**Supplemental material**

Title: The drivers and consequences of unstable *Plasmodium* dynamics: A long-term study of three malaria parasite species infecting a tropical lizard



Figure S1. Overall prevalence of three malaria parasites infecting *Anolis gundlachi* over time at the El Verde field station in eastern Puerto Rico in 15 surveys conducted between 1990 and 2017. Means and standard errors among trails are shown.



Figure S2: Partial relationships predicted by the most parsimonious multinomial model describing the probability of *Anolis gundlachi* becoming infected by three *Plasmodium* parasites showing a similar pattern among the parasite species. The probability of infection increases with host body size, regardless of parasite species.



Figure S3: Partial relationships predicted by the most parsimonious multinomial model describing the probability of *Anolis gundlachi* becoming infected by three *Plasmodium* parasites showing a different pattern by sex and parasite species. The model predicts little differences in the probability of males and females getting infected by *P. azurophilum*. However, the probability of getting infected by *P. floridense* and *P. leucocytica* is greater in females.

Table S1: AICc comparison for binomial models describing the individual probability of *Anolis gundlachi* getting infected by *Plasmodium* parasites between 1990 and 2017. The symbol *K*  represents the number of parameters and LL the log-likelihood of the model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Covariates in model** | ***K*** | **ΔAICc** | **AICc Weight** | **LL** |
| sex\*svl+season+year | 18 |  0.00 | 0.99 | -4188.69 |
| sex+svl+season+year | 17 |  10.31 | 0.01 | -4194.85 |
| year  | 15 |  275.15 | 0.00 | -4329.28 |
| sex\*svl+season  |  5 |  296.50 | 0.00 | -4349.97 |
| sex+svl+season  |  4 |  299.09 | 0.00 | -4352.27 |
| svl  |  2 |  337.48 | 0.00 | -4373.47 |
| sex  |  2 |  520.34 | 0.00 | -4464.90 |
| Null  |  1 |  661.77 | 0.00 | -4536.61 |

Table S2: Parameter estimates from the most parsimonious binomial model explaining temporal variability in the risk of infection of *Anolis gundlachi* by *Plasmodium* parasites. Winter seasons are denoted with a "w" in the year, while summer seasons with an "s". The asterisk symbol represent parameters for which the *z* test resulted in *P*<0.05.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Estimate** | **Std. Error** | **z value** | **Pr(>|z|)** |  |
| (Intercept)  | -0.99 | 0.88 | -1.12 | 0.26 |  |
| sex  | -2.5 | 0.76 | -3.25 | <0.001\* |  |
| svl  | -0.01 | 0.01 | -0.82 | 0.4 |  |
| season (winter) | -1.04 | 0.23 | -4.36 | <0.001\* |  |
| year1991  | 0.33 | 0.42 | 0.77 | 0.44 |  |
| year1996  | 0.25 | 0.09 | 2.67 | <0.001\* |  |
| year1997  | 0.49 | 0.09 | 5.26 | <0.001\* |  |
| year1997w  | 1.19 | 0.25 | 4.75 | <0.001\* |  |
| year1998  | 0.54 | 0.12 | 4.23 | <0.001\* |  |
| year1998w  | 1.22 | 0.25 | 4.76 | <0.001\* |  |
| year1999  | 1.12 | 0.3 | 3.66 | <0.001\* |  |
| year2001  | 1.56 | 0.26 | 5.83 | <0.001\* |  |
| year2002  | 1.1 | 0.26 | 4.23 | <0.001\* |  |
| year2015  | -0.6 |  0.11 | -5.43 | <0.001\* |  |
| year2016s  | -1.21 | 0.16 | -7.37 | <0.001\* |  |
| year2016w  | 0.2 | 0.26 | 0.77 | 0.43 |  |
| year2017s  | -0.43 | 0.18 | -2.29 | 0.02\* |  |
| year2017w  | NA | NA | NA | NA |  |
| sex:svl  | 0.05 | 0.01 | 3.45 | 0 |  |

