Ecography

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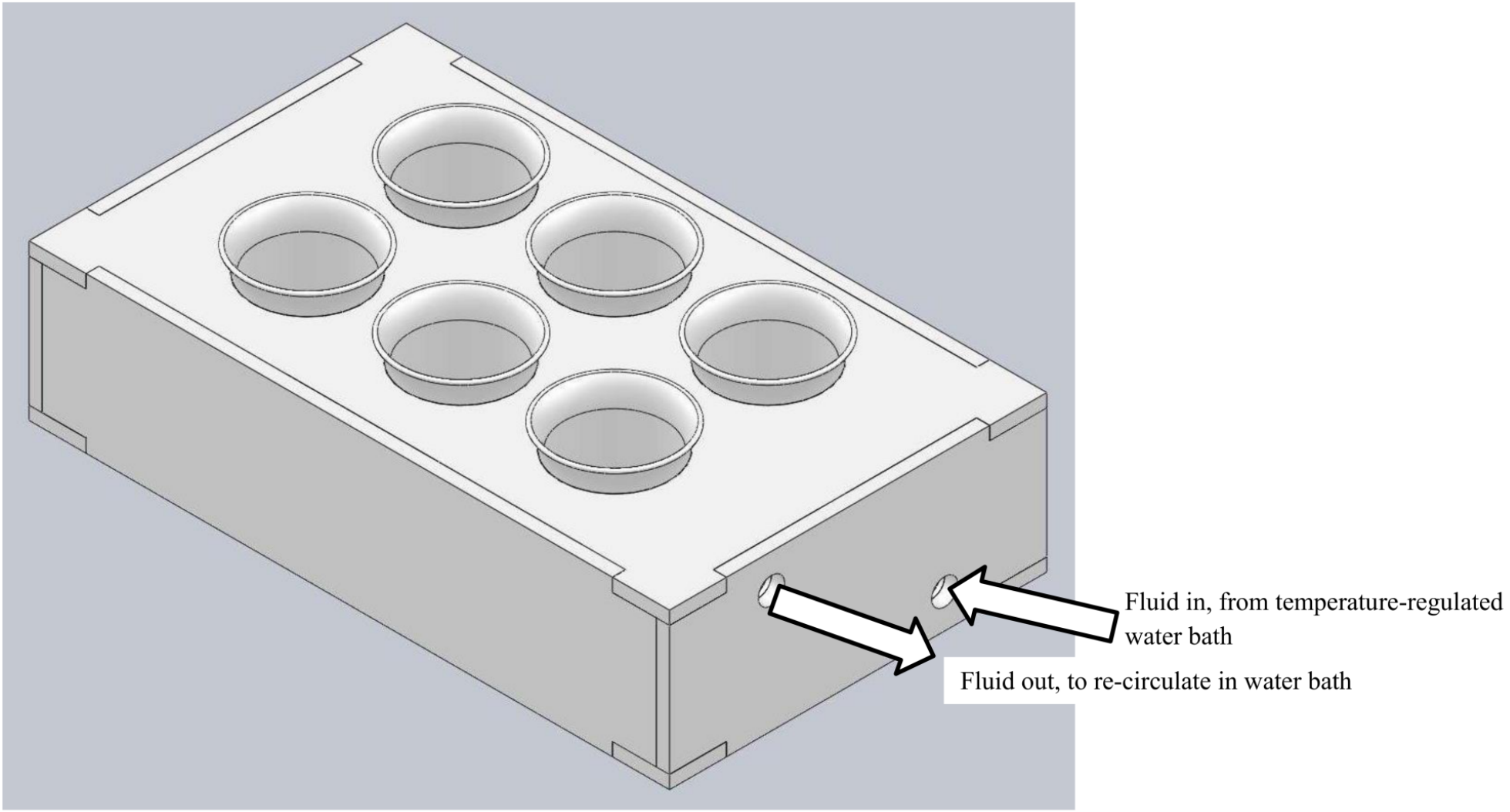
Supplementary material

Appendix 1. Schematic of the thermal tolerance chamber. A clear lid with a small hole in the top was placed over each 50 ml beaker, to allow air flow into and out of the chamber but prevent the grasshopper escaping.



