0.54
Average humidity during the days when the nectar measurements were made (%)	3.27×10^{-3}	1.33×10^{-2}	0.06	0.80
Age of bee at start of experiment (days)	-4.17×10^{-4}	0.04	0.01	0.94
Dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	-5.77×10^{-4}	4.50×10^{-4}	1.98	0.16
Dose rate ($\mu\text{Gy hr}^{-1}$) by average humidity during the days when the nectar measurements were made (%)	-1.55×10^{-4}	1.32×10^{-4}	1.96	0.16
Average temperature (°C) by humidity (%) during the days when the nectar measurements were made	0.33	0.25	2.26	0.13
Dose rate ($\mu\text{Gy hr}^{-1}$) by days in the phase	9.90×10^{-5}	1.26×10^{-4}	0.76	0.38
Dose rate ($\mu\text{Gy hr}^{-1}$) by average temperature during the days when the nectar measurements were made (°C)	-0.01	0.01	0.34	0.56
Dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	-3.9×10^{-7}	3.98×10^{-4}	0.01	0.90
Access to a second-high nectar concentration feeder	1.57×10^{-2}	4.48×10^{-2}	0.03	0.10

186
 187
 188
 189
 190
 191
 192
 193
 194
 195
 196
 197
 198
 199
 200
 201
 202
 203
 204
 205
 206

207 **Table S7.** Parameter estimates for models investigating the effect of previous radiation dose rate on bumblebee
 208 nectar consumption (40%) during the recovery phase of the experiment. The response variable (ml) was square
 209 root transformed. All variables except dose rate and days were mean centered and scaled by the standard
 210 deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and bumblebee
 211 mass of bee at start of the experiment 1.02 g. Model was linear mixed effects with normally distributed errors.
 212 Multiple measures were made on 288 bumblebees during these observations. Table S7a describes minimal
 213 model used. Table S7b describes terms removed from the model in reverse order of deletion during model
 214 simplification.
 215

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	404.00	16.10	-	-
Days within the experiment	15.00	3.00	24.44	7.66x10 ⁻⁷
Prior dose rate received ($\mu\text{Gy hr}^{-1}$)	0.66	0.14	21.35	3.84x10 ⁻⁶
Mass of bee at start of experiment (g)	28.00	9.75	8.24	4.00x10 ⁻³
Average temperature for days leading up to nectar measurements at the data logger closest to the bumblebee (°C)	-53.50	67.70	0.63	0.43
Average humidity for days leading up to nectar measurements at the data logger closest to the bumblebee (%)	-15.50	3.68	17.70	2.59x10 ⁻⁵
Prior dose rate received ($\mu\text{Gy hr}^{-1}$) by days within the experiment	0.08	0.02	12.48	4.11x10 ⁻⁴
Average temperature (°C) by humidity levels (%) for days leading up to nectar measurements at the data logger closest to the bumblebee	-61.50	30.20	4.17	0.04
b. Terms removed from model in reverse order of deletion				
Access to a second low nectar concentration feeder	-23.5	19.9	1.42	0.23
Age of bee at start of experiment at start of experiment (days)	3.93	8.39	0.23	0.63
Prior dose rate received ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	0.04	0.14	0.09	0.77
Prior dose rate received ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	-0.02	0.12	0.03	0.86

216
 217
 218
 219
 220
 221
 222
 223
 224
 225
 226
 227
 228
 229
 230
 231
 232
 233
 234

235
 236
 237
 238
 239
 240
 241
 242
 243
 244

Table 8. Parameter estimates for models investigating whether the effect of radiation on bumblebee nectar consumption (40%) changed across the radiation and recovery phases of the experiment. The response variable (ml) was square root transformed. All variables except dose rate and days were mean centered and scaled by the standard deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and bumblebee mass of bee at start of the experiment 1.02 g. Model was linear mixed effects with normally distributed errors. Multiple measures were made on 288 bumblebees during these observations. Table S8a describes minimal model used. Table S8b describes terms removed from the model in reverse order of deletion during model simplification.

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	539.00	26.00	-	-
Days within the phase of the experiment	8.92	1.31	45.67	1.40x10 ⁻¹¹
Dose rate / Prior dose rate ($\mu\text{Gy hr}^{-1}$)	0.64	0.10	39.45	3.37x10 ⁻¹⁰
Mass of bee at start of experiment (g)	31.70	7.33	18.25	1.94x10 ⁻⁵
Average temperature during the days when the nectar measurements were made ($^{\circ}\text{C}$)	121.00	55.40	4.77	0.03
Change from radiation to recovery phase	-108.00	12.00	91.93	<2.2x10 ⁻¹⁶
Average humidity during the days when the nectar measurements were made (%)	-8.82	1.68	27.31	1.74x10 ⁻⁷
Dose rate / Prior dose rate ($\mu\text{Gy hr}^{-1}$) by days within phase	0.12	0.02	58.95	1.62x10 ⁻¹⁴
Average temperature ($^{\circ}\text{C}$) by humidity (%) during the days when the nectar measurements were made	46.90	16.00	8.59	3.00x10 ⁻³
Days within the phase by recovery phase	6.98	3.00	5.35	0.02
b. Terms removed from model in reverse order of deletion				
Access to a second low nectar concentration feeder	-25.40	14.70	3.04	0.08
Age of bee at start of experiment (days)	2.40	6.27	0.15	0.70
Dose rate / Prior dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	0.04	0.09	0.19	0.66
Dose rate / Prior dose rate ($\mu\text{Gy hr}^{-1}$) by removal of radiation in the recovery phase	0.05	0.10	0.22	0.64
Dose rate / Prior dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	-0.03	0.10	0.09	0.76