Table S3: AICc comparison of binomial models describing the drivers of fluctuations in the proportion of *Anolis gundlachi* infected by *Plasmodium* parasites in a 27-year period. These models compare the effect of mean and variance in rainfall, and mean minimum, maximum and variability in temperature 30 and 120 days before the sampling. Note that *K* represents the number of paramters and LL the log-likelihood of the model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Explanatory variables** | ***K*** | **∆ AICc** | **AICc weight** | **LL** |
| mean\_rain120^2+mean\_maxT120^2 |  5  |  0.00 |  1 | -205.78 |
| mean\_rain120^2+mean\_minT120^2 |  5  |  25.72 |  0 | -219.60 |
| mean\_rain120^2+mean\_maxT30^2  |  5  |  36.25 |  0 | -223.91 |
| mean\_rain30^2+mean\_maxT120^2  |  5  |  42.01 |  0 | -226.79 |
| mean\_rain30^2+mean\_maxT30^2  |  5  |  42.81 |  0 | -227.19 |
| mean\_rain120^2+mean\_minT30^2  |  5  |  79.47 |  0 | -246.47 |
| mean\_rain30+mean\_maxT120  |  3  |  82.98 |  0 | -252.22 |
| mean\_rain30^2+mean\_minT30^2  |  5  |  92.82 |  0 | -253.14 |
| cumulative\_rain120^2+mean\_maxT120^2  |  5  |  95.34 |  0 | -253.45 |
| mean\_rain30+mean\_minT30  |  3  |  98.84 |  0 | -260.40 |
| mean\_rain30^2+mean\_minT120^2  |  5  | 102.67 |  0 | -258.07 |
| mean\_rain120+mean\_maxT120  |  3  | 103.68 |  0 | -262.57 |
| mean\_minT30^2  |  3  | 108.45 |  0 | -265.21 |
| var\_minT120  |  2  | 115.77 |  0 | -270.45 |
| mean\_rain30+mean\_maxT30  |  3  | 117.42 |  0 | -269.45 |
| var\_maxT120  |  2  | 117.78 |  0 | -271.36 |
| mean\_rain120+mean\_maxT30  |  3  | 135.18 |  0 | -278.33 |
| mean\_rain120+mean\_minT30  |  3  | 135.74 |  0 | -278.85 |
| mean\_rain120  |  3  | 139.65 |  0 | -280.81 |
| mean\_rain30^2  |  3  | 141.89 |  0 | -281.92 |
| mean\_minT30  |  2  | 143.68 |  0 | -284.41 |
| mean\_maxT120  |  2  | 147.23 |  0 | -286.08 |
| mean\_maxT30^2  |  3  | 148.37 |  0 | -284.92 |
| mean\_maxT120^2  |  3  | 148.92 |  0 | -285.20 |
| mean\_rain30  |  2  | 153.85 |  0 | -289.49 |
| mean\_rain30+mean\_minT30  |  3  | 157.02 |  0 | -289.49 |
| mean\_minT120^2  |  3  | 158.49 |  0 | -290.22 |
| mean\_rain120+mean\_minT30  |  3  | 180.47 |  0 | -301.21 |
| mean\_rain120  |  2  | 180.87 |  0 | -303.00 |
| var\_maxT30  |  2  | 182.29 |  0 | -303.61 |
| mean\_maxT30  |  2  | 185.55 |  0 | -305.24 |
| var\_rain120  |  2  | 196.86 |  0 | -311.00 |
| var\_rain30  |  2  | 204.39 |  0 | -314.77 |
| mean\_minT120  |  2  | 212.78 |  0 | -318.96 |
| Null  |  1  | 218.38 |  0 | -323.11 |

Table S4: Parameter estimates from the most parsimonious binomial model explaining the relationship between rainfall, temperature and the temporal variation in the proportion of infected *Anolis gundlachi* with *Plasmodium* parasites from 1990 to 2017. The asterisk symbol represent parameters for which the *z* test resulted in *P*<0.05.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Estimate** | **Standard error** | **z value** | **Pr(>|z|)** |  |
| (Intercept) | -18.14 | 2.74 | -6.62 | <0.001\* |  |
| Mean rainfall | 0.94 | 0.08 | 10.93 | <0.001\* |  |
| Mean maximum temperature | 0.99 | 0.21 | 4.56 | <0.001\* |  |
| I(mean rainfall)2 | -0.04 | <0.01 | 10.31 | <0.001\* |  |
| I(mean maximum temperature)2 | -0.01 | <0.01 | -4.17 | <0.001\* |  |

