**Supplementary materials**

**Tables**

**Table S1.** Incubator temperatures (IT in °C) at which *Harmonia axyridis* performed best in terms of reproduction and population growth characteristics (R0 = net reproductive rate; T = mean generation time; r = intrinsic rate of natural increase; λ = finite rate of population increase; DT = population doubling time). Best performance defined as either “lowest” or “highest” response values is however dependent on the environmental conditions and season of the region studied (e.g. depending on context and season, higher developmental time can be advantageous). Incubator temperatures represent the temperatures tested in each study. Multiple temperatures listed per trait indicates that there were no significant differences in the trait of interest across temperatures.

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| **Incubator temperatures (IT in °C)** | **IT of lowest developmental time (°C)** | **IT of lowest pre-oviposition period (°C)** | **IT of highest oviposition period (°C)** | **IT of highest longevity (°C)** | **IT of highest fecundity (°C)** | **IT of highest survival % (egg/larva-pupa/adult) (°C)** | **IT of lowest mortality %** | **IT of highest R0** | **IT of lowest T** | **IT of highest r** | **IT of highest λ** | **IT of lowest DT** | **Reference** |
| 15, 20, 25 | 25 | 15, 20, 25 | 15, 20, 25 | 15, 20, 25 | 15 |  |  | 15 | 25 | 25 | 25 | 25 | Castro et al. 2011 |
| 18, 21, 24, 27, 30 | 27, 30 | 27, 30 | 18, 21, 24, 27 | 18, 21, 24 |  | 18, 24, 27 |  |  |  |  |  |  | de Oliveira Ramos et al. 2014 |
| 10, 14, 18, 22, 26,30, 34 | 30 |  |  |  |  |  | 22, 26 |  |  |  |  |  | LaMana & Miller 1998 |
| 17.8, 20.8 | 20.8 |  |  |  |  |  | 20.8 |  |  |  |  |  | Krengel et al. 2012 |
| 15, 20, 25, 30 | 30 | 25, 30 |  |  |  |  |  |  |  |  |  |  | Stathas et al. 2011 |
| 25, 37, 39, 41 | 25, 37, 39 | 25 | 25 | 25 | 25 | 25 | 25 |  |  |  |  |  | Zhang et al. 2014 |
| 20, 24, 30, 33 | 30 |  |  |  | 24 | 20 |  |  |  |  |  |  | Barahona-Segovia et al. 2016 |
| **Average** | **29.4** | **24.6** | **21.9** | **21.1** | **21.3** | **22.8** | **23.5** | **15** | **25** | **25** | **25** | **25** |  |
| **SD** | **5.5** | **5** | **4.1** | **3.8** | **5.5** | **3.7** | **2.5** |  |  |  |  |  |  |

The lower developmental threshold for *H. axyridis* varied from 10.8 to 12.4°C (egg to adult) (de Oliveira Ramos et al. 2014; LaMana and Miller 1998; Stathas et al. 2011). *Harmonia axyridis* eggs did not hatch at 10°C (LaMana & Miller 1998), 33°C (Barahona-Segovia et al. 2016), 34°C (LaMana & Miller 1998) and 41°C (Zhang et al. 2014).

**Table S2.** *Harmonia axyridis* and *Cheilomenes lunata* collection sites (GPS coordinates) in Stellenbosch (Western Cape Province, South Africa).

|  |  |  |
| --- | --- | --- |
| **Site** | **Latitude** | **Longitude** |
| Stellenbosch CBD | 34°91'60.13"S | 18°86'42.12"E |
| Die Bergkelder | 33°56'3.35"S | 18°51'6.24"E |
| Avontuur Wine Estate | 34°1'35.61"S | 18°49'20.61"E |
| Oude Libertas | 33°94'00.48"S | 18°83'80.01"E |
| Spice Route | 33°46'9.54"S | 18°55'3.72"E |
| Ride-in | 33°94'17.47"S | 18°90'4.25"E |
| Postcard Café | 33°57'14.44"S | 18°54'37.89"E |
| Ludwig's Rose Farm | 33°49'37.22"S | 18°47'41.70"E |
| Slaley Wine Farm | 33°51'56.90"S | 18°50'51.39"E |
| Kanonkop Winery | 33°51'7.88"S | 18°51'27.73"E |

**Table S3.** Best model outputs for each trait: (a) Starvation resistance, (b) CTmin, (c) CTmax, (d) preoviposition period, (e) total eggs laid, (f) hatching success, (g) developmental time, (h) pupal emergence success, (i) adult mass, and (j) intrinsic rate of increase. Terms with significant parameter estimates shown in bold. Two tables are presented for each trait: the first table is the model output with the cold temperature as the reference treatment; the second table is with the Medium treatment as the reference level (reference levels were changed to test for significant slope differences between interacting terms). HA = *Harmonia axyridis*, CL: *Cheilomenes lunata*.

1. Starvation resistance

Full model: Starvation resistance ~ Mass loss\*Sex\*Species\*Treatment + (1|Family\_ID)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| Mass\_loss | -0.01 | 0.02 | -0.50 | 0.62 |
| SexMale | 0.37 | 0.62 | 0.60 | 0.55 |
| **SpeciesHA** | **0.68** | **0.38** | **1.78** | **0.08** |
| **Temp\_treatMedium** | **3.04** | **0.69** | **4.43** | **9.60E-06** |
| **Temp\_treatWarm** | **4.14** | **0.71** | **5.87** | **4.30E-09** |
| Mass\_loss:SexMale | 0.04 | 0.04 | 1.12 | 0.26 |
| Mass\_loss:Temp\_treatMedium | -0.02 | 0.03 | -0.72 | 0.47 |
| Mass\_loss:Temp\_treatWarm | 0.05 | 0.03 | 1.67 | 0.10 |
| SexMale:Temp\_treatMedium | -0.60 | 0.87 | -0.69 | 0.49 |
| SexMale:Temp\_treatWarm | 0.89 | 0.87 | 1.02 | 0.31 |
| SpeciesHA:Temp\_treatMedium | -0.55 | 0.40 | -1.36 | 0.17 |
| **SpeciesHA:Temp\_treatWarm** | **-1.16** | **0.37** | **-3.16** | **0.002** |
| Mass\_loss:SexMale:Temp\_treatMedium | 0.03 | 0.05 | 0.52 | 0.61 |
| **Mass\_loss:SexMale:Temp\_treatWarm** | **-0.13** | **0.05** | **-2.80** | **0.01** |

