Methods and Results

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# Tables & Figures

Table 2. ANOVA table for predicted body temperature (Tb Predict), accuracy of thermoregulation (db), thermal quality of habitat (de), and effectiveness of thermoregulation (E) for *Pogona vitticeps*. Each estimate is compared across season, sex, and the interaction. Depending on the id of lizard (or model id) was treated as a repeated (random) variable. Bold values indicate significant difference.

| Model Name | Sum Sq | Mean Sq | NumDF | DenDF | F value | Pr(>F) |
| --- | --- | --- | --- | --- | --- | --- |
| Tb Predict | 9.80 | 9.80 | 1 | 37 | 0.70 | 0.41 |
| **743,844.79** | **247,948.26** | **3** | **24,044** | **17,810.07** | **<0.01** |
| **1,814.79** | **604.93** | **3** | **24,044** | **43.45** | **<0.01** |
| db | 5.66 | 5.66 | 1 | 33 | 0.73 | 0.4 |
| **201,042.09** | **67,014.03** | **3** | **8,233** | **8,670.41** | **<0.01** |
| **816.86** | **272.29** | **3** | **8,233** | **35.23** | **<0.01** |
| de | **9,628.16** | **9,628.16** | **1** | **329,180** | **590.95** | **< 0.01** |
| **910,774.49** | **303,591.50** | **3** | **329,217** | **18,633.77** | **< 0.01** |
| **12,904.13** | **4,301.38** | **3** | **329,180** | **264.01** | **< 0.01** |
| E | 0.46 | 0.46 | 1 | 83 | 4.10 | 0.05 |
| **2.14** | **0.71** | **3** | **83** | **6.34** | **<0.01** |
| **1.69** | **0.56** | **3** | **83** | **4.99** | **<0.01** |

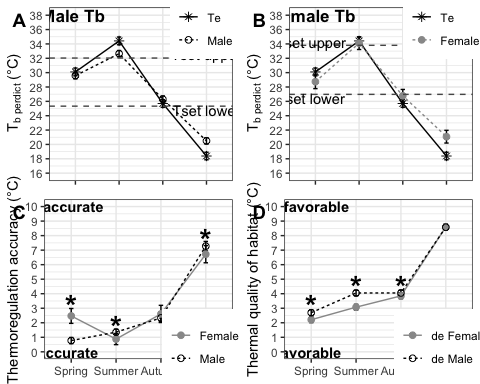
Figure 1. The overall workflow for the experimental design used to determine trade-offs associated with thermoregulation and how this relates to survival. Panel A we used a laboratory thermal for two experiments: 1) to measure preferred body temperature (Tset) and how this varies by sex and 2) to determine the relationship between surface temperatures (Tsurf) measured with accelerometers and internal body temperatures to determine correction for accelerometer temperatures in the field (Tb predict). Panel B we investigated seasonal thermoregulation and associated proxies with the use of accelerometers. Panel C copper pipes were placed in various microhabitats to determine the available thermal environment for lizards in the field (Te). Panel D lists the proxies that were estimated from experiments A-C. These proxies were then used as covariates to determine how they relate to the fate of animals while accounting for sex, during the spring season when they experience their highest predation pressures (Panel E). ![](data:application/pdf;base64,) Figure 2. ![](data:application/pdf;base64,) Figure 3. E index (effectiveness of thermoregulation) by sex and season in *Pogona vitticeps*. Values are grand means accounting for all individuals for each season and error bars are ±1 standard error of the grand mean. The asterisk symbol indicates a significant difference between sex when comparing mean differences for that season using a Tukey-Kramer post-hoc test.. ![](data:application/pdf;base64,) Figure 4. Grand mean predicted body temperature (T\_(b Predict)), operative temperatures, and time spent in locomotory activity as a function of time of day for free-ranging *Pogona vitticeps*. Panel A are data for males: where open circles denote male T\_(b Predict) and panel B are data for females: where closed grey circles denote female T\_(b Predict). The preferred body temperature ranges (T\_set) for each respective sex are represented by dashed line. Triangles represent activity for each hour (min) for each sex. Colour circles represent mean operative temperature for each respective habitat.  
 ![](data:application/pdf;base64,) Figure 5. Field thermal performance curves across season and sex in free-ranging *Pogona vitticeps*. Data were extracted from top-performing GAMM (Table S5). Each point is the predicted mean performance (95^th percentile of acceleration) for a given temperature across all individuals for each season and by sex. Females are denoted by the triangles and grey fitted lines, and males are denoted by open circles and black fitted lines. light grey bands denote SE of model fit. ![](data:application/pdf;base64,) Figure 6. Survivorship as a function of effectiveness of thermoregulation (E index) for free-ranging *Pogona vitticeps*. Data are extracted from candidate model in program Mark. E index generally range from 0-1, where values near zero indicate thermoconformity and values towards 1 indicate precise thermoregulation. # Supplementary information Table S2. Tukey-Kramer multiple comparisons from Tb predict model (Table 2). Contrasts were extracted from season x sex interaction.