245
 246
 247
 248
 249
 250
 251
 252
 253
 254
 255
 256
 257
 258
 259
 260
 261
 262

263 Experiment 1: The effect of radiation on bumblebee metabolic rate and activity

264

265 **Table S9.** Parameter estimates for models investigating the effect of radiation exposure (0.11 vs 200 $\mu\text{Gy hr}^{-1}$)
 266 on mean bumblebee metabolic rate over a 5-minute observation period during the radiation phase of the
 267 experiment. The response variable ($\mu\text{mol min}^{-1}\text{CO}_2$) was square root transformed. All variables except dose rate
 268 and days were mean centered and scaled by the standard deviation. For this model one standard deviation of
 269 temperature is 0.07°C, humidity is 3.41% and bumblebee mass of bee at start of the experiment 1.02 g. Model
 270 was linear mixed effects with normally distributed errors. Multiple measures were made on 60 bumblebees for
 271 each time point. Table S9a describes minimal model used. Table S9b describes terms removed from the model
 272 in reverse order of deletion during model simplification.
 273

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	3.82	0.12	-	-
Day	-0.29	0.06	20.70	5.36x10 ⁻⁶
Radiation exposure	0.34	0.15	4.80	0.03
Temperature of air drawn over bee (°C)	3.94	1.93	4.26	0.04
b. Terms removed from model in reverse order of deletion				
Time bee spent moving during measurement (s)	1.00x10 ⁻³	6.92x10 ⁻⁴	2.33	0.13
Humidity levels of air drawn over bee (%)	0.04	0.03	1.46	0.23
Age of bee at start of experiment at start of experiment (days)	-0.04	0.07	0.38	0.54
Access to a second low nectar concentration feeder	-0.08	0.16	0.30	0.59
Mass of bee at start of experiment (g)	-0.54	1.47	0.13	0.72
Radiation exposure by mass of bee (g)	-0.12	0.16	0.68	0.41
Radiation exposure by age of bee at start of experiment (days)	-0.10	0.16	0.42	0.52
Temperature levels (°C) by humidity levels (%) of air drawn over bee	0.27	0.51	0.28	0.60
Radiation exposure by days in experiment	0.03	0.08	0.11	0.75
Radiation exposure by humidity levels of air drawn over bee (%)	-7.96x10 ⁻³	7.73x10 ⁻²	0.014	0.91
Radiation exposure by temperature of air drawn over bee (°C)	-3.84x10 ⁻²	1.76x10 ⁻¹	4.0x10 ⁻³	0.99

274

275

276

277

278

279

280

281

282

283

284

285

286

287

288

289

290

291

292

293 **Table S10.** Parameter estimates for models investigating the effect of the previous radiation exposure (0.11 vs
 294 200 $\mu\text{Gy hr}^{-1}$) dose rate on mean bumblebee metabolic rate over a 5-minute observation period during the
 295 recovery phase of the experiment. The response variable ($\mu\text{mol min}^{-1} \text{CO}_2$) was square root transformed. All
 296 variables except dose rate and days were mean centered and scaled by the standard deviation. For this model
 297 one standard deviation of temperature is 0.07°C , humidity is 3.41% and bumblebee mass of bee at start of the
 298 experiment 1.02 g Model was linear mixed effects with normally distributed errors. Multiple measures were
 299 made on 60 bumblebees for each timepoint. Table S10a describes minimal model used. Table S10b describes
 300 terms removed from the model in reverse order of deletion during model simplification.
 301

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	3.90	0.07	-	-
Humidity levels of air drawn over bee (%)	-0.05	0.02	5.37	0.02
b. Terms removed from model in reverse order of deletion				
Mass of bee at start of experiment (g)	1.60	1.28	1.58	0.21
Prior radiation exposure	-0.17	0.14	1.66	0.20
Temperature levels of air drawn over bee ($^\circ\text{C}$)	1.81	1.68	1.20	0.27
Time bee spent moving during measurement (s)	3.62×10^{-4}	6.79×10^{-4}	0.30	0.58
Access to a second low nectar concentration feeder	-0.06	0.14	0.17	0.68
Days within the experiment	-0.01	0.06	7.0×10^{-3}	0.93
Age of bee at start of experiment at start of experiment (days)	4.0×10^{-3}	0.06	4.0×10^{-3}	0.95
Prior radiation exposure by days within the experiment	-0.12	0.09	3.46	0.06
Temperature levels ($^\circ\text{C}$) by humidity levels (%) of air drawn over bee	1.09	1.18	0.92	0.34
Prior radiation exposure by age of bee at start of experiment (days)	0.09	0.12	0.60	0.44
Prior radiation exposure by mass of bee (g)	-0.08	0.15	0.36	0.55