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|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| Mass\_loss | -0.04 | 0.02 | -1.47 | 0.14 |
| SexMale | -0.23 | 0.59 | -0.38 | 0.70 |
| SpeciesHA | 0.12 | 0.41 | 0.30 | 0.76 |
| **Temp\_treatCold** | **-3.04** | **0.69** | **-4.43** | **9.60E-06** |
| Temp\_treatWarm | 1.11 | 0.71 | 1.57 | 0.12 |
| **Mass\_loss:SexMale** | **0.07** | **0.03** | **2.00** | **0.05** |
| Mass\_loss:Temp\_treatCold | 0.02 | 0.03 | 0.72 | 0.47 |
| **Mass\_loss:Temp\_treatWarm** | **0.08** | **0.03** | **2.37** | **0.02** |
| SexMale:Temp\_treatCold | 0.60 | 0.87 | 0.69 | 0.49 |
| SexMale:Temp\_treatWarm | 1.48 | 0.85 | 1.74 | 0.08 |
| SpeciesHA:Temp\_treatCold | 0.55 | 0.40 | 1.36 | 0.17 |
| SpeciesHA:Temp\_treatWarm | -0.61 | 0.39 | -1.54 | 0.12 |
| Mass\_loss:SexMale:Temp\_treatCold | -0.03 | 0.05 | -0.52 | 0.61 |
| **Mass\_loss:SexMale:Temp\_treatWarm** | **-0.16** | **0.05** | **-3.53** | **0.0004** |

1. CTmin

Full model: CTmin ~ Mass\*Sex\*Species\*Treatment + (1|Family\_ID)

Variance structures: Species, Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **1.29** | **0.38** | **3.37** | **<0.001** |
| **Mass** | **-0.04** | **0.01** | **-2.92** | **0.004** |
| Temp\_treatMedium | 0.41 | 0.21 | 1.93 | 0.060 |
| **Temp\_treatWarm** | **0.64** | **0.19** | **3.38** | **<0.001** |

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| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **1.70** | **0.39** | **4.41** | **<0.0001** |
| **Mass** | **-0.04** | **0.01** | **-2.92** | **0.004** |
| Temp\_treatCold | -0.41 | 0.21 | -1.93 | 0.060 |
| Temp\_treatWarm | 0.23 | 0.19 | 1.20 | 0.23 |

1. CTmax

Full model: CTmax ~ Mass\*Sex\*Species\*Treatment + (1|Family\_ID)

Variance structures: Species, Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **45.04** | **0.38** | **120.06** | **0.000** |
| Mass | 0.004 | 0.018 | 0.23 | 0.82 |
| **SexMale** | **-1.51** | **0.48** | **-3.13** | **0.002** |
| **SpeciesHA** | **-1.17** | **0.48** | **-2.46** | **0.02** |
| **Temp\_treatMedium** | **0.31** | **0.10** | **3.03** | **0.003** |
| **Temp\_treatWarm** | **0.77** | **0.11** | **6.84** | **0.000** |
| **Mass:SexMale** | **0.08** | **0.02** | **3.30** | **0.001** |
| Mass:SpeciesHA | 0.02 | 0.02 | 0.82 | 0.41 |
| **SexMale:SpeciesHA** | **2.00** | **0.60** | **3.31** | **0.001** |
| SexMale:Temp\_treatMedium | -0.26 | 0.14 | -1.82 | 0.07 |
| **SexMale:Temp\_treatWarm** | **-0.37** | **0.15** | **-2.46** | **0.015** |
| **Mass:SexMale:SpeciesHA** | **-0.09** | **0.03** | **-3.07** | **0.002** |

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|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **45.36** | **0.37** | **122.54** | **0.000** |
| Mass | 0.004 | 0.018 | 0.232 | 0.82 |
| **SexMale** | **-1.76** | **0.47** | **-3.74** | **0.0002** |
| **SpeciesHA** | **-1.17** | **0.48** | **-2.46** | **0.02** |
| **Temp\_treatCold** | **-0.31** | **0.10** | **-3.03** | **0.003** |
| **Temp\_treatWarm** | **0.46** | **0.11** | **4.02** | **0.0001** |
| **Mass:SexMale** | **0.08** | **0.02** | **3.30** | **0.001** |
| Mass:SpeciesHA | 0.02 | 0.02 | 0.82 | 0.41 |
| **SexMale:SpeciesHA** | **2.00** | **0.60** | **3.31** | **0.001** |
| SexMale:Temp\_treatCold | 0.26 | 0.14 | 1.82 | 0.07 |
| SexMale:Temp\_treatWarm | -0.12 | 0.15 | -0.75 | 0.45 |
| **Mass:SexMale:SpeciesHA** | **-0.09** | **0.03** | **-3.07** | **0.002** |

1. Preoviposition period

Full model: Preoviposition period ~ Female mass\*Species\*Treatment + (1|Family\_ID)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **2.15** | **0.10** | **22.35** | **2.00E-16** |
| **SpeciesHA** | **-0.55** | **0.13** | **-4.41** | **1.05E-05** |
| **Temp\_treatMedium** | **-0.70** | **0.11** | **-6.44** | **1.17E-10** |
| **Temp\_treatWarm** | **-0.95** | **0.11** | **-8.47** | **2.00E-16** |

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|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **1.45** | **0.11** | **13.06** | **2.00E-16** |
| **SpeciesHA** | **-0.55** | **0.13** | **-4.41** | **1.05E-05** |
| **Temp\_treatCold** | **0.70** | **0.11** | **6.44** | **1.17E-10** |
| **Temp\_treatWarm** | **-0.25** | **0.13** | **-1.96** | **0.05** |