Table S3. Tukey-Kramer multiple comparisons from Tb predict model (Table 2). Contrasts were extracted from overall seasonal effect.

Table S4. Tukey-Kramer multiple comparisons of overall seasonal activity rate (min/hr). Activity rate was log (x+1) scale for all *P. vitticeps*.

| contrast | estimate | SE | df | t.ratio | p.value |
| --- | --- | --- | --- | --- | --- |
| Spring - Summer | -0.28 | 0.15 | 92 | -1.86 | 0.25 |
| Spring - Autumn | 0.12 | 0.20 | 83 | 0.61 | 0.93 |
| **Spring - Winter** | **0.80** | **0.21** | **83** | **3.89** | **<0.01** |
| Summer - Autumn | 0.40 | 0.20 | 82 | 2.03 | 0.19 |
| **Summer - Winter** | **1.08** | **0.21** | **82** | **5.23** | **<0.01** |
| **Autumn - Winter** | **0.68** | **0.23** | **69** | **3.01** | **0.02** |

Table S5. General additive mixed-models for investigating how performance curves varied across season, sex and their interactions for *Pogona vitticeps*. a) accounted for all individuals in study, b) accounted for smooth per individual, c) accounted for sex as a fixed factor, d) accounted for sex as a fixed factor and allowed for smooth per individual, e) accounted for season as a fixed factor, f) accounted for season as a fixed factor and allowed for smooth per individual, g) accounted for season and sex as a fixed factor, h) accounted for season and sex as a fixed factor and allowed for smooth per individual, i) accounted for season, sex, and their interaction as a fixed factor, and j) accounted for season, sex, and their interaction as a fixed factor and allowed for smooth per individual. Models b:j accounted for random intercept for individual lizard.

| Model.id | Model | Residual.DF | Residual.Deviance | DF | AIC | Delt\_AIC | Dev.Expl... |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **j** | **Season + Sex + Season\*Sex + s(Temprature, by = id) + (1|id)** | **2756.35** | **262.57** | **277.61** | **1688.84** | **0** | **70.57** |
| h | Season + Sex + s(Temprature, by = id) + (1|id) | 2760.13 | 264.88 | 273.83 | 1707.66 | 18.82 | 70.31 |
| f | Season + s(Temprature, by = id) + (1|id) | 2760.12 | 264.93 | 273.84 | 1707.87 | 19.03 | 70.3 |
| e | Season s(Temperature) + (1|id) | 2967.9 | 299.67 | 66.06 | 1724.75 | 35.91 | 66.41 |
| d | Sex + s(Temprature, by = id) + (1|id) | 2766.84 | 270.68 | 267.12 | 1760.11 | 71.27 | 69.66 |
| b | s(Temprature) + (1|id) | 2766.56 | 270.73 | 267.4 | 1760.93 | 72.09 | 69.65 |
| i | Season + Sex + Season\*Sex + s(Temprature) + (1|id) | 2989.09 | 315.19 | 44.87 | 1840.57 | 151.73 | 64.67 |
| g | Season + Sex + s(Temperature) + (1|id) | 2992.13 | 317.28 | 41.84 | 1854.36 | 165.52 | 64.43 |
| c | Sex + s(Temprature) + (1|id) | 2986.68 | 319.93 | 47.28 | 1888.45 | 199.61 | 64.14 |
| a | s(Temprature) | 3033.96 | 358.89 | 8.96 | 2152.09 | 463.25 | 59.77 |

