Ecography

ECOG-03458
Birkett, A. J., Blackburn, G. A. and Menéndez, R. 2017. Linking species thermal tolerance to elevational range shifts in upland dung beetles. – Ecography doi: 10.1111/ecog.03458

Supplementary material

Appendix 1

Table A1. Dung beetle species and the number of individuals collected during the surveys in 2008 and 2013 in the Moor House study area. Shown in bold are the three focal species of the study (*Acrossus depressus*, *Agoliinus lapponum* and *Agrilinus ater*).

Species	Number of individuals
APHODIIDAE	
Acrossus depressus (Kugelann 1792)	**701**
Acrossus rufipes (Linnaeus 1758)	74
Agoliinus lapponum (Gyllenhal 1808)	**1282**
Agrilinus rufus (Moll 1782)	25
Agrilinus ater (De Geer 1774)	**1524**
Agrilinus constans (Duftschmid 1805)	56
Aphodius fimetarius (Linnaeus 1758)	75
Esymus merdarius (Fabricius 1775)	9
Melinopterus prodromus (Brahm 1790)	27
Nimbus contaminatus (Herbst 1783)	136
Planolinus borealis (Gyllenhal 1827)	10
Planolinus uliginosus (Hardy 1847)	21
Teuchestes fossor (Linnaeus 1758)	4
Aphodiidae sp	2
GEOTRUPIDAE	
Anoplotrupes stercorosus (Scriba 1791)	1
Geotrupes stercorarius (Linnaeus 1758)	2

Table A2. Number of individuals of the three species (*Agoliinus lapponum*, *Agrilinus ater* and *Acrossus depressus*) used in thermal tolerance assays, by the elevation from which they were collected along the southerly transect of the Moor House study site (Fig. 1). Data in brackets are the total number of individuals recorded of each species at the corresponding 100 m elevation band during the 2008 and 2013 surveys. Elytra length range also provided as proxy for body size.

Source elevation (m a.s.l.)	*A. lapponum*	*A. depressus*	*A. ater*
335	(0)	10 (212)	10 (303)
443	(0)	10 (131)	10 (182)
512	10 (17)	10 (136)	10 (422)
582	10 (237)	10 (105)	10 (270)
727	10 (361)	(56)	10 (179)
782	10 (799)	(16)	(41)
Elytra length	4.5 – 6.5 mm	5.8 – 7.6 mm	3.5 – 5.2 mm

Table A3. Abundance and likelihood ratio (LR) of *Agoliinus lapponum* along the elevational gradient in (a) 1956, (b) 2008 and (c) 2013 surveys. LR for elevations outside the recorded species range is calculated based on the abundance of the species across its observed range relative to the overall sampling effort at that elevation (total number of beetles collected). Values of LR above 8 indicate strong evidence that the target species do not occur at that elevation (Rowe, et al. 2010).

a) 1956 survey

Elevation (m a.s.l.)	Total captured individuals	*A. lapponum* abundance	LR
275	94	0	9.3×10^{19}
305	56	0	2.7×10^{12}
320	106	0	1.6×10^{22}
335	47	4	-
335	54	6	-
365	94	0	-
365	36	3	-
365	82	16	-
395	63	27	-
410	76	0	-
425	46	40	-
425	55	27	-
425	48	35	-
440	63	17	-
440	42	0	-
440	37	2	-
455	40	36	-
470	63	42	-
490	38	38	-
580	62	56	-
610	102	94	-
Total	**1304**	**443**	

b) 2008 survey

Elevation (m a.s.l.)	Total captured individuals	*A. lapponum* abundance	LR
292	83	0	4.9×10^{17}
314	53	0	3.9×10^{11}
335	115	0	7.0×10^{23}
397	61	0	1.8×10^{13}
399	44	0	5.1×10^{09}
443	82	0	3.1×10^{17}
467	107	2	-
478	255	0	-
512	124	2	-
539	119	26	-
562	46	10	-
582	88	15	-
671	134	72	-
673	74	56	-
727	58	15	-
778	131	125	-
782	177	170	-
810	94	86	-
Total	**1845**	**579**	

c) 2013 survey

Elevation (m a.s.l.)	Total captured individuals	*A. lapponum* abundance	LR
292	149	0	4×10^{53}
314	72	0	1.6×10^{28}
335	107	0	1.9×10^{40}
397	32	0	1.4×10^{13}
399	79	0	4.9×10^{30}
443	85	0	6.2×10^{32}
467	76	0	4.2×10^{29}
478	85	0	6.2×10^{32}
512	134	13	-

