Ecography

E7458
Treasure, A. M. and Chown, S. L. 2012. Contingent absences account for range limits but not the local abundance structure of an invasive springtail. – Ecography 35: xxx–xxx.

Supplementary material

Appendix 1

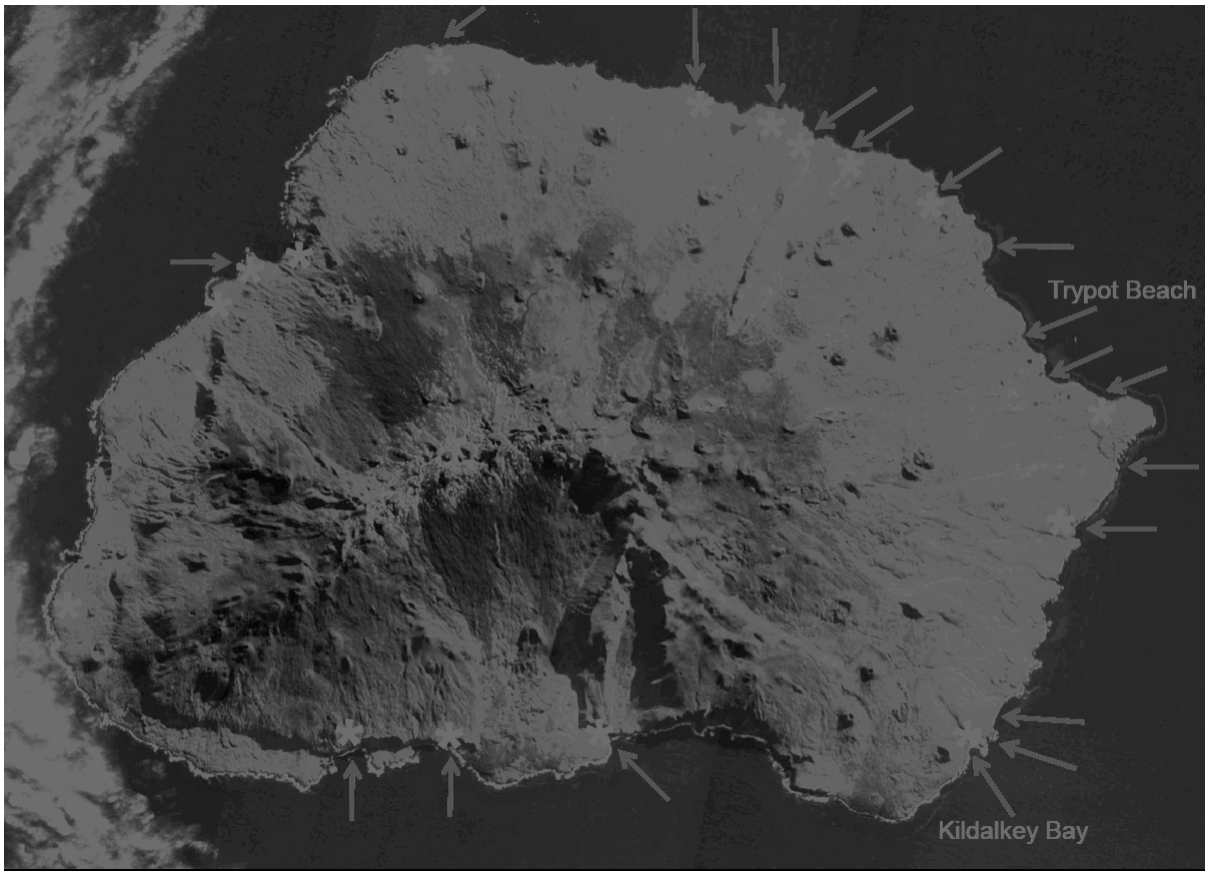

Figure A1. Areas of significant *Poa cookii* habitat on Marion Island, as indicated by the yellow arrows. Main penguin and seal colonies are indicated by the white stars (Image courtesy of NASA's Earth Observatory, http://earthobservatory.nasa.gov/IOTD/view.php?id=40806).