Table S6. Tukey-Kramer multiple comparisons from Pmax model that accounted for season, sex and the interaction. Contrasts were extracted from seasonal effect.

| Contrast | Estimate | SE | df | t Ratio | p value |
| --- | --- | --- | --- | --- | --- |
| Autumn - Spring | -0.01 | 0.01 | 45 | -1.3 | 0.57 |
| Autumn - Summer | 0.07 | 0.01 | 45 | 13.4 | <0.01 |
| Autumn - Winter | 0.10 | 0.01 | 45 | 18.6 | <0.01 |
| Spring - Summer | 0.08 | 0.00 | 45 | 15.1 | <0.01 |
| Spring - Winter | 0.11 | 0.01 | 45 | 18.4 | <0.01 |
| Summer - Winter | 0.03 | 0.01 | 45 | 6.1 | <0.01 |

Table S7. Tukey-Kramer multiple comparisons from Pmax model that accounted for season, sex and the interaction. Contrasts were extracted from season and sex interaction.

| Contrast | Season | Estimate | SE | df | t Ratio | p value |
| --- | --- | --- | --- | --- | --- | --- |
| ZWf - ZZm | Autumn | 0.03 | 0.1 | 39 | 0.34 | 0.74 |
| ZWf - ZZm | Spring | -0.13 | 0.1 | 38 | -1.33 | 0.19 |
| ZWf - ZZm | Summer | -0.15 | 0.1 | 38 | -1.49 | 0.14 |
| ZWf - ZZm | Winter | 0.01 | 0.1 | 39 | 0.14 | 0.89 |

Table S8. Model comparisons of spring survival probability (φ) for *Pogona vitticeps*, depending on sex, movement (mins), accuracy of thermoregulation (de), effectiveness of thermoregulation (E), and maximum performance (Pmax). Sex interactions for d\_b and E were accounted for because of the differences between males and females during the spring (Table 1). Values within the brackets are nested variables and variables outside of brackets are covariates. Bold values indicate values were considered to have support (ΔAICc of < 2.0).

| Model | AICc | Delta AICc | AICc Weights | Model Likelihood | Number of Parameters | Deviance |
| --- | --- | --- | --- | --- | --- | --- |
| **φ(Sex) Eindex** | **33.42** | **0.00** | **0.42** | **1.00** | **2** | **28.92** |
| **φ(.)** | **34.98** | **1.56** | **0.19** | **0.46** | **1** | **32.82** |
| **φ(Sex)** | **35.51** | **1.90** | **0.16** | **0.39** | **2** | **30.81** |
| φ(Activity - mins) | 35.98 | 2.67 | 0.12 | 0.28 | 1 | 33.82 |
| φ(Topt) | 36.52 | 3.11 | 0.09 | 0.21 | 1 | 34.36 |
| φ(Sex) db | 39.98 | 6.56 | 0.02 | 0.04 | 2 | 35.48 |

Figure S1.

## [1] 5

## [1] 21

Figure S2. Environmental temperature range and how adult *Pogona vitticeps* thermoregulated during the duration of the study. Black solid lines represent the grand mean environmental temperatures of operative models (Te) for each day and grey bands represent the daily mean minimum and maximum of Te. Coloured lines represent the daily grand mean (green), mean minimum (blue), and mean maximum (red) predicted body temperatures Tb Predict for all lizards during the study.