302
 303
 304
 305
 306
 307
 308
 309
 310
 311
 312
 313
 314
 315
 316
 317
 318
 319
 320
 321
 322
 323
 324
 325
 326
 327
 328

329 **Table S11.** Parameter estimates for models investigating changes in the effect of radiation dose rate (0.11 vs
330 200 $\mu\text{Gy hr}^{-1}$) on mean bumblebee metabolic rate over a 5-minute observation period across the radiation and
331 recovery phases of the experiment. The response variable ($\mu\text{mol min}^{-1} \text{CO}_2$) was square root transformed. All
332 variables except dose rate and days were mean centered and scaled by the standard deviation. For this model
333 one standard deviation of temperature is 0.07°C , humidity is 3.41% and bumblebee mass of bee at start of the
334 experiment 1.02 g. Model was linear mixed effects with normally distributed errors. Multiple measures were
335 made on 60 bumblebees during these observations. Table S11a describes minimal model used. Table S11b
336 describes terms removed from the model in reverse order of deletion during model simplification.
337

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	3.83	0.11	-	-
Days within the experiment	-0.29	0.06	16.50	4.88×10^{-5}
Radiation exposure	0.35	0.14	1.66	0.20
Phase of the experiment	0.03	0.15	1.69	0.19
Temperature of air drawn over bee ($^\circ\text{C}$)	3.96	1.36	5.05	0.03
Radiation exposure by phase	-0.44	0.19	5.54	0.02
Days within experiment by phase	0.21	0.06	10.93	1.00×10^{-3}
b. Terms removed from model in reverse order of deletion				
Time bee spent moving during measurement (s)	7.15×10^{-4}	4.95×10^{-4}	2.14	0.14
Access to a second low nectar concentration feeder	-0.07	0.11	0.39	0.53
Mass of bee at start of experiment (g)	0.02	0.05	0.22	0.64
Humidity levels of air drawn over bee (%)	-0.01	0.02	0.26	0.61
Age of bee at start of experiment at start of experiment (days)	2.00×10^{-3}	0.05	0.01	0.91
Radiation exposure by days in experiment	-0.07	0.06	1.26	0.26
Radiation exposure by mass of bee (g)	0.07	0.11	0.43	0.51
Radiation exposure by age of bee at start of experiment (days)	-0.01	0.07	0.10	0.76
Temperature levels ($^\circ\text{C}$) by humidity levels (%) of air drawn over bee	-0.02	0.47	3.0×10^{-3}	0.96
Phase by radiation exposure by days within the experiment	-0.16	0.13	1.70	0.19

338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360

361 **Table S12.** Parameter estimates for zero inflated model investigating the effect of radiation dose rate (0.11 vs
 362 200 $\mu\text{Gy hr}^{-1}$) on the time a bee spent active during the radiation phase of the experiment. The response variable
 363 (s) was not square root transformed. All variables except dose rate and days were mean centered and scaled by
 364 the standard deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and
 365 bumblebee mass of bee at start of the experiment 1.02 g. Model is zero inflated which assumed errors had a
 366 Gaussian distribution. Multiple measures were made on 60 bumblebees for each timepoint. Table 12a describes
 367 minimal model used. Table S12b describes terms removed from the model in reverse order of deletion during
 368 model simplification. Table S12c describes terms removed from the zero inflated part of the model in reverse
 369 order of deletion during model simplification. No terms were significant for the zero inflated part of the model.
 370

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	127.50	12.51	-	-
Radiation exposure	37.80	18.01	2.10	0.04
b. Terms removed from model in reverse order of deletion				
Days within the experiment	8.40	5.94	1.41	0.16
Age of bee at start of experiment (days)	-9.65	8.35	-1.16	0.25
Temperature levels of air drawn over bee (°C)	139.07	246.22	0.57	0.57
Mass of bee at start of experiment (g)	0.82	9.12	0.09	0.93
Radiation exposure by age of bee at start of experiment (days)	15.59	11.88	1.31	0.19
c. Terms removed from the Zero-inflated part of the model in reverse order of deletion				
Radiation exposure	0.55	0.46	1.19	0.24
Mass of bee at start of experiment (g)	-0.24	0.22	-1.05	0.30
Days within the experiment	-0.05	0.15	-0.34	0.74
Age of bee at start of experiment (days)	-0.02	0.22	-0.07	0.94
Temperature levels of air drawn over bee (°C)	0.90	6.82	0.13	0.90
Radiation exposure by age of bee at start of experiment (days)	0.23	0.31	0.72	0.47