1. Total eggs

Full model: Total eggs ~ Female mass\*Species\*Treatment + (1|Family\_ID)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **3.55** | **0.20** | **17.87** | **2.00E-16** |
| **Mass** | **0.02** | **0.01** | **2.24** | **0.03** |
| **SpeciesHA** | **2.22** | **0.26** | **8.66** | **2.00E-16** |
| **Temp\_treatMedium** | **0.66** | **0.19** | **3.56** | **0.0004** |
| **Temp\_treatWarm** | **0.91** | **0.21** | **4.37** | **1.25E-05** |
| **Mass:SpeciesHA** | **-0.06** | **0.01** | **-4.47** | **7.67E-06** |
| Mass:Temp\_treatMedium | 0.01 | 0.01 | 0.86 | 0.39 |
| Mass:Temp\_treatWarm | -0.01 | 0.01 | -0.51 | 0.61 |
| **SpeciesHA:Temp\_treatMedium** | **-0.88** | **0.24** | **-3.61** | **0.0003** |
| **SpeciesHA:Temp\_treatWarm** | **-1.41** | **0.26** | **-5.45** | **5.08E-08** |
| **Mass:SpeciesHA:Temp\_treatMedium** | **0.03** | **0.01** | **2.48** | **0.01** |
| **Mass:SpeciesHA:Temp\_treatWarm** | **0.07** | **0.01** | **5.00** | **5.77E-07** |

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|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **4.21** | **0.13** | **31.75** | **2.00E-16** |
| **Mass** | **0.03** | **0.01** | **5.39** | **6.89E-08** |
| **SpeciesHA** | **1.34** | **0.17** | **7.97** | **1.56E-15** |
| **Temp\_treatCold** | **-0.66** | **0.19** | **-3.56** | **0.0004** |
| Temp\_treatWarm | 0.25 | 0.15 | 1.61 | 0.11 |
| **Mass:SpeciesHA** | **-0.02** | **0.01** | **-3.60** | **0.0003** |
| Mass:Temp\_treatCold | -0.01 | 0.01 | -0.86 | 0.39 |
| Mass:Temp\_treatWarm | -0.01 | 0.01 | -1.78 | 0.08 |
| **SpeciesHA:Temp\_treatCold** | **0.88** | **0.24** | **3.61** | **0.0003** |
| **SpeciesHA:Temp\_treatWarm** | **-0.53** | **0.18** | **-2.87** | **0.004** |
| **Mass:SpeciesHA:Temp\_treatCold** | **-0.03** | **0.01** | **-2.48** | **0.01** |
| **Mass:SpeciesHA:Temp\_treatWarm** | **0.04** | **0.01** | **3.94** | **8.28E-05** |

1. Hatching success

Full model: Hatching success~ Female mass\*Species\*Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **-0.08** | **0.03** | **-2.74** | **0.01** |
| Temp\_treatMedium | -0.01 | 0.04 | -0.36 | 0.72 |
| Temp\_treatWarm | -0.07 | 0.04 | -1.86 | 0.06 |

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| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **-0.09** | **0.02** | **-3.88** | **0.0001** |
| Temp\_treatCold | 0.01 | 0.04 | 0.36 | 0.72 |
| Temp\_treatWarm | -0.06 | 0.03 | -1.67 | 0.09 |

1. Developmental time

Full model: Developmental time ~ Mass\*Sex\*Species\*Treatment + (1|Family\_ID)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **3.90** | **0.04** | **101.31** | **2.00E-16** |
| **Mass** | **-0.007** | **0.002** | **-4.73** | **2.00E-06** |
| **SexMale** | **-0.03** | **0.01** | **-3.58** | **0.0003** |
| SpeciesHA | 0.02 | 0.04 | 0.43 | 0.67 |
| **Temp\_treatMedium** | **-0.39** | **0.04** | **-9.27** | **2.00E-16** |
| **Temp\_treatWarm** | **-0.64** | **0.04** | **-14.20** | **2.00E-16** |
| Mass:Temp\_treatMedium | -0.002 | 0.002 | -1.12 | 0.26 |
| **Mass:Temp\_treatWarm** | **-0.005** | **0.002** | **-2.07** | **0.04** |
| **SpeciesHA:Temp\_treatMedium** | **-0.05** | **0.03** | **-2.03** | **0.04** |
| **SpeciesHA:Temp\_treatWarm** | **-0.07** | **0.03** | **-2.69** | **0.01** |
|  |  |  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **3.50** | **0.04** | **88.88** | **2.00E-16** |
| **Mass** | **-0.010** | **0.002** | **-5.61** | **2.00E-07** |
| **SexMale** | **-0.03** | **0.01** | **-3.58** | **0.0003** |
| SpeciesHA | -0.04 | 0.04 | -1.01 | 0.31 |
| **Temp\_treatCold** | **0.39** | **0.04** | **9.27** | **2.00E-16** |
| **Temp\_treatWarm** | **-0.24** | **0.05** | **-5.27** | **1.00E-07** |
| Mass:Temp\_treatCold | 0.002 | 0.002 | 1.12 | 0.26 |
| Mass:Temp\_treatWarm | -0.002 | 0.002 | -0.94 | 0.35 |
| **SpeciesHA:Temp\_treatCold** | **0.05** | **0.03** | **2.03** | **0.04** |
| SpeciesHA:Temp\_treatWarm | -0.02 | 0.03 | -0.65 | 0.51 |

1. Pupal emergence success

Full model: Pupal emergence ~Species\*Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **P value** |
| **(Intercept)** | **-0.25** | **0.04** | **-5.63** | **2.00E-08** |
| **SpeciesHA** | **0.14** | **0.06** | **2.36** | **0.02** |

1. Adult mass

Full model: Adult mass ~ Sex\*Species\*Treatment + (1|Family\_ID)