Appendix 2

Fine scale abundance structure

Four transects were sampled perpendicularly from the island's largest penguin colony at Kildalkey Bay. Along each transect, 4 m x 4 m quadrats were sampled from the colony edge outwards at a minimum of 3 m - 5 m intervals in various vegetation complexes until zero abundance of *Pogonognathellus flavescens* was reached. The first quadrat was placed at the colony edge and subsequent quadrats followed vegetation complex boundaries. Four vegetation complexes were identified from the edge of the penguin colony outwards: habitat one was dominated by *Poa cookii* Hook. f.; habitat two was dominated by *Blechnum penna-marina* (Poir.) Kuhn but *P. cookii* was still present; habitat three was dominated by *B. penna-marina*; and, habitat four consisted of mixed vegetation with two or more of soil, stone, rock, *Azorella selago* Hook. f., *Agrostis magellanica* Lam., *Sagina procumbens* L., *B. penna-marina*, *Acaena magellanica* (Lam.) Vahl. and bryophytes.

At least two quadrats were sampled in habitat one and *P. cookii* was sampled as above. For habitats two, three and four, quadrats were placed on the vegetation and five 25 cm x 25 cm vegetation samples were dug out per quadrat (one at each corner and one in the middle). These samples were placed in individually labelled ziplock bags and returned to the field hut where they were hand sorted and *P. flavescens* individuals counted. Four quadrats were sampled in habitat two, one quadrat was sampled in habitat three (only one was possible due to the small size of this habitat), and at least two quadrats were sampled in habitat four. Quadrats were sampled in habitat four until zero presence of *P. flavescens* was found for two consecutive quadrats.

Appendix 3

Soil pH and conductivity measurements

A soil sample was collected from each of the Kildalkey fine scale survey sites using a 34 mm stainless steel soil corer. Each core was placed in an individually labelled ziplock plastic bag and returned to the laboratory. The litter and vegetation was removed from the surface of each core and the top 5 cm of the cores used for analysis. For each sample, 10 g of fresh soil was placed in a 100 ml glass beaker to which enough distilled water was added to cover the soil. A glass rod was used to thoroughly stir the sample after which the sample was left to settle for 30 minutes. The bulb of a series 50 50 fixed-wire cable pH glass electrode (Crison Instruments, SA) was then placed into the soil at the bottom of the liquid (measurement in a soil slurry) and the pH, conductivity and temperature were read using a Portable PH 25 pH-meter (Crison Instruments, SA). Date and time of measurement were also recorded. The pH meter was calibrated before measurement and after every ten samples using three buffer solutions: pH 4.01, pH 7.00 and pH 9.21. Care was taken to avoid cross contamination between samples. Beakers and the glass rod were washed with distilled water in-between samples and the electrode was rinsed with distilled water in-between each sample and after each calibration.