371
 372
 373
 374
 375
 376
 377
 378
 379
 380
 381
 382
 383
 384
 385
 386
 387
 388
 389
 390
 391
 392
 393
 394
 395
 396
 397

398 **Table S13.** Parameter estimates for zero inflated model investigating the effect of radiation dose rate (0.11 vs
399 200 $\mu\text{Gy hr}^{-1}$) on the time a bee spent active during the recovery phase of the experiment. All variables except
400 dose rate and days were mean centered and scaled by the standard deviation. For this model one standard
401 deviation of temperature is 0.07°C, humidity is 3.41% and bumblebee mass of bee at start of the experiment
402 1.02 g. Model investigating time a bee was active is zero inflated which assumed errors had a Gaussian
403 distribution. Multiple measures were made on 60 bumblebees for each timepoint. Table S13a describes minimal
404 model used. Table S13b describes terms removed from the model in reverse order of deletion during model
405 simplification. Table S13c describes terms removed from the zero inflated part of the model in reverse order of
406 deletion during model simplification. No terms were significant for the zero inflated part of the model.

407

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	130.32	10.53	-	-
b. Terms removed from model in reverse order of deletion				
Temperature levels of air drawn over bee (°C)	260.49	276.96	0.94	0.35
Days within the experiment	2.27	7.65	0.30	0.77
Mass of bee at start of experiment (g)	-2.42	11.18	-0.22	0.83
Radiation exposure	4.61	21.21	0.22	0.83
Age of bee at start of experiment (days)	-1.44	9.03	-0.16	0.88
Radiation exposure by age of bee at start of experiment (days)	3.11	14.15	0.22	0.83
c. Terms removed from the Zero-inflated part of the model in reverse order of deletion				
Radiation exposure	0.04	0.42	0.91	0.36
Days within the experiment	-0.22	0.14	-1.51	0.13
Mass of bee at start of experiment (g)	-0.16	0.22	-0.74	0.46
Temperature levels of air drawn over bee (°C)	-2.37	5.49	-0.43	0.67
Age of bee at start of experiment (days)	0.01	0.19	0.05	0.96
Radiation exposure by age of bee at start of experiment (days)	-0.53	0.29	-1.81	0.07

408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431

432 **Table S14.** Parameter estimates for zero inflated model investigating the effect of radiation dose rate (0.11 vs
 433 200 $\mu\text{Gy hr}^{-1}$) on the distance a bee moved during the radiation phase of the experiment. To investigate distance
 434 a bee moved, all variables except dose rate and days were mean centered and scaled by the standard deviation.
 435 For this model one standard deviation of temperature is 0.07°C, humidity is 3.41% and bumblebee mass of bee
 436 at start of the experiment 1.02 g. Model is zero inflated which assumed errors had a Gaussian distribution.
 437 Multiple measures were made on 60 bumblebees for each timepoint. Table S14a describes minimal model used.
 438 Table S14b describes terms removed from the model in reverse order of deletion during model simplification.
 439 Table S14c describes terms removed from the zero inflated part of the model in reverse order of deletion during
 440 model simplification. No terms were significant for the zero inflated part of the model.

441

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	100.78	9.79	-	-
Radiation exposure	25.21	14.29	1.76	0.05
b. Terms removed from model in reverse order of deletion				
Temperature levels of air drawn over bee (°C)	225.06	140.86	1.60	0.11
Age of bee at start of experiment (days)	-4.03	6.56	-0.62	0.54
Mass of bee at start of experiment (g)	3.35	7.01	0.48	0.63
Days within the experiment	0.05	6.73	7.0x10 ⁻³	0.99
Radiation exposure by age of bee at start of experiment (days)	9.77	9.51	1.03	0.30
c. Terms removed from the Zero-inflated part of the model in reverse order of deletion				
Radiation exposure	0.72	0.45	1.58	0.12
Mass of bee at start of experiment (g)	-0.15	0.22	-0.67	0.50
Days within the experiment	-0.04	0.15	-0.28	0.78
Age of bee at start of experiment (days)	-0.04	0.22	-0.19	0.85
Temperature levels of air drawn over bee (°C)	0.59	6.57	0.09	0.93
Radiation exposure by age of bee at start of experiment (days)	0.22	0.31	0.72	0.47

442
 443
 444
 445
 446
 447
 448
 449
 450
 451
 452
 453
 454
 455
 456
 457
 458
 459
 460
 461
 462
 463
 464
 465