Appendix 2: Summary of microclimate data

Table A2.1 Characteristics of the study sites, including temperature conditions measured over the study period. Daily mean, maximum and minimum temperatures, as well as daily temperature ranges (in brackets), were averaged over 53 days of recordings from February 18th to April 10th, 2014 at two microhabitat patches (sheltered within vegetation, or exposed ground) within each site, for a total of 106 daily records per site. Microclimate variation was estimated by calculating the difference in temperature between sheltered and exposed microhabitat patches within each site, for each temperature recording (at 15-minute intervals). For this measure, means are for the absolute difference, and the range is given with positive values indicating that the exposed microhabitat is warmer than the sheltered microhabitat, and negative values indicating that it is colder. Data are given as mean ± SD (minimum, maximum).

	Site				
	Thredbo 1	**Thredbo 2**	**Thredbo 3**	**Guthega**	**Island Bend**
Elevation (m a.s.l)	1974 m	1681 m	1571 m	1659 m	1260 m
Floristic zone[1]	Alpine	Sub-alpine	Sub-alpine	Sub-alpine	Montane
Overall mean temperature (exposed)	10.17 ± 5.58	11.53 ± 5.37	12.38 ± 6.51	11.66 ± 7.92	15.35 ± 6.94
Overall mean temperature (sheltered)	9.18 ± 2.86	11.07 ± 3.99	10.33 ± 2.75	10.77 ± 4.52	14.09 ± 3.82
Daily minimum (exposed)	5.08 ± 2.95 (-0.42, 11.07)	6.33 ± 2.99 (0.10, 12.17)	6.00 ± 3.17 (0.06, 13.05)	4.76 ± 3.84 (-4.71, 11.20)	9.01 ± 3.05 (1.65, 13.96)
Daily minimum (sheltered)	6.55 ± 2.28	7.05 ± 2.60	7.34 ± 2.39	6.60 ± 3.09	10.50 ± 2.60

	(1.50, 11.37)	(1.10, 12.95)	(1.97, 13.14)	(-0.89, 10.88)	(3.98, 13.93)
Daily maximum (exposed)	19.13 ± 6.26 (8.00, 32.65)	21.30 ± 5.13 (10.39, 30.26)	23.32 ± 5.54 (11.44, 34.25)	25.47 ± .842 (9.82, 44.43)	26.63 ± 7.68 (13.83, 41.20)
Daily maximum (sheltered)	12.50 ± 2.92 (4.64, 18.08)	17.06 ± 2.96 (10.36, 23.03)	13.73 ± 2.30 (6.68, 18.91)	18.46 ± 4.44 (7.37, 26.10)	19.89 ± 4.29 (11.67, 29.28)
Daily range (exposed)	14.05 ± 5.97 (1.50, 28.37)	14.97 ± 5.87 (2.13, 26.72)	17.33 ± 6.49 (3.20, 31.45)	20.68 ± 9.04 (4.01, 44.85)	17.62 ± 7.61 (2.32, 36.77)
Daily range (sheltered)	5.94 ± 2.67 (0.53, 14.39)	10.01 ± 3.51 (2.13, 19.30)	6.39 ± 2.54 (1.13, 12.87)	11.78 ± 5.00 (1.82, 23.13)	9.39 ± 4.53 (0.69, 17.66)
Microclimate variation	2.20 ± 2.50 (-6.95, 15.39)	1.28 ± 1.55 (-4.54, 11.75)	3.08 ± 3.69 (-3.80, 17.66)	2.60 ± 3.19 (-4.74, 27.54)	2.53 ± 3.22 (-4.23, 17.39)
Kosciuscola species present	*K. usitatus* *K. tristis*	*K. usitatus* *K. tristis*	*K. usitatus*	*K. usitatus* *K. tristis* *K. cognatus*	*K. cognatus*

[1]Floristic zones are described by Costin (1954).

Appendix 3. Weather station information and microclimate regression models.

Table A3.1. Australian Bureau of Meteorology weather stations in the Kosciuszko region used for microclimate predictions.

Weather station number	Weather station name	Weather observations (abbreviation)
071041	Thredbo Village	Maximum (TV_{max}), minimum (TV_{min})
071032	Thredbo Top Station	Maximum (TT_{max}), minimum (TT_{min}), solar radiation (TT_{solar})
071075	Perisher Valley	Solar radiation (PV_{solar})
071003	Charlotte Pass	Solar radiation (CP_{solar})

Table A3.2. Final models, identified by the lowest AIC values following stepwise model selection, for microclimate predictions at each of the five study sites. Daily maximum and minimum values were modelled separately.