Appendix 4

Locomotion performance

P. flavescens individuals were collected from the field by beating coastal *P. cookii* tussocks into a sorting tray. An aspirator was used to transfer the springtails to 100 ml plastic jars with moist plaster-of-paris substrates and small pieces of *P. cookii* and other decaying plant material from the base of the *P. cookii* tussocks as a food source and for shelter. Animals were returned to the laboratory within one hour and transferred to individual blue top containers with moist plaster-of-paris and pieces of vegetation as above. The springtails were placed in a climate chamber (LABCON, Johannesburg, SA, accurate to ±1°C) at 7°C with a photoperiod set to match the day light cycle at the time of year that the study was conducted (12 L : 12 D). This acclimation temperature was chosen to represent the mean temperature as recorded inside the base of *P. cookii* tussocks on the day of collection by using a Vaisala HUMICAP© HM 34 temperature and humidity meter (Vaisala Inc, Woburn, MA, USA). A period of seven days was selected for acclimation following Hoffmann and Watson (1993) and previous studies on arthropods on both Marion (e.g. Klok and Chown 2003; Terblanche et al. 2007; Marais and Chown 2008) and elsewhere (e.g. Terblanche et al. 2006) as sufficient for phenotypic responses to temperature that could alter performance (Angilletta 2009) to equilibrate (Terblanche et al. 2007). Shelf effects in the climate chamber were unlikely to have had any influence on the temperature as the containers took up very little space on a single shelf. A temperature controlled walking stage was attached to a Grant LTC 12 water bath which was set to regulate stage temperature. Stage temperature was monitored at each end using Type T 20-gauge thermocouples connected to CHY 507 Digital Thermometers (Taiwan). A single springtail was introduced to the stage at a time using an aspirator. Springtails were given two minutes to equilibrate to the set temperature by placing a small round metal lid (radius 2 cm x height 0.5 cm) over them. The path that the individuals then

ran in 10 seconds was traced using a non-permanent marker and this line was measured using string. The fastest speed from three repetitions was used for each individual and ten individuals were examined at eight temperatures (0°C, 7°C, 14°C, 21°C, 24°C, 28°C, 32°C and 35°C).

Appendix 5

Laboratory trials with fluorescent powder

Laboratory experiments were conducted to determine whether fluorescent powder (Day-Glo® powder (Day Glo Corp, Cleveland, OH)) affects the survival of *P. flavescens* and also how long the powder adheres to the springtails before rubbing off onto the surrounding vegetation. Fifty *P. flavescens* individuals were collected from the field by beating coastal *P. cookii* tussocks into a sorting tray. An aspirator was used to transfer the springtails to 100 ml plastic jars with moist plaster-of-paris substrates and small pieces of *P. cookii* and other decaying plant material from the base of the *P. cookii* tussocks as a food source and for shelter. Animals were returned to the laboratory within one hour. Twenty five springtails were transferred into a 35 ml blue top container with 0.0015 (±0.0005) g of fluorescent powder (Kristensen et al. 2008). The container was shaken gently to ensure that the springtails were coated in the powder. Five powdered individuals were then placed in each of five 30 ml plastic pill vials with moist plaster-of-paris and small pieces of *P. cookii* and decaying plant matter. As a control, the remaining 25 un-powdered springtails were divided into five further pill vials with moist plaster-of-paris and pieces of vegetation. The vials were placed in a climate chamber (LABCON, Johannesburg, SA, accurate to ±1°C) set to a fluctuating temperature cycle of 5°C - 15°C (12 D : 12 L photoperiod). Springtail survival and powder adhesion were monitored twice daily for seven days. A survival analysis run using the `survival` package in `R`2.12.0 (R Development Core Team 2010) indicated no significant differences in survival of *P. flavescens* over time between the two treatments ($X^2 = 0.3$, $p = 0.564$) (Fig. A2).