466 **Table S15.** Parameter estimates for zero inflated model investigating whether the effect of radiation dose rate
 467 (0.11 vs 200 $\mu\text{Gy hr}^{-1}$) on the time a bee spent active changed between the radiation and recovery phases of the
 468 experiment. Multiple measures were made on 60 bumblebees for each timepoint. Table S15a describes minimal
 469 model used. For time a bee spent active all variables except dose rate and days were mean centered and scaled
 470 by the standard deviation. For this model one standard deviation of temperature is 0.07°C, humidity is 3.41%
 471 and bumblebee mass of bee at start of the experiment 1.02 g. Model is zero inflated which assumed errors had
 472 a Gaussian distribution. Table S15b describes terms removed from the model in reverse order of deletion during
 473 model simplification. Table S15c describes terms removed from the zero inflated part of the model in reverse
 474 order of deletion during model simplification. No terms were significant for the zero inflated part of the model.
 475

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	138.21	7.01	-	-
b. Terms removed from model in reverse order of deletion				
Radiation exposure	21.87	13.92	1.57	0.12
Phase of the experiment (Recovery)	-15.43	13.87	-1.11	0.27
Temperature levels of air drawn over bee (°C)	246.11	155.10	1.59	0.11
Age of bee at start of experiment (days)	-5.45	6.19	-0.88	0.38
Days within the experiment	2.42	5.58	0.43	0.67
Mass of bee at start of experiment (g)	-1.64	7.08	-0.23	0.82
Radiation exposure) by age of bee at start of experiment (days)	9.38	9.21	1.02	0.31
Days within the experiment by phase (recovery)	-1.53	9.56	-0.16	0.87
Radiation exposure by phase (Recovery)	-1.16	9.51	-0.12	0.90
c. Terms removed from the Zero-inflated part of the model in reverse order of deletion				
Radiation exposure	0.45	0.31	1.47	0.14
Days within the experiment	-0.14	0.10	-1.30	0.19
Mass of bee at start of experiment (g)	-0.20	0.16	-1.25	0.21
Phase of the experiment (Recovery)	0.32	0.31	1.04	0.30
Temperature levels of air drawn over bee (°C)	-0.50	4.16	-0.12	0.91
Age of bee at start of experiment (days)	1.00x10 ⁻³	0.14	0.01	0.99
Days within the experiment by phase (recovery)	-0.18	0.22	-0.86	0.39
Radiation exposure by age of bee at start of experiment (days)	-0.18	0.21	-0.87	0.39
Radiation exposure by phase (Recovery)	-0.14	0.64	-0.22	0.83

476
 477
 478
 479
 480
 481
 482
 483
 484
 485
 486
 487
 488
 489
 490
 491

492 Experiment 2: The dose-rate threshold of the effect of radiation on bumblebee nectar
 493 consumption

494

495 **Table S16.** Parameter estimates for model investigating the effect of radiation dose rate on bumblebee nectar
 496 consumption (ml). Multiple measures were made on 141 bumblebees during these observations. Table S16a
 497 describes minimal model used. The response variable (ml) was square root transformed. All variables except
 498 dose rate and days were mean centered and scaled by the standard deviation. For this model one standard
 499 deviation of temperature is 0.36°C, humidity is 2.68% and bumblebee mass of bee at start of the experiment
 500 1.04 g. Model was linear mixed effects with normally distributed errors. Table S16b describes terms removed
 501 from the model in reverse order of deletion during model simplification.
 502

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	727.00	12.82	-	-
Concentration of nectar	-3.63	1.16	6.79	0.01
Days within the experiment	3.98	1.00	27.57	1.5x10 ⁻⁷
Dose rate ($\mu\text{Gy hr}^{-1}$)	0.39	0.16	4.89	0.03
Average temperature during the days when the nectar measurements were made ($^{\circ}\text{C}$)	-0.07	0.01	21.21	4.12x10 ⁻⁶
Concentration of nectar by days within experiment	744.00	8.97	10.86	9.80x10 ⁻⁴
Concentration of nectar by dose rate ($\mu\text{Gy hr}^{-1}$)	-2.36	0.84	4.39	0.04
Concentration of nectar by dose rate ($\mu\text{Gy hr}^{-1}$) by days within the experiment	-4.88	1.97	6.03	0.01
b. Terms removed from model in reverse order of deletion				
Dose rate ($\mu\text{Gy hr}^{-1}$) by days within experiment	-0.08	0.01	2.0x10 ⁻³	0.96
Mass of bee at start of experiment (g)	-1.49	9.48	2.85	0.08
Age of bee at start of experiment at start of experiment (days)	-2.16	2.41	1.02	0.32
Average humidity during the days when the nectar measurements were made (%)	0.04	0.03	0.91	0.34
Dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee (g)	0.39	0.16	4.74	0.29
Dose rate ($\mu\text{Gy hr}^{-1}$) by age of bee at start of experiment (days)	-0.07	0.05	3.25	0.06
Average temperature ($^{\circ}\text{C}$) by humidity (%) during the days when the nectar measurements were made	8.73x10 ⁻³	6.49x10 ⁻³	1.80	0.18
Dose rate ($\mu\text{Gy hr}^{-1}$) by average temperature during the days when the nectar measurements were made ($^{\circ}\text{C}$)	-1.9x10 ⁻⁴	2.66x10 ⁻⁴	0.53	0.47
Dose rate ($\mu\text{Gy hr}^{-1}$) by average humidity during the days when the nectar measurements were made (%)	0.01	0.01	0.18	0.67