Variance structures: Sex, Species, Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **18.09** | **0.93** | **19.47** | **<0.0001** |
| **SexMale** | **-2.09** | **0.50** | **-4.18** | **<0.0001** |
| **SpeciesHA** | **9.74** | **1.34** | **7.28** | **<0.0001** |
| Temp\_treatMedium | 0.10 | 0.54 | 0.19 | 0.85 |
| Temp\_treatWarm | -0.10 | 0.55 | -0.19 | 0.85 |
| **SexMale:SpeciesHA** | **-1.72** | **0.62** | **-2.77** | **0.01** |
| SexMale:Temp\_treatMedium | 0.14 | 0.67 | 0.21 | 0.84 |
| SexMale:Temp\_treatWarm | -0.52 | 0.68 | -0.76 | 0.45 |
| **SpeciesHA:Temp\_treatMedium** | **-1.98** | **0.68** | **-2.91** | **0.004** |
| **SpeciesHA:Temp\_treatWarm** | **-7.16** | **0.71** | **-10.07** | **<0.0001** |
| SexMale:SpeciesHA:Temp\_treatMedium | 0.07 | 0.86 | 0.08 | 0.93 |
| **SexMale:SpeciesHA:Temp\_treatWarm** | **2.06** | **0.88** | **2.33** | **0.02** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **18.19** | **0.90** | **20.10** | **<0.0001** |
| **SexMale** | **-1.95** | **0.45** | **-4.36** | **<0.0001** |
| **SpeciesHA** | **7.76** | **1.32** | **5.86** | **<0.0001** |
| Temp\_treatCold | -0.10 | 0.54 | -0.19 | 0.85 |
| Temp\_treatWarm | -0.21 | 0.51 | -0.41 | 0.68 |
| **SexMale:SpeciesHA** | **-1.65** | **0.60** | **-2.75** | **0.01** |
| SexMale:Temp\_treatCold | -0.14 | 0.67 | -0.21 | 0.84 |
| SexMale:Temp\_treatWarm | -0.66 | 0.65 | -1.02 | 0.31 |
| **SpeciesHA:Temp\_treatCold** | **1.98** | **0.68** | **2.91** | **0.004** |
| **SpeciesHA:Temp\_treatWarm** | **-5.18** | **0.69** | **-7.47** | **<0.0001** |
| SexMale:SpeciesHA:Temp\_treatCold | -0.07 | 0.86 | -0.08 | 0.93 |
| **SexMale:SpeciesHA:Temp\_treatWarm** | **1.99** | **0.87** | **2.29** | **0.02** |

1. Intrinsic rate of increase

Full model: Intrinsic rate of increase ~ Female mass\*Species\*Treatment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **0.10** | **0.02** | **4.46** | **<0.0001** |
| Mass | -0.002 | 0.001 | -1.86 | 0.07 |
| **SpeciesHA** | **-0.06** | **0.03** | **-2.47** | **0.02** |
| Temp\_treatMedium | 0.01 | 0.03 | 0.35 | 0.73 |
| Temp\_treatWarm | 0.002 | 0.029 | 0.08 | 0.94 |
| **Mass:SpeciesHA** | **0.004** | **0.001** | **2.67** | **0.01** |
| Mass:Temp\_treatMedium | 0.001 | 0.001 | 0.94 | 0.35 |
| Mass:Temp\_treatWarm | 0.003 | 0.001 | 2.00 | 0.05 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fixed effect** | **Estimate** | **SE** | **t value** | **P value** |
| **(Intercept)** | **0.11** | **0.03** | **4.00** | **<0.0001** |
| Mass | -0.001 | 0.001 | -0.62 | 0.54 |
| **SpeciesHA** | **-0.06** | **0.03** | **-2.47** | **0.02** |
| Temp\_treatCold | -0.01 | 0.03 | -0.35 | 0.73 |
| Temp\_treatWarm | -0.01 | 0.03 | -0.29 | 0.77 |
| **Mass:SpeciesHA** | **0.004** | **0.001** | **2.67** | **0.01** |
| Mass:Temp\_treatCold | -0.001 | 0.001 | -0.94 | 0.35 |
| Mass:Temp\_treatWarm | 0.002 | 0.001 | 1.12 | 0.27 |

**Table S5.** Summary statistics (mean, standard deviation and sample size) for each trait and temperature treatment: (a) starvation resistance, (b) thermal tolerance, (c) life-history traits. HA = *Harmonia axyridis*, CL: *Cheilomenes lunata*.

1. Starvation resistance

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |
| ***Trait*** | ***Species*** | ***Sex*** | ***Treatment*** | ***Mean ± SD*** | ***n*** |
| **Number of days until death** | HA | Male | Cold | 8.39 ± 1.53 | 19 |
|  | HA | Male | Medium | 5.77 ± 1.56 | 22 |
|  | HA | Male | Warm | 4.71 ± 1.20 | 17 |
|  | CL | Male | Cold | 9.70 ± 3.50 | 20 |
|  | CL | Male | Medium | 5.62 ± 1.50 | 13 |
|  | CL | Male | Warm | 4.55 ± 1.14 | 29 |
|  | HA | Female | Cold | 9.94 ± 2.17 | 17 |
|  | HA | Female | Medium | 6.32 ± 1.79 | 19 |
|  | HA | Female | Warm | 4.50 ± 1.16 | 18 |
|  | CL | Female | Cold | 11.61 ± 3.35 | 23 |
|  | CL | Female | Medium | 6.77 ± 1.90 | 24 |
|  | CL | Female | Warm | 3.92 ± 1.19 | 24 |
| **Body mass loss (%)** | HA | Male | Cold | 13.43 ± 4.36 | 19 |
|  | HA | Male | Medium | 12.53 ± 5.53 | 22 |
|  | HA | Male | Warm | 18.01 ± 10.07 | 17 |
|  | CL | Male | Cold | 16.08 ± 7.72 | 20 |
|  | CL | Male | Medium | 18.12 ± 10.10 | 13 |
|  | CL | Male | Warm | 19.44 ± 9.05 | 29 |
|  | HA | Female | Cold | 11.74 ± 8.11 | 17 |
|  | HA | Female | Medium | 13.85 ± 7.63 | 19 |
|  | HA | Female | Warm | 19.09 ± 9.10 | 18 |
|  | CL | Female | Cold | 17.34 ± 8.06 | 23 |
|  | CL | Female | Medium | 18.6 ± 9.00 | 24 |
|  | CL | Female | Warm | 21.16 ± 7.07 | 24 |