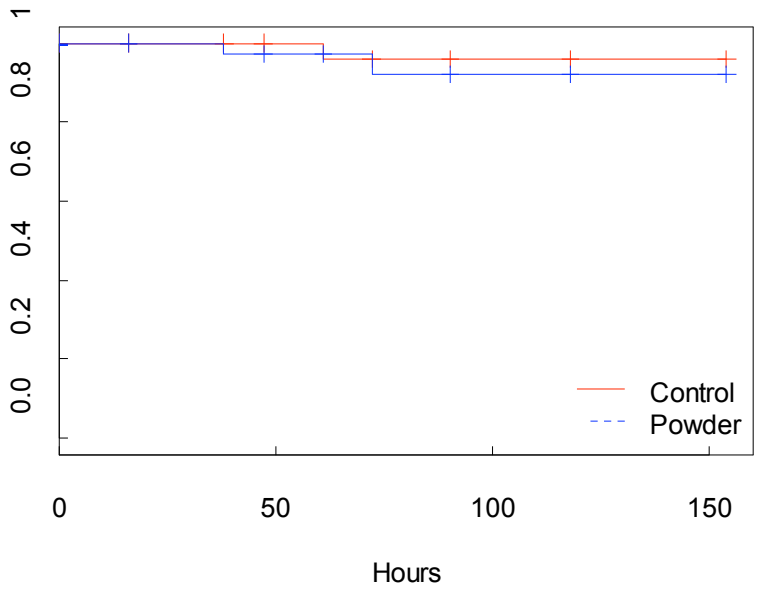

Figure A2. Survival function estimates calculated from a survival analysis of powdered versus non-powdered (Control) *P. flavescens* individuals.

Field dispersal experiments

Field dispersal experiments were conducted during April 2010. For these experiments, 150 springtails were marked by lightly shaking them with 0.0015 (±0.0005) g fluorescent powder in a plastic vial (Kristensen et al. 2008), and then releasing 50 of them into each of three randomly selected *P. cookii* tussocks at Trypot Beach. Tussocks were at least 20 m apart and each was in the centre of a separate marked out grid in a tussock grassland. Care was taken to not spill any excess powder onto the tussocks or ground. Movements were tracked 12 and 59 hours later at night using a Futronic rechargeable stand-by light (KN-886) with one 8W 12 inch black-light-blue bulb and one fluorescent bulb. Powdered springtails or powder residue were easily identified. Tussocks and the ground were carefully inspected so as to cause minimal disturbance and the number of powdered *P. flavescens* and occurrences of powder residue (equivalent to the presence of a springtail) in tussocks or on the ground noted. Re-sight rate was calculated as the percent of the total number of powdered springtails released that were re-sighted for each night. Distances travelled per unit time were used to estimate a

rate of spread, i.e. the amount of time needed to populate the entire island.

Appendix 6

Figure A3. *P. cookii* habitat recorded at 500 m on Long Ridge South, Marion Island.

Appendix 7. Outcome of a generalized linear model (assuming a Poisson distribution, using a log link function and corrected for overdispersion) investigating the effects of distance to the edge of the *P. cookii* habitat (Distance), presence of vertebrate species in the vicinity (Vertebrate) and aspect on the abundance of *P. flavescens* along a 6.5 km stretch of coastline incorporating most of the range of the springtail.

Variable (Response: *P. flavescens* abundance)	df	X^2	*p*
Distance	2	2.44	0.295
Vertebrate	4	30.72	<0.001
Aspect	6	10.82	0.094
Distance * Vertebrate	1	0.41	0.522
Distance * Aspect	2	1.85	0.396
Vertebrate * Aspect	5	9.68	0.085
Distance * Vertebrate * Aspect	0		