Table S5: AICc comparison of linear models describing the drivers of fluctuations in body condition of *Anolis gundlachi* males in a 26-year period. These models compare the effect of mean maximum temperature 30 days before the survey, and cumulative rain 30 days before the survey in addition to the effect of infection state. Note that *K* represents the number of parameters and LL the log-likelihood of the model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Explanatory variables** | **K** | **∆ AICc** | **AICc weight** | **LL** |
| mean\_maxT30^2+cumulative\_rain30^2  | 6 |  0.00 | 0.56 | 1615.70 |
| mean\_maxT30^2+cumulative\_rain30^2+Infection | 7 |  0.49 | 0.44 | 1616.46 |
| cumulative\_rain30^2  | 4 |  23.24 | 0.00 | 1602.07 |
| cumulative\_rain30^2+Infection  | 5 |  23.59 | 0.00 | 1602.90 |
| cumulative\_rain30  | 3 |  24.25 | 0.00 | 1600.56 |
| cumulative\_rain30+Infection  | 4 |  24.51 | 0.00 | 1601.43 |
| mean\_maxT30+cumulative\_rain30+Infection  | 5 |  24.97 | 0.00 | 1602.21 |
| mean\_maxT30+cumulative\_rain30  | 4 |  25.18 | 0.00 | 1601.10 |
| mean\_maxT30^2  | 4 |  26.34 | 0.00 | 1600.52 |
| mean\_maxT30^2+Infection  | 5 |  28.00 | 0.00 | 1600.69 |
| mean\_maxT30  | 3 | 113.12 | 0.00 | 1556.12 |
| mean\_maxT30+Infection  | 4 | 115.00 | 0.00 | 1556.19 |
| Null  | 2 | 115.97 | 0.00 | 1553.69 |
| Infection  | 3 | 117.98 | 0.00 | 1553.69 |

Table S6: Parameter estimates from the average model (top two) explaining the relationship between rainfall, temperature, infection state and body condition of *Anolis gundlachi* females over the 26-year study period.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Estimate** | **Standard error** |  |
| (Intercept) | -6.61 | 1.32 |  |
| cumulative\_rain30 |  5.10e-06 | 9.57e-05 |  |
| mean\_maxT30 |  5.07e-01 | 1.00e-01 |  |
| cumulative\_rain30^2 | -3.23e-07 | 2.50e-07 |  |
| mean\_maxT30^2 | -9.67e-03 | 1.90e-03 |  |
| infection (=1) |  7.53e-03 | 6.11e-03 |  |

Table S7: AICc comparison of models describing the drivers of fluctuations in body condition of *Anolis gundlachi* males in a 26-year period. These models compare the effect of mean maximum temperature and cumulative rain 30 days before the survey in addition to the effect of infection state. Note that *K* represents the number of parameters and LL represents the log-likelihood of the model.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Explanatory variables** | **K** | **∆ AICc** | **AICc weight** | **LL** |
| cumulative\_rain30^2  | 4 |  0.00 | 0.47 | 3417.25 |
| cumulative\_rain30^2+Infection  | 5 |  0.34 | 0.39 | 3418.08 |
| mean\_maxT30^2+cumulative\_rain30^2  | 6 |  3.69 | 0.07 | 3417.42 |
| mean\_maxT30^2+cumulative\_rain30^2+Infection | 7 |  4.00 | 0.06 | 3418.26 |
| cumulative\_rain30+Infection  | 4 |  50.44 | 0.00 | 3392.03 |
| cumulative\_rain30  | 3 |  50.96 | 0.00 | 3390.77 |
| mean\_maxT30+cumulative\_rain30+Infection  | 5 |  51.04 | 0.00 | 3392.74 |
| mean\_maxT30+cumulative\_rain30  | 4 |  52.12 | 0.00 | 3391.19 |
| mean\_maxT30^2+Infection  | 5 |  61.54 | 0.00 | 3387.48 |
| Infection  | 3 |  61.59 | 0.00 | 3385.45 |
| mean\_maxT30+Infection  | 4 |  61.96 | 0.00 | 3386.27 |
| Null  | 2 |  65.07 | 0.00 | 3382.71 |
| mean\_maxT30^2  | 4 |  65.84 | 0.00 | 3384.33 |
| mean\_maxT30  | 3 |  66.26 | 0.00 | 3383.12 |