1. Thermal tolerance

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | |  | |  | |
| ***Trait*** | ***Species*** | ***Sex*** | ***Treatment*** | ***Mean ± SD*** | | ***n*** | |
| **Critical thermal minimum** | HA | Male | Cold | 0.04 ± 1.16 | | 26 | |
|  | HA | Male | Medium | 0.88 ± 1.59 | | 21 | |
|  | HA | Male | Warm | 1.02 ± 0.95 | | 25 | |
|  | CL | Male | Cold | 0.34 ± 1.90 | | 16 | |
|  | CL | Male | Medium | 0.91 ± 1.49 | | 15 | |
|  | CL | Male | Warm | 1.00 ± 1.92 | | 21 | |
|  | HA | Female | Cold | 0.32 ± 1.78 | | 25 | |
|  | HA | Female | Medium | 0.56 ± 1.20 | | 23 | |
|  | HA | Female | Warm | 0.96 ± 1.28 | | 23 | |
|  | CL | Female | Cold | 0.59 ± 1.63 | | 24 | |
|  | CL | Female | Medium | 0.71 ± 1.85 | | 22 | |
|  | CL | Female | Warm | 1.11 ± 1.22 | | 16 | |
| **Critical thermal maximum** | HA | Male | Cold | 44.70 ± 0.52 | | 28 | |
|  | HA | Male | Medium | 44.71 ± 0.51 | | 28 | |
|  | HA | Male | Warm | 44.88 ± 0.47 | | 29 | |
|  | CL | Male | Cold | 44.95 ± 0.52 | | 21 | |
|  | CL | Male | Medium | 45.04 ± 0.83 | | 25 | |
|  | CL | Male | Warm | 45.67 ± 0.70 | | 25 | |
|  | HA | Female | Cold | 44.42 ± 0.46 | | 23 | |
|  | HA | Female | Medium | 44.71 ± 0.36 | | 23 | |
|  | HA | Female | Warm | 45.25 ± 0.63 | | 25 | |
|  | CL | Female | Cold | 45.21 ± 0.62 | | 17 | |
|  | CL | Female | Medium | 45.52 ± 0.75 | | 20 | |
|  | CL | Female | Warm | 45.96 ± 0.71 | | 20 | |

1. Life-history traits

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Trait*** | ***Species*** | ***Treatment*** | ***Mean±SD*** | ***n*** |
| **Preoviposition period (days)** | HA | Cold | 5.21±1.89 | 21 |
|  | HA | Medium | 2.95±1.69 | 19 |
|  | HA | Warm | 2.35±1.39 | 24 |
|  | CL | Cold | 9.65±5.69 | 17 |
|  | CL | Medium | 4.58±3.38 | 19 |
|  | CL | Warm | 3.60±2.69 | 21 |
| **Total number of eggs** | HA | Cold | 162.81±78.27 | 21 |
|  | HA | Medium | 326.47±119.82 | 19 |
|  | HA | Warm | 389.17±120.52 | 24 |
|  | CL | Cold | 57.12±46.09 | 17 |
|  | CL | Medium | 122.47±61.23 | 19 |
|  | CL | Warm | 130.95±71.13 | 21 |
| **Egg hatching success (%)** | HA | Cold | 90.52±8.82 | 20 |
|  | HA | Medium | 93.34±6.76 | 19 |
|  | HA | Warm | 87.61±8.74 | 24 |
|  | CL | Cold | 95.04±7.18 | 13 |
|  | CL | Medium | 92.36±8.61 | 19 |
|  | CL | Warm | 87.59±8.05 | 19 |
| **Developmental time (days)- Males** | HA | Cold | 41.95±5.63 | 161 |
| (from egg to pupal emergence) | HA | Medium | 25.93±3.87 | 160 |
|  | HA | Warm | 19.84±2.86 | 185 |
|  | CL | Cold | 40.91±4.58 | 103 |
|  | CL | Medium | 27.46±5.61 | 162 |
|  | CL | Warm | 20.33±3.51 | 187 |
| **Developmental time (days)- Females** | HA | Cold | 42.16±6.20 | 183 |
| (from egg to pupal emergence) | HA | Medium | 25.95±3.84 | 184 |
|  | HA | Warm | 20.17±2.91 | 154 |
|  | CL | Cold | 41.09±4.54 | 128 |
|  | CL | Medium | 27.65±5.77 | 180 |
|  | CL | Warm | 20.86±3.57 | 172 |
| **Pupal emergence success (%)** | HA | Cold | 95.24±4.21 | 13 |
|  | HA | Medium | 93.16±5.27 | 13 |
|  | HA | Warm | 83.27±13.44 | 14 |
|  | CL | Cold | 75.23±27.97 | 10 |
|  | CL | Medium | 75.08±20.20 | 14 |
|  | CL | Warm | 76.41±19.54 | 13 |
| **Adult mass (mg)- Males** | HA | Cold | 23.00±4.12 | 161 |
|  | HA | Medium | 21.44±3.88 | 160 |
|  | HA | Warm | 17.86±4.93 | 185 |
|  | CL | Cold | 17.61±4.25 | 103 |
|  | CL | Medium | 16.41±5.21 | 162 |
|  | CL | Warm | 16.38±4.40 | 187 |
| **Adult mass (mg)- Females** | HA | Cold | 27.02±4.89 | 183 |
|  | HA | Medium | 25.37±5.13 | 184 |
|  | HA | Warm | 20.26±5.83 | 154 |
|  | CL | Cold | 19.96±5.38 | 128 |
|  | CL | Medium | 18.38±5.54 | 180 |
|  | CL | Warm | 18.19±5.36 | 172 |
| **Intrinsic rate of increase** | HA | Cold | 0.06±0.01 | 13 |
|  | HA | Medium | 0.10±0.02 | 13 |
|  | HA | Warm | 0.12±0.03 | 14 |
|  | CL | Cold | 0.06±0.02 | 10 |
|  | CL | Medium | 0.09±0.04 | 14 |
|  | CL | Warm | 0.12±0.03 | 13 |
| **Net reproductive rate (R0)** | HA | Cold | 14.08±3.12 | 13 |
|  | HA | Medium | 14.15±3.11 | 13 |
|  | HA | Warm | 11.00±3.28 | 14 |
|  | CL | Cold | 12.80±7.22 | 10 |
|  | CL | Medium | 12.86±6.56 | 14 |
|  | CL | Warm | 13.23±4.64 | 13 |
| **Generation time (Tg)** | HA | Cold | 42.20±5.79 | 13 |
|  | HA | Medium | 26.16±3.41 | 13 |
|  | HA | Warm | 20.21±2.55 | 14 |
|  | CL | Cold | 43.15±5.64 | 10 |
|  | CL | Medium | 28.49±4.71 | 14 |
|  | CL | Warm | 21.12±3.45 | 13 |