503

504

505

506

507

508

509

510

511

512

513

514

515

516

517

518 **Table S17.** A breakdown of parameter estimates for model S16 when dose rates are removed in increments to
 519 investigates a potential threshold effect of radiation dose rate on bumblebee nectar consumption (ml). For each
 520 line of the table, data from dose rates above the threshold stated were removed (in 10 $\mu\text{Gy hr}^{-1}$ increments) and
 521 the parameter estimate for the effect of radiation was recalculated.
 522

Dose rates	Estimate	SE	χ^2	P Value
192	3.53×10^{-4}	1.61×10^{-4}	2.16	0.03
180	2.42×10^{-4}	1.83×10^{-4}	1.85	0.18
170	1.36×10^{-4}	2.08×10^{-4}	0.32	0.57
160	1.35×10^{-4}	2.06×10^{-4}	0.31	0.56
150	2.64×10^{-4}	2.34×10^{-4}	4.51	0.03
140	2.66×10^{-4}	2.51×10^{-4}	1.41	0.25
130	2.17×10^{-4}	3.08×10^{-4}	0.59	0.44
120	2.17×10^{-4}	3.09×10^{-4}	3.80	0.05
110	5.15×10^{-4}	3.54×10^{-4}	2.92	0.08
100	5.43×10^{-4}	3.74×10^{-4}	1.63	0.20
90	2.75×10^{-4}	4.37×10^{-4}	0.58	0.44
80	4.77×10^{-4}	5.08×10^{-4}	2.11	0.15
70	5.56×10^{-4}	6.22×10^{-4}	4.51	0.03
60	5.97×10^{-4}	6.79×10^{-4}	0.57	0.45
50	2.54×10^{-4}	7.70×10^{-4}	0.09	0.76
40	1.72×10^{-3}	1.10×10^{-3}	4.29	0.04
30	1.50×10^{-3}	1.33×10^{-3}	0.23	0.63
20	2.82×10^{-3}	2.11×10^{-3}	0.35	0.56

523
 524
 525
 526
 527
 528
 529
 530
 531
 532
 533
 534
 535
 536
 537
 538
 539
 540
 541
 542
 543
 544
 545
 546
 547
 548
 549
 550
 551
 552
 553

554
555
556
557
558
559
560
561

Table S18. Parameter estimates for model investigating the effect of radiation dose rate on bumblebee (wet) mass. Multiple measures were made on 141 bumblebees during these observations. Table S18a describes minimal model used. The response variable (grams) was square root transformed. All variables except dose rate and days were mean centered and scaled by the standard deviation. For this model one standard deviation of temperature is 0.36°C, humidity is 2.68% and bumblebee mass of bee at start of the experiment 1.04 g. Model was linear mixed effects with normally distributed errors. Table S18b describes terms removed from the model in reverse order of deletion during model simplification.

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	0.14	2.86x10 ⁻³	-	-
Days within the experiment	-56.69x10 ⁻⁴	1.22x10 ⁻⁴	18.09	2.17x10 ⁻⁵
Mass of bee at start of experiment (g)	2.61x10 ⁻²	2.64x10 ⁻³	71.99	< 2.2x10 ⁻¹⁶
b. Terms removed from model in reverse order of deletion				
Average humidity during the days when the nectar measurements were made (%)	8.34x10 ⁻⁴	6.66x10 ⁻⁴	2.96	0.09
Concentration of nectar	1.37x10 ⁻⁴	3.39x10 ⁻⁴	1.09	0.31
Dose rate ($\mu\text{Gy hr}^{-1}$)	2.68x10 ⁻⁵	4.27x10 ⁻⁵	0.53	0.47
Average temperature during the days when the nectar measurements were made (°C)	1.55x10 ⁻⁴	2.75x10 ⁻³	0.02	0.88
Dose ($\mu\text{Gy hr}^{-1}$) by days within the experiment	2.82x10 ⁻⁶	2.47x10 ⁻⁶	1.34	0.25
Concentration of nectar by days within the experiment	9.17x10 ⁻⁶	1.15x10 ⁻⁵	0.82	0.38
Concentration of nectar by dose rate ($\mu\text{Gy hr}^{-1}$)	2.24x10 ⁻⁶	3.78x10 ⁻⁶	0.40	0.53
Average temperature (°C) by humidity (%) during the days when the nectar measurements were made	4.71x10 ⁻⁴	1.20x10 ⁻³	0.12	0.38
Dose rate ($\mu\text{Gy hr}^{-1}$) by average humidity during the days when the nectar measurements were made (%)	-1.98x10 ⁻⁶	6.92x10 ⁻⁶	0.08	0.35
Dose rate ($\mu\text{Gy/hr}^{-1}$) by mass of bee at start of experiment (g)	9.69x10 ⁻⁶	4.69x10 ⁻⁵	0.08	0.73
Dose rate ($\mu\text{Gy hr}^{-1}$) by average temperature during the days when the nectar measurements were made (°C)	7.11x10 ⁻⁶	4.88x10 ⁻⁵	0.02	0.88