Table S8: Parameter estimates from the most parsimonious model explaining the relationship between rainfall, temperature, infection state and body condition of *Anolis gundlachi* males over the 26-year study period.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Estimate** | **Standard error** |  |
| (Intercept) | -8.91e-03 | 3.27e-03 |  |
| cumulative\_rain30 |  2.89e-04 | 4.76e-05 |  |
| cumulative\_rain30^2 | -9.58e-07 | 1.31e-07 |  |
| infection (=1) | -4.22e-03 | 3.27e-03 |  |

Table S9: AICc comparison of models describing the probability of individuals being in four infection categories: non-infected, infected by *P. azurohilum*, infected by *P. floridense*, or infected by *P. leucocytica*. Note that *K* represents the number of parameters and LL the log-likelihood.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Covariates in model** | **K** | **Delta\_AICc** | **AICcWt** | **LL** |
| year+svl+sex | 36 |  0.00  | 0.99 | -2518.00 |
| year\*slv+sex | 63 |  9.02  | 0.01 | -2494.84 |
| year\*sex+svl | 63 |  12.70  | 0.00 | -2496.68 |
| svl+year  | 33 |  28.50  | 0.00 | -2535.30 |
| svl\*year  | 60 |  38.29  | 0.00 | -2512.58 |
| Year  | 30 |  145.43  | 0.00 | -2596.81 |
| sex+svl  |  9 |  167.34  | 0.00 | -2628.98 |
| svl  |  6 |  195.47  | 0.00 | -2646.05 |
| sex  |  6 |  320.46  | 0.00 | -2708.54 |
| Null  |  3 |  411.22  | 0.00 | -2756.94 |

Table S10: Parameter estimates from the most parsimonious multinomial model explaining the probability of getting infected by three *Plasmodium* parasites. First table shows parameter estimates, while the second shows predicted standard errors.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parasite spp** | **Intercept** | **Sex (F)** | **SVL** | **1998** | **1999** | **2001** | **2002** | **2015** | **2016w** | **2016s** | **2017w** | **2017s** |
| *P. azurophilum* | -4.1 | 0.02 | 0.05 | 0.28 | 0.003 |  0.20 | -0.12 | -0.69 | -0.88 | -0.98 | -1.19 | -0.16 |
| *P. leucocytica* | -7.2 | 0.67 | 0.07 | 0.65 | 0.58 |  0.82 |  0.16 | -0.01 | -0.13 | -0.76 | -0.64 | -0.59 |
| *P. floridense* | -5.8 | 0.30 | 0.07 | 0.30 | -0.62 | -0.39 | -0.25 | -1.53 | -2.24 | -30.65 | -1.39 | -2.25 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Parasite spp** | **Intercept** | **Sex (F)** | **SVL** | **1998** | **1999** | **2001** | **2002** | **2015** | **2016w** | **2016s** | **2017w** | **2017s** |
| *P. azurophilum* | 0.5 | 0.2 | 0.007 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 2e-01 | 0.3 | 0.2 |
| *P. leucocytica* | 0.8 | 0.3 | 0.012 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 4e-01 | 0.5 | 0.5 |
| *P. floridense* | 0.9 | 0.3 | 0.014 | 0.3 | 0.5 | 0.3 | 0.3 | 0.3 | 0.4 | 2e-12 | 0.5 | 0.7 |