**Table S6.** Averaged model summary outputs: (a) CTmin, (b) CTmax, (c) developmental time, and (d) hatching success. HA = *Harmonia axyridis*, CL: *Cheilomenes lunata*.

1. CTmin

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **95% CI lb** | **95% CI ub** | **Relative variable importance** |
| **(Intercept)** | **1.33** | **0.39** | **3.36** | **0.55** | **2.10** | **1** |
| **Mass** | **-0.04** | **0.01** | **2.94** | **-0.07** | **-0.01** | **1** |
| Temp\_treatMedium | 0.41 | 0.21 | 1.91 | -0.01 | 0.83 | 1 |
| **Temp\_treatWarm** | **0.64** | **0.19** | **3.38** | **0.27** | **1.02** | **1** |
| SexMale | -0.04 | 0.11 | 0.39 | -0.27 | 0.18 | 0.32 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **95% CI lb** | **95% CI ub** | **Relative variable importance** |
| **(Intercept)** | **1.74** | **0.40** | **4.38** | **0.96** | **2.52** | **1** |
| **Mass** | **-0.04** | **0.01** | **2.94** | **-0.07** | **-0.01** | **1** |
| Temp\_treatCold | -0.41 | 0.21 | 1.91 | -0.83 | 0.01 | 1 |
| Temp\_treatWarm | 0.23 | 0.19 | 1.21 | -0.14 | 0.61 | 1 |
| SexMale | -0.04 | 0.11 | 0.39 | -0.27 | 0.18 | 0.32 |

1. CTmax

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | |  | |  | |  | |  | |
| **Fixed effect** | | **Estimate** | | **SE** | | **z value** | | **95% CI lb** | | **95% CI ub** | | **Relative variable importance** |
| **(Intercept)** | | **45.02** | | **0.38** | | **118.15** | | **44.27** | | **45.77** | | **1** |
| Mass | | 0.004 | | 0.018 | | 0.23 | | -0.031 | | 0.039 | | 1 |
| **SexMale** | | **-1.59** | | **0.49** | | **3.20** | | **-2.56** | | **-0.62** | | **1** |
| **SpeciesHA** | | **-1.14** | | **0.48** | | **2.30** | | **-2.12** | | **-0.17** | | **1** |
| **Temp\_treatMedium** | | **0.35** | | **0.15** | | **2.29** | | **0.05** | | **0.64** | | **1** |
| **Temp\_treatWarm** | | **0.81** | | **0.18** | | **4.43** | | **0.45** | | **1.17** | | **1** |
| **Mass:SexMale** | | **0.08** | | **0.02** | | **3.33** | | **0.03** | | **0.13** | | **1** |
| Mass:SpeciesHA | | 0.02 | | 0.02 | | 0.83 | | -0.02 | | 0.06 | | 1 |
| **SexMale:SpeciesHA** | | **2.09** | | **0.62** | | **3.36** | | **0.87** | | **3.30** | | **1** |
| SexMale:Temp\_treatMedium | | -0.19 | | 0.20 | | 0.94 | | -0.59 | | 0.21 | | 1 |
| SexMale:Temp\_treatWarm | | -0.23 | | 0.28 | | 0.82 | | -0.78 | | 0.32 | | 1 |
| **Mass:SexMale:SpeciesHA** | | **-0.09** | | **0.03** | | **3.06** | | **-0.14** | | **-0.03** | | **1** |
| SpeciesHA:Temp\_treatMedium | | -0.05 | | 0.17 | | 0.32 | | -0.38 | | 0.27 | | 0.6 |
| SpeciesHA:Temp\_treatWarm | | -0.06 | | 0.22 | | 0.28 | | -0.49 | | 0.37 | | 0.6 |
| SexMale:SpeciesHA:Temp\_treatMedium | | -0.10 | | 0.22 | | 0.44 | | -0.53 | | 0.34 | | 0.32 |
| SexMale:SpeciesHA:Temp\_treatWarm | | -0.21 | | 0.36 | | 0.59 | | -0.92 | | 0.49 | | 0.32 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **95% CI lb** | **95% CI ub** | **Relative variable importance** |
| **(intercept)** | **45.37** | **0.37** | **122.07** | **44.64** | **46.10** | **1** |
| Mass | 0.004 | 0.018 | 0.23 | -0.031 | 0.039 | 1 |
| **SexMale** | **-1.78** | **0.47** | **3.76** | **-2.71** | **-0.85** | **1** |
| **SpeciesHA** | **-1.19** | **0.48** | **2.42** | **-2.16** | **-0.23** | **1** |
| **Temp\_treatCold** | **-0.35** | **0.15** | **2.29** | **-0.64** | **-0.05** | **1** |
| **Temp\_treatWarm** | **0.46** | **0.16** | **2.85** | **0.14** | **0.78** | **1** |
| **Mass:SexMale** | **0.08** | **0.02** | **3.33** | **0.03** | **0.13** | **1** |
| Mass:SpeciesHA | 0.02 | 0.02 | 0.83 | -0.02 | 0.06 | 1 |
| **SexMale:SpeciesHA** | **1.99** | **0.61** | **3.25** | **0.79** | **3.19** | **1** |
| SexMale:Temp\_treatCold | 0.19 | 0.20 | 0.94 | -0.21 | 0.59 | 1 |
| SexMale:Temp\_treatWarm | -0.04 | 0.22 | 0.17 | -0.48 | 0.40 | 1 |
| **Mass:SexMale:SpeciesHA** | **-0.09** | **0.03** | **3.06** | **-0.14** | **-0.03** | **1** |
| SpeciesHA:Temp\_treatCold | 0.05 | 0.17 | 0.32 | -0.27 | 0.38 | 0.6 |
| SpeciesHA:Temp\_treatWarm | -0.01 | 0.18 | 0.04 | -0.36 | 0.34 | 0.6 |
| SexMale:SpeciesHA:Temp\_treatCold | 0.10 | 0.22 | 0.44 | -0.34 | 0.53 | 0.32 |
| SexMale:SpeciesHA:Temp\_treatWarm | -0.12 | 0.25 | 0.47 | -0.61 | 0.37 | 0.32 |