Appendix 8

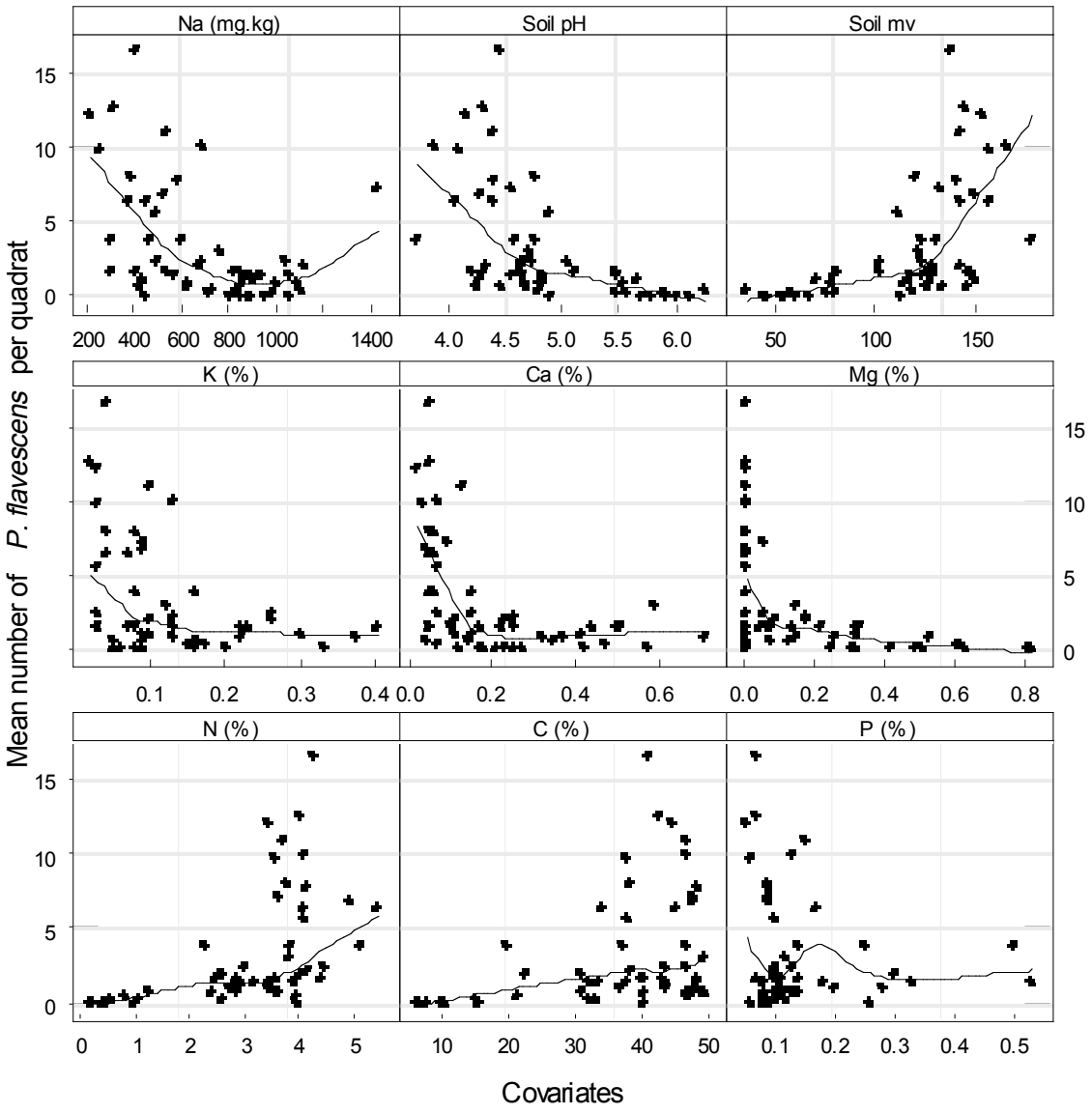

Figure A4. Multi-panel scatterplots between the mean number of *P. flavescens* per quadrat and soil nutrients, pH and conductivity (mv). LOESS smoothers were added to aid visual interpretation.

Appendix 9. Outcome of a generalized additive model (with a Poisson distribution, using a logit link function, corrected for overdispersion and including cubic spline smoothers) investigating the effects of soil parameters on the small scale abundance of *P. flavescens*.

R-sq. (adj) = 0.751

GCV score = 1.978 Deviance explained = 82.8 % n = 52

Variable (Response: *P. flavescens* abundance)	df	Ref. df	*F*	*p*
K	7.868	8.523	1.959	0.083
Ca	2.198	2.785	4.944	0.007
Na	0.956	1.296	1.605	0.218
Soil pH	8.868	8.982	3.689	0.003

Appendix 10

Performance curve fitting

For the performance curve fitting procedure, a curve was fitted to the performance data using TableCurve 2D (SYSTAT Inc, 2002, San Jose, California, USA). The curve with the largest coefficient of determination was selected, irrespective of the number of terms. The best fit was provided by an intercept form Beta curve, which has the following equation:

$$y = \frac{a\left[\frac{x-b+\frac{c(d-1)}{d+e-2}}{c}\right]^{d-1}\left[1-\frac{x-b+\frac{c(d-1)}{d+e-2}}{c}\right]^{e-1}}{\left[\frac{d-1}{d+e-2}\right]^{d-1}\left[\frac{e-1}{d+e-2}\right]^{e-1}}$$

A fitted curve typically took the form indicated in Fig. A5 below.