Site		Model
Thredbo 1	Maximum	$TT_{max} + TT_{solar} + TT_{max}*TT_{solar}$
	Minimum	$TV_{min} + TT_{solar} + TT_{min} + CP_{solar}$
Thredbo 2	Maximum	$TV_{max} + TT_{solar}$
	Minimum	$TT_{min} + PV_{solar} + TV_{min} + TT_{min}*TV_{min}$

Thredbo 3	Maximum	$TT_{max} + TV_{max} + TT_{solar} + PV_{solar}$
	Minimum	$TV_{min} + TT_{solar} + PV_{solar} + CP_{solar} + TV_{min}*TT_{solar} + TV_{min}*CP_{solar}$
Guthega	Maximum	$TT_{max} + TT_{solar} + PV_{solar} + CP_{solar}$
	Minimum	$TV_{min} + PV_{solar} + CP_{solar}$
Island Bend	Maximum	$TT_{max} + TV_{max} + PV_{solar}$
	Minimum	$TV_{min} + TT_{solar}$

Appendix 4. Trait means, results of ANOVAs and effect sizes.

Table A4.1. Trait means, standard deviation (SD), standard error (SE) and sample size (N) for each species at each study site.

Trait/Species	Site	Mean	SD	SE	N
CT_{min} (°C)					
K. usitatus	Thredbo 1	-3.0	0.6	0.1	20
	Thredbo 3	-2.7	0.7	0.1	20
	Guthega	-3.1	0.4	0.1	10
K. tristis	Thredbo 1	-2.5	0.7	0.2	18
	Thredbo 2	-2.3	0.7	0.2	20
	Guthega	-2.3	0.4	0.1	8
K. cognatus	Guthega	-1.8	0.6	0.1	20
	Island Bend	-2.0	0.9	0.2	20
$CT_{min\text{-}recovery}$ (°C)					
K. usitatus	Thredbo 1	10.7	4.1	0.9	20
	Thredbo 3	11.0	4.4	1.0	20
	Guthega	14.1	3.2	1.0	10

K. tristis	Thredbo 1	14.4	4.1	1.0	18
	Thredbo 2	11.9	4.2	0.9	20
	Guthega	13.4	4.7	1.7	8
K. cognatus	Guthega	10.8	3.5	0.8	20
	Island Bend	11.1	5.0	1.1	20
SCP (°C)					
K. usitatus	Thredbo 1	-3.3	1.1	0.2	22
	Thredbo 3	-3.7	0.9	0.3	7
K. tristis	Thredbo 1	-3.8	1.2	0.3	18
	Thredbo 2	-4.1	1.1	0.4	10
K. cognatus	Guthega	-3.6	1.1	0.2	19
	Island Bend	-3.0	0.7	0.2	10
CT_{max} (°C)					
K. usitatus	Thredbo 1	49.2	0.7	0.2	20
	Thredbo 3	48.6	1.0	0.2	20
	Guthega	49.5	0.5	0.2	11

K. tristis	Thredbo 1	49.1	0.6	0.1	20
	Thredbo 2	48.5	1.2	0.3	20
	Guthega	49.4	0.5	0.1	10
K. cognatus	Guthega	49.0	1.3	0.3	20
	Island Bend	49.1	0.8	0.2	20
HMT_{time} (min)					
K. usitatus	Thredbo 1	16.1	6.1	1.4	20
	Threbdo 3	14.6	4.6	1.0	20
K. tristis	Thredbo 1	18.6	7.0	1.6	20
	Thredbo 2	14.9	5.4	1.2	20
K. cognatus	Guthega	17.1	7.6	1.7	20
	Island Bend	15.1	7.4	1.7	20

Table A4.2. ANOVA results for interspecific comparisons of cold and heat tolerance. Six traits were measured: critical thermal minimum (CT_{min}), chill coma recovery ($_{CTmin\text{-}recovery}$), supercooling point (SCP), critical thermal maximum (CT_{max}) and the time to heat movement threshold at 50°C (HMT_{time}). Statistically significant effects ($p < 0.05$) are in bold.

	Guthega			**Thredbo**		
Trait	*df*	*F*	*p*	*df*	*F*	*p*
CT_{min}						
Species	2, 24	**21.92**	**<0.001**	1, 35	**6.50**	**0.015**
Sex	1, 24	2.05	0.165	1, 35	1.72	0.199
$CT_{min\text{-}recovery}$						
Species	2, 24	0.24	0.792	1, 35	**7.68**	**0.009**
Sex	1, 24	2.41	0.147	1, 35	0.29	0.593
SCP						
Species		-		1, 37	1.55	0.220
Sex		-		1, 37	0.08	0.786
CT_{max}						

Species	2, 27	0.15	0.858	1, 37	1.43	0.240
Sex	1, 27	0.10	0.760	1, 37	0.73	0.399
HMT_{time}						
Species		-		1, 37	1.08	0.306
Sex		-		1, 37	0.16	0.688

Table A4.3. ANOVA results for intraspecific comparisons of cold and heat tolerance. Six traits were measured: critical thermal minimum (CT_{min}), chill coma recovery ($CT_{min\text{-}recovery}$), supercooling point (SCP), critical thermal maximum (CT_{max}) and the time to heat movement threshold at 50°C (HMT_{time}). Statistically significant effects ($p < 0.05$) are in bold.