539	92	34	-
562	104	88	-
582	195	64	-
671	141	83	-
673	110	102	-
727	95	33	-
778	68	64	-
782	226	214	-
810	167	140	-
Total	**2017**	**835**	

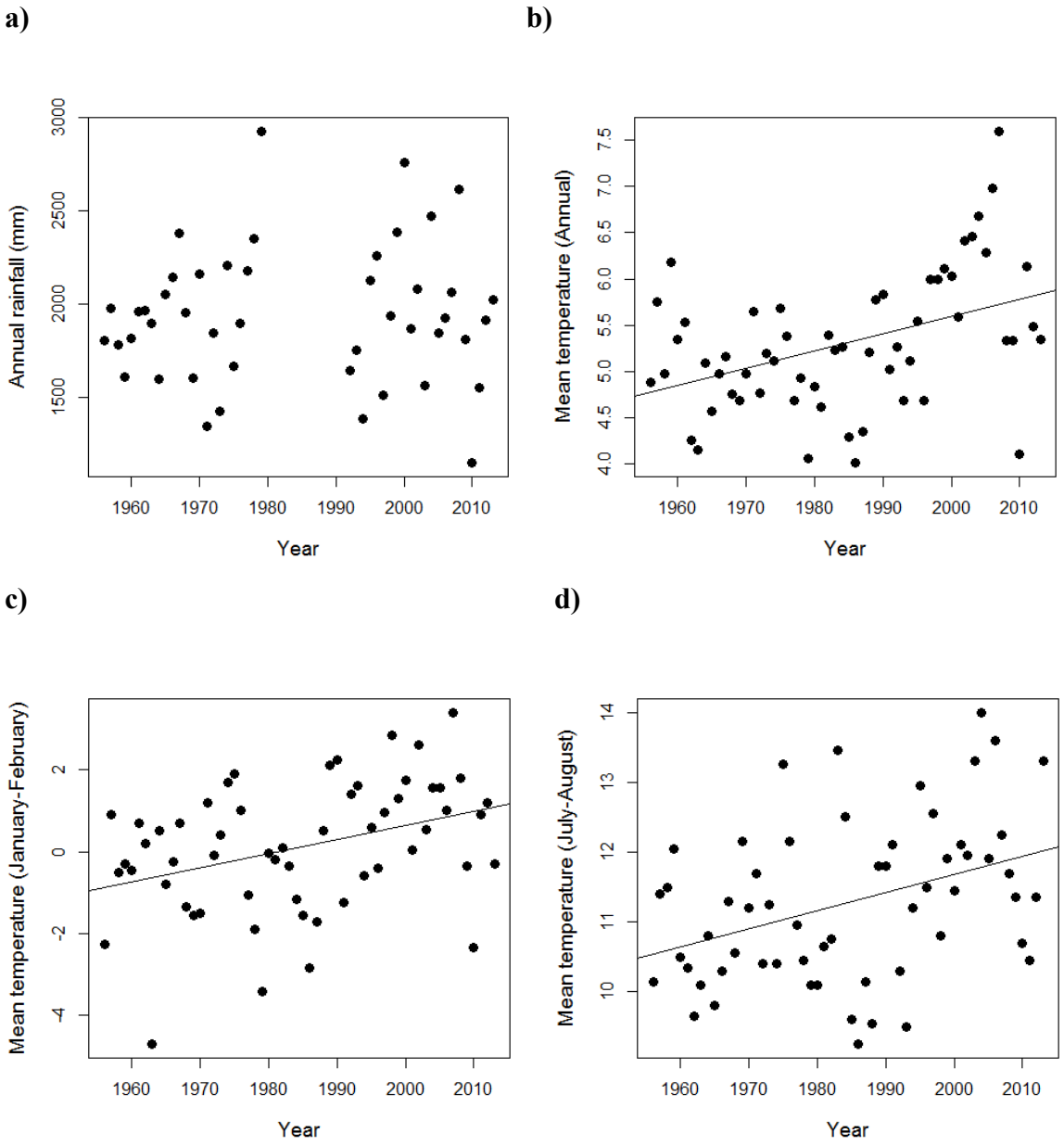

Figure A1. Climate trends from 1956 to 2013, showing (a) mean annual rainfall, (b) mean annual temperature in ^{o}C (c) mean temperature of the coldest months (January-February) in ^{o}C and (c) mean temperature of the warmest months (July-August) in ^{o}C. Lines depict significant linear trend over time. Data were recorded at the meteorological station situated in the study area at 560 m a.s.l. (Fig. 1), and provided by the UK Environmental Change Network (<http://www.ecn.ac.uk>). For the period of 1980-91 