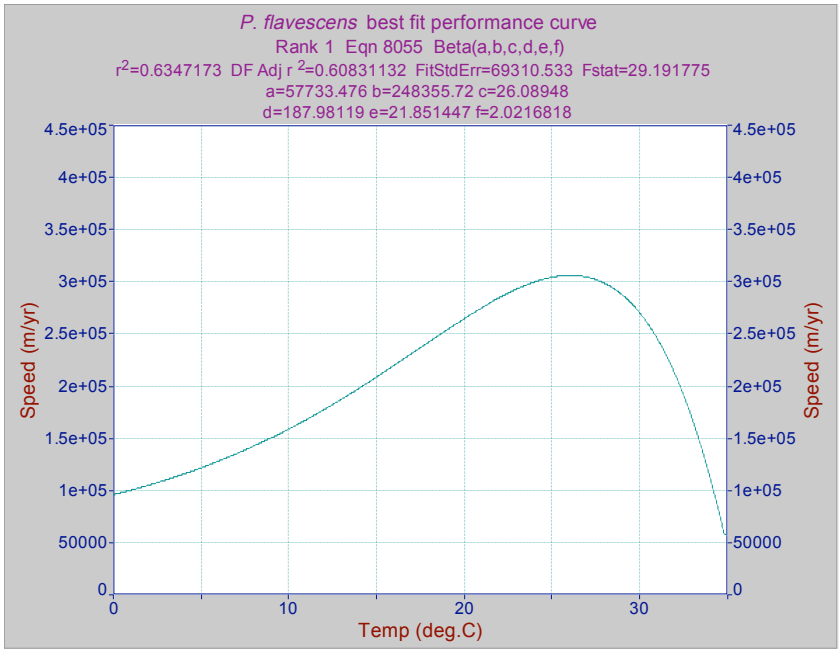

Figure A5. A beta curve fitted to the performance data for *P. flavescens*.

Appendix 11

Figure A6. Spiders are thought to be the main predators of *P. flavescens* on Marion Island. No other predator on the island has been seen to eat this invasive springtail species.

References

Angilletta Jr., M. J. 2009. Thermal adaptation: a theoretical and empirical synthesis. - Oxford Univ. Press.

Hoffmann, A. A. and Watson, M. 1993. Geographical variation in the acclimation responses of Drosophila to temperature extremes. - Am. Nat. 142: S93-S113.

Klok, C. J. and Chown, S. L. 2003. Resistance to temperature extremes in sub-Antarctic weevils: interspecific variation, population differentiation and acclimation. - Biol. J. Linn. Soc. 78: 401-414.

Kristensen, T. N. et al. 2008. Costs and benefits of cold acclimation in field-released Drosophila. - Proc. Natl. Acad. Sci. USA 105: 216-221.

Marais, E. and Chown, S. L. 2008. Beneficial acclimation and the Bogert effect. - Ecol. Lett. 11: 1027-1036.

R Development Core Team. 2010. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Terblanche, J. S. et al. 2006. Phenotypic plasticity and geographic variation in thermal tolerance and water loss of the tsetse *Glossina pallidipes* (Diptera: Glossinidae): implications for distribution modelling. - Am. J. Trop. Med. Hyg. 74: 786-794.

Terblanche, J. S. et al. 2007. Stage-related variation in rapid cold hardening as a test of the environmental predictability hypothesis. - J. Insect Physiol. 53: 455- 465.