1. Developmental time

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **95% CI lb** | **95% CI ub** | **Relative variable importance** |
| **(Intercept)** | **3.90** | **0.04** | **94.24** | **3.82** | **3.98** | **1** |
| **Mass** | **-0.008** | **0.002** | **4.34** | **-0.011** | **-0.004** | **1** |
| **SexMale** | **-0.03** | **0.01** | **3.54** | **-0.05** | **-0.01** | **1** |
| SpeciesHA | -0.001 | 0.051 | 0.01 | -0.100 | 0.099 | 1 |
| **Temp\_treatMedium** | **-0.39** | **0.04** | **9.27** | **-0.48** | **-0.31** | **1** |
| **Temp\_treatWarm** | **-0.64** | **0.04** | **14.20** | **-0.72** | **-0.55** | **1** |
| Mass:Temp\_treatMedium | -0.002 | 0.002 | 1.07 | -0.007 | 0.002 | 1 |
| **Mass:Temp\_treatWarm** | **-0.0048** | **0.0023** | **2.04** | **-0.0094** | **-0.0002** | **1** |
| **SpeciesHA:Temp\_treatMedium** | **-0.053** | **0.026** | **2.03** | **-0.104** | **-0.002** | **1** |
| **SpeciesHA:Temp\_treatWarm** | **-0.07** | **0.03** | **2.54** | **-0.12** | **-0.02** | **1** |
| Mass:SpeciesHA | 0.001 | 0.002 | 0.48 | -0.002 | 0.004 | 0.37 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |
| **Fixed effect** | **Estimate** | **SE** | **z value** | **95% CI lb** | **95% CI ub** | **Relative variable importance** |
| **(Intercept)** | **3.51** | **0.04** | **85.33** | **3.43** | **3.59** | **1** |
| **Mass** | **-0.010** | **0.002** | **5.40** | **-0.014** | **-0.007** | **1** |
| **SexMale** | **-0.03** | **0.01** | **3.54** | **-0.05** | **-0.01** | **1** |
| SpeciesHA | -0.05 | 0.05 | 1.06 | -0.15 | 0.05 | 1 |
| **Temp\_treatCold** | **0.39** | **0.04** | **9.27** | **0.31** | **0.48** | **1** |
| **Temp\_treatWarm** | **-0.24** | **0.05** | **5.26** | **-0.33** | **-0.15** | **1** |
| Mass:Temp\_treatCold | 0.002 | 0.002 | 1.07 | -0.002 | 0.007 | 1 |
| Mass:Temp\_treatWarm | -0.002 | 0.002 | 0.96 | -0.007 | 0.002 | 1 |
| **SpeciesHA:Temp\_treatCold** | **0.053** | **0.026** | **2.03** | **0.002** | **0.104** | **1** |
| SpeciesHA:Temp\_treatWarm | -0.01 | 0.03 | 0.55 | -0.07 | 0.04 | 1 |
| Mass:SpeciesHA | 0.001 | 0.002 | 0.48 | -0.002 | 0.004 | 0.37 |

1. Hatching success

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | |  | |  | |  | |  | |
| **Fixed effect** | **Estimate** | | **SE** | | **z value** | | **95% CI lb** | | **95% CI ub** | | **Relative variable importance** | |
| **(Intercept)** | **-0.09** | | **0.03** | | **3.01** | | **-0.15** | | **-0.03** | | **1** | |
| Temp\_treatMedium | -0.01 | | 0.03 | | 0.27 | | -0.07 | | 0.05 | | 1 | |
| Temp\_treatWarm | -0.04 | | 0.04 | | 0.95 | | -0.13 | | 0.04 | | 0.61 | |
| SpeciesHA | 0.0001 | | 0.0129 | | 0.01 | | -0.0252 | | 0.0253 | | 0.16 | |