there is a gap in the climate records so not rainfall data are available for this period, temperature data for this period have been calculated from a nearby station 6.6 km away, situated at similar elevation and habitat

type (see Holden & Rose 2011 for more details on how the data were calibrated to make all data comparable for the period 1956-2013).

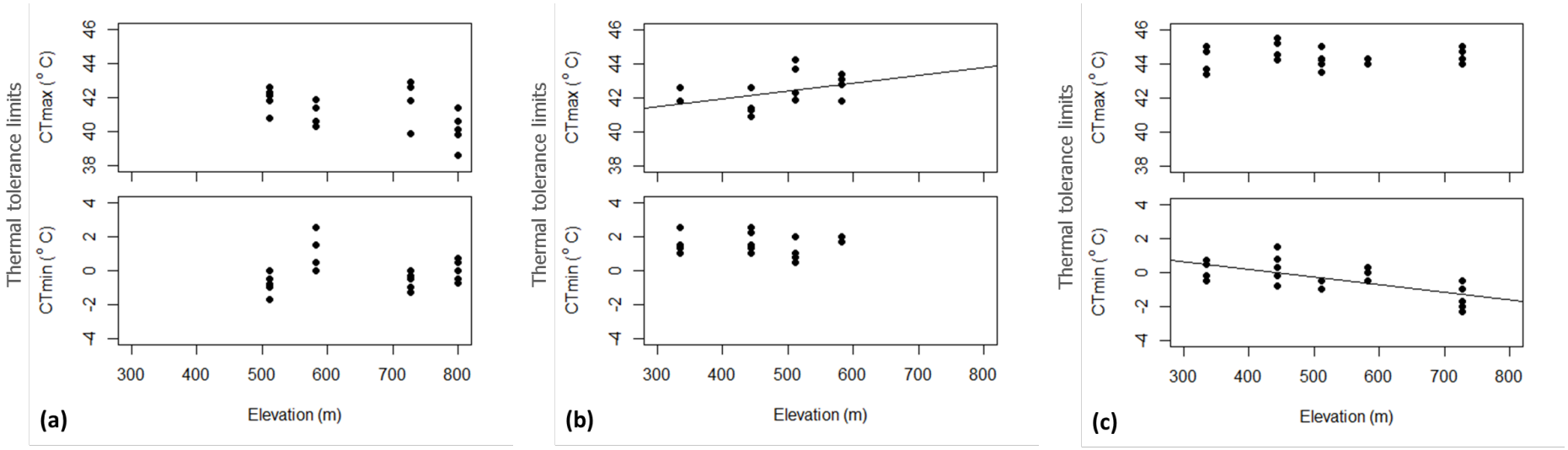

Figure A2. Relationship between the elevation from which the beetle was collected and the maximum (CTmax: top) and minimum (CTmin: bottom) thermal limits (^{o}C) of each individual of (a) *Agoliinus lapponum*, (b) *Acrossus depressus* and (c) *Agrilinus ater* tested. Lines depict significant trend.