562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582

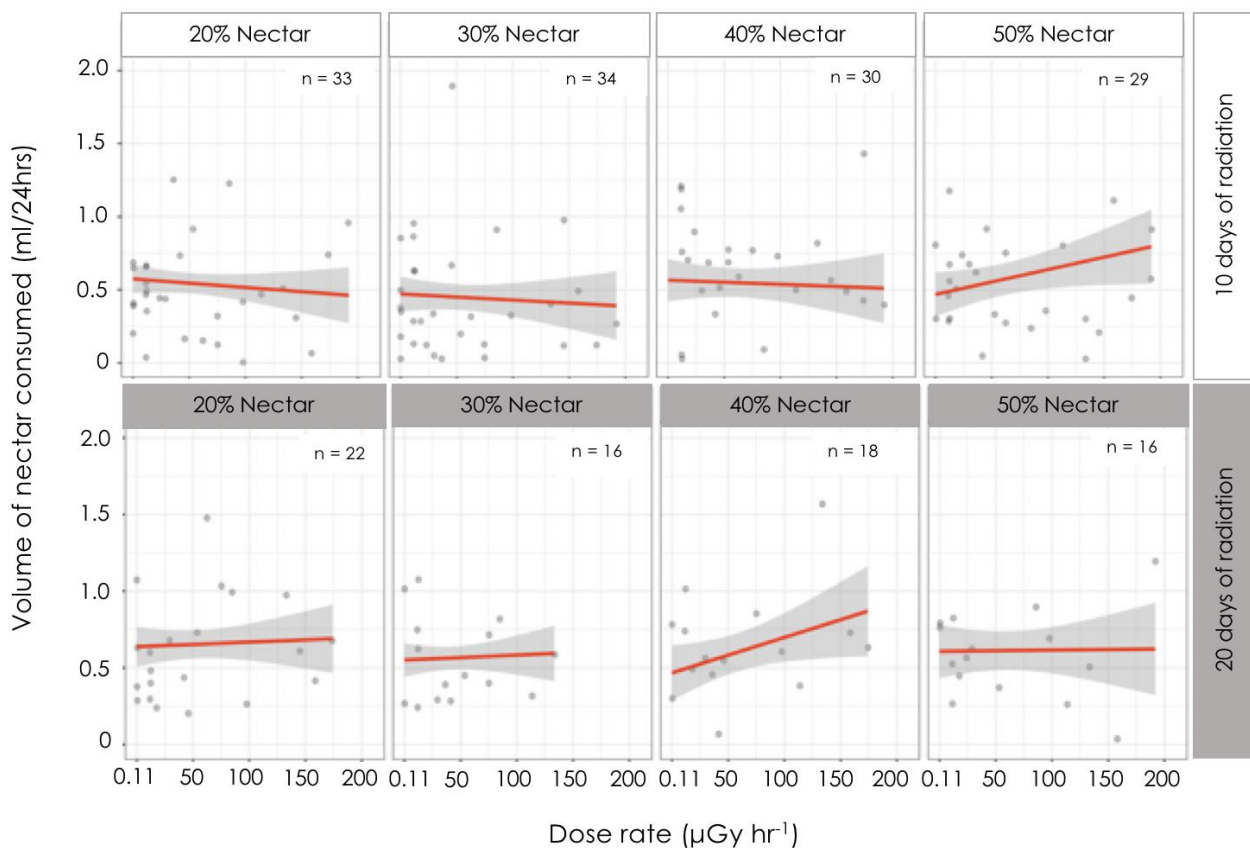
583 **Table S19.** Parameter estimates for model investigating the effect of radiation dose rate on bumblebee dry
 584 weight. The response variable (grams) was square root transformed. All variables except dose rate and days
 585 were mean centered and scaled by the standard deviation. For this model one standard deviation of bumblebee
 586 mass of bee at start of the experiment is 1.04 g. Model was linear mixed effects with normally distributed errors.
 587 Multiple measures were made on 141 bumblebees during these observations. Table S19a describes minimal
 588 model used. Table S19b describes terms removed from the model in reverse order of deletion during model
 589 simplification.
 590