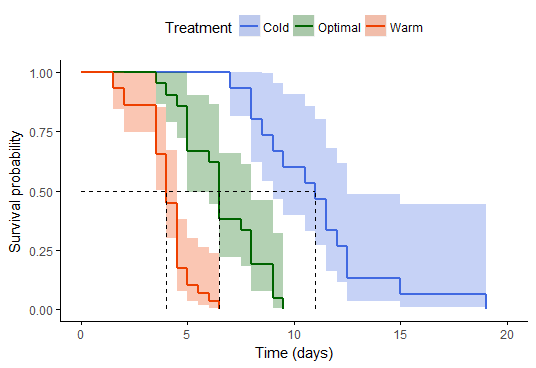
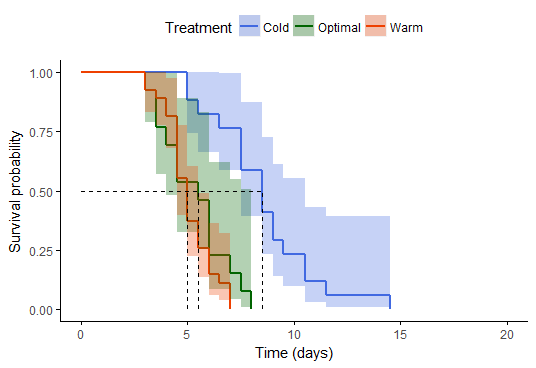
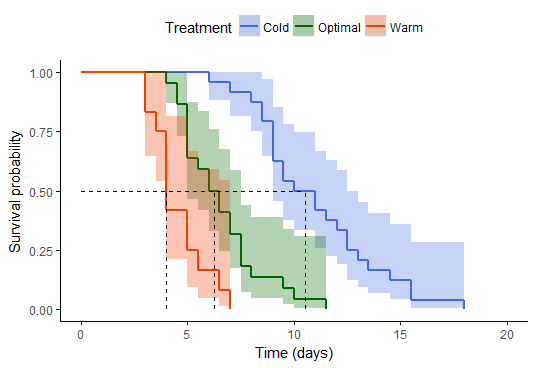
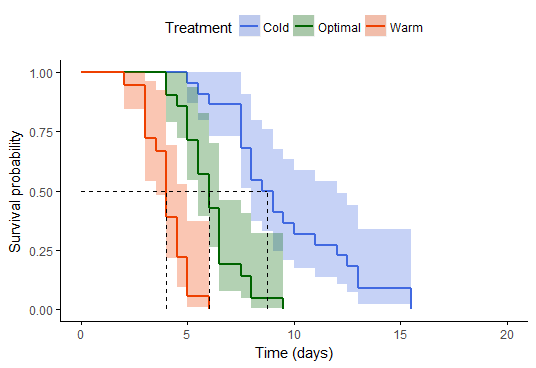
|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  |  |  |  |  |
| **Fixed effect** | **Estimate** | | **SE** | **z value** | **95% CI lb** | **95% CI ub** | **Relative variable importance** | |
| **(Intercept)** | **-0.10** | | **0.02** | **4.11** | **-0.14** | **-0.05** | **1** | |
| Temp\_treatCold | 0.01 | | 0.03 | 0.27 | -0.05 | 0.07 | 1 | |
| Temp\_treatWarm | -0.03 | | 0.04 | 0.91 | -0.11 | 0.04 | 0.61 | |
| SpeciesHA | 0.0001 | | 0.0129 | 0.01 | -0.0252 | 0.0253 | 0.16 | |

**Figures**

**Diagram

Description automatically generated**

**Figure S1.** Study experimental design for rearing and determining physiological and life-history traits of the two beetle species. T1 to 3: treatments 1 to 3. CTL= Critical Thermal Limits. Ladybird illustration by Corneile Minnaar.



**(a)**

**(b)**

**Figure S2.** Kaplan-Meier survival curves used to plot starvation resistance data of *Harmonia axyridis* and *Cheilomenes lunata* for the cold (right - blue), medium (middle - green) and warm (left - orange) temperature treatments for beetles that had a) low mass loss (≤16.43%, the median mass loss percentage for all beetles in all treatments) and b) high mass loss (>16.43%) groups. Female data are shown on the left and males on the right. Dotted lines represent 50% survival probability per treatment and corresponding number of days. Species’ effects are not shown here but in Fig. 2 of main article.

Diagram

Description automatically generated

**Figure S3.** Critical thermal maximum (CTmax, °C) of male and female beetles of *Harmonia axyridis* and *Cheilomenes lunata* for each temperature treatment. Values are model parameter estimates.

**Chart

Description automatically generated with medium confidence**

**Figure S4.** Total number of eggs laid by *Harmonia axyridis* (top row) and *Cheilomenes lunata* (bottom row) within the cold (left), medium (middle) and warm (right) treatments as a function of female body mass (mg). Values are model parameter estimates.

**Line chart

Description automatically generated**

Chart, line chart

Description automatically generated**Figure S5.** Developmental time (days) from egg to pupal emergence of *Cheilomenes lunata* (left) and *Harmonia axyridis* (right) in each temperature treatment. Values are model parameter estimates.

**Figure S6.** Developmental time (days) of *Harmonia axyridis* and *Cheilomenes lunata* beetles within the cold (left), medium (middle) and warm (right) treatments as a function of adult mass. Values are model parameter estimates.

Chart

Description automatically generated

**Figure S7.** Adult (F3) mass (mg) of male and female *Harmonia axyridis* (top row) and *Cheilomenes lunata* (bottom row) within each temperature treatment. Values are model parameter estimates.

**Chart

Description automatically generated**

**Figure S8.** Intrinsic rate of increase of *Cheilomenes lunata* (left) and for *Harmonia axyridis* (right) as a function of female mass (mg). Values are model parameter estimates.

Chart, histogram

Description automatically generated

**Figure S9** Density plots of measured critical thermal maximum (CTmax) data for *Harmonia axyridis* (left column) and *Cheilomenes lunata* (right column) in the cold (top row), medium (middle row) and warm (bottom row) treatments. The red line in each plot represents the heatwave event of 45°C experienced during simulations and the corresponding % mortality (individuals with CTmax<45°C) is shown in the upper left-hand corner. To estimate how many beetles survived the heatwave, CTmax was randomly sampled for each individual using the observed CTmax probability density distribution per temperature treatment for each species once established, and the number of individuals that had a CTmax >45°C was counted. The simulation ran for 1000 repeats for each species and each temperature scenario (all stages maintained at cold, medium or warm).