	K. usitatus			***K. tristis***			***K. cognatus***		
Trait	df	*F*	*p*	df	*F*	*p*	df	*F*	*p*
CT_{min}									
Elevation (high/low)	1, 35	2.81	0.103	1, 33	1.15	0.292	1, 35	0.64	0.430
Acclimation (y/n)	1, 35	**8.84**	**0.005**	1, 33	**12.41**	**0.001**	1, 35	0.968	0.335
Sex	1, 35	1.38	0.248	1, 33	**5.45**	**0.026**	1, 35	0.91	0.347
Elevation*acclimation	1, 35	1.04	0.315	1, 33	0.56	0.460	1, 35	0.20	0.655
$CT_{min\text{-}recovery}$									
Elevation (high/low)	1, 35	0.05	0.828	1, 33	3.76	0.061	1, 35	0.08	0.777
Acclimation (y/n)	1, 35	0.58	0.450	1, 33	**5.30**	**0.028**	1, 35	**24.77**	**<0.001**
Sex	1, 35	0.66	0.421	1, 33	0.05	0.833	1, 35	3.25	0.080
Elevation*acclimation	1, 35	0.63	0.432	1, 33	1.81	0.188	1, 35	0.80	0.378
SCP									
Elevation (high/low)	1, 26	0.63	0.434	1, 25	0.60	0.445	1, 26	2.42	0.132

Sex	1, 26	0.40	0.533	1, 25	0.61	0.441	1, 26	0.91	0.350
CT_{max}									
Elevation (high/low)	1, 35	**5.83**	**0.021**	1, 35	**5.42**	**0.026**	1, 35	0.00	0.949
Acclimation (y/n)	1, 35	1.93	0.173	1, 35	**16.60**	**<0.001**	1, 35	2.17	0.149
Sex	1, 35	1.55	0.222	1, 35	1.36	0.252	1, 35	**10.68**	**0.002**
Elevation*acclimation	1, 35	0.43	0.515	1, 35	**5.42**	**0.026**	1, 35	0.00	0.949
HMT_{time}									
Elevation (high/low)	1, 35	0.56	0.458	1, 35	2.85	0.101	1, 35	1.18	0.285
Acclimation (y/n)	1, 35	0.37	0.546	1, 35	0.06	0.802	1, 35	**21.76**	**<0.001**
Sex	1, 35	0.10	0.759	1, 35	0.39	0.536	1, 35	0.24	0.628
Elevation*acclimation	1, 35	0.03	0.875	1, 35	2.90	0.098	1, 35	0.41	0.529

Table A4.4. Standardised mean effect sizes (Hedges' *g* with small-sample correction). Interspecific comparisons are shown below (Guthega) and above (Thredbo 1) the diagonal, and intra-specific comparisons (for the main effect of elevation) are shown on the diagonal. Values in bold are statistically significant after correction for multiple comparisons using false discovery rates.

CT_{min}	*K. usitatus*	*K. tristis*	*K. cognatus*
K. usitatus	0.5	**0.8**	
K. tristis	**2.0**	0.3	
K. cognatus	**3.1**	**1.3**	0.3

CT_{max}	*K. usitatus*	*K. tristis*	*K. cognatus*
K. usitatus	**0.7**	0.2	
K. tristis	0.1	**0.7**	
K. cognatus	0.2	0.2	0.1

$CT_{min\text{-}recovery}$	*K. usitatus*	*K. tristis*	*K. cognatus*
K. usitatus	0.1		
K. tristis	0.2	0.6	
K. cognatus	0.3	0.1	0.1

HMT_{time}	*K. usitatus*	*K. tristis*	*K. cognatus*
K. usitatus	0.3	0.4	
K. tristis		0.6	
K. cognatus			0.3

SCP	*K. usitatus*	*K. tristis*	*K. cognatus*
K. usitatus	0.4	0.9	
K. tristis		0.3	
K. cognatus			0.6