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	4.24x10 ⁻²	5.51x10 ⁻⁴	-	-
Concentration of nectar	1.56x10 ⁻⁴	4.87x10 ⁻⁵	19.77	9.93x10 ⁻⁶
Dose rate ($\mu\text{Gy hr}^{-1}$)	1.13x10 ⁻⁵	6.98x10 ⁻⁶	2.11	0.11
Mass of bee at start of experiment (g)	7.22x10 ⁻³	5.32x10 ⁻⁴	470.57	< 2.2x10 ⁻¹⁶
Dose rate ($\mu\text{Gy hr}^{-1}$) by mass of bee at start of experiment (g)	3.03x10 ⁻⁵	7.02x10 ⁻⁶	18.71	1.76x10 ⁻⁵
b. Terms removed from model in reverse order of deletion				
Concentration of nectar by dose rate ($\mu\text{Gy hr}^{-1}$)	-1.89x 0 ⁻⁷	5.96x10 ⁻⁷	0.10	0.75

591
 592
 593 **Table S20.** Parameter estimates for model investigating the effect of radiation dose rate on bumblebee thorax
 594 temperature. The response variable (degrees centigrade) was square root transformed. All variables except dose
 595 rate and days were mean centered and scaled by the standard deviation. For this model one standard deviation
 596 of bumblebee mass of bee at start of the experiment 1.04 g. Model was linear mixed effects with normally
 597 distributed errors. Multiple measures were made on 141 bumblebees during these observations. Table S20a
 598 describes minimal model used. Table S20b describes terms removed from the model in reverse order of deletion
 599 during model simplification.
 600

a. Minimal Model				
Predictors	Estimate	SE	χ^2	P Value
(Intercept)	26.22	0.05	-	-
b. Terms removed from model in reverse order of deletion				
Dose rate ($\mu\text{Gy hr}^{-1}$)	1.57x10 ⁻³	2.04x10 ⁻⁵	2.54	0.11
Mass of bee (g)	0.06	0.04	2.28	0.13
Concentration of nectar	4.00x10 ⁻³	3.00x10 ⁻³	1.39	0.24
Days within the experiment	3.00x10 ⁻³	0.01	0.47	0.50
Thorax width of bee (mm)	-1.00x10 ⁻³	0.05	0.05	0.83
Dose rate ($\mu\text{Gy hr}^{-1}$) by thorax width of bee (mm)	9.59x10 ⁻⁴	7.15x10 ⁻⁴	1.64	0.24
Dose rate ($\mu\text{Gy hr}^{-1}$) by bee mass (g)	-1.00x10 ⁻³	8.71x10 ⁻⁴	2.23	0.14
Concentration of nectar by days in experiment	5.33x10 ⁻⁴	4.11x10 ⁻⁴	1.71	0.19
Concentration of nectar by dose rate ($\mu\text{Gy hr}^{-1}$)	-5.70x10 ⁻⁵	5.69x10 ⁻⁵	0.80	0.37
Days in experiment by dose rate ($\mu\text{Gy hr}^{-1}$)	5.46x10 ⁻⁵	8.16x10 ⁻⁵	0.46	0.50
Mass of bee (g) by thorax width (mm)	3.00x10 ⁻³	0.04	0.01	0.95
Days in experiment by dose rate ($\mu\text{Gy hr}^{-1}$) by concentration of nectar	5.46x10 ⁻⁶	8.16x10 ⁻⁶	0.97	0.49

601
 602
 603
 604
 605
 606
 607
 608
 609
 610



611
 612 **Figure S3** The volume of nectar consumed for bees provided with a nectar concentration of either 20%, 30%,
 613 40% or 50% whilst exposed to a gradient of radiation exposure. The top four panels represent the model
 614 estimates for volume of nectar consumed on day 10, following 10 days of radiation exposure. The bottom four
 615 panels represent the model estimates for volume of nectar consumed at day 20 after a further 10 days of
 616 radiation exposure. Lines denote model fit. Points on each graph represent raw data values from each bee
 617 measured. The full model from which this was calculated was the minimal model presented in Table S16.
 618 However, for this figure nectar concentration was fitted as a fixed factor rather than a covariate to enable
 619 independent estimates of the radiation effect for each panel.

620
 621
 622
 623 References

624
 625 Australian Nuclear Science and Technology. (2022). *What is radiation?*. Available:
 626 <https://www.ansto.gov.au/education/nuclear-facts/what-is-radiation>. Last accessed 8th
 627 March 2022.

628
 629 Beresford, N. A., Barnett, C. L., Gashchak, S., et al. (2020). Radionuclide transfer to wildlife at
 630 a “Reference site” in the Chernobyl Exclusion Zone and resultant radiation exposures. *Journal*
 631 *of Environmental Radioactivity*, 105661. doi: 10.1016/j.jenvrad.2018.02.007.

632
 633 Chancellor, J. C. et al. (2018) ‘Limitations in predicting the space radiation health risk for
 634 exploration astronauts’, *npj Microgravity*. Springer US, 8(3), pp. 1–11. doi: 10.1038/s41526-
 635 018-0043-2.

