**Models for the rates of pupal development, fat consumption and mortality in tsetse (*Glossina* spp)**

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**SUPPLEMENTARY MATERIAL**

**Tables for main body of the text**

**Table SM1.** Parameter estimates providing the best fit to the data for pupal duration (fig. 1a, main text) for male and female *G. m. morsitan*s maintained in the laboratory at constant temperatures between 16 and 32°C. Data were fitted using the model shown in Equation (1). Parameter estimates, values of *t*, P and the 95% confidence intervals were calculated using Stata’s non-linear least squares programme.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | Standard  error | t | P>|t| | 95% Confidence Interval | |
| Males | *R*2 = 0.998 | N =12 |  |  |  |  |
| *A* | 19.09 | 0.752 | 25.37 | 0.000 | 17.38 | 20.79 |
| *B* | 84.0 | 1.04 | 80.73 | 0.000 | 81.7 | 86.4 |
| *C* | -0.241 | 0.00891 | -27.04 | 0.000 | -0.261 | -0.221 |
| Females | *R*2 = 0.999 | N =12 |  |  |  |  |
| *A* | 17.94 | 0.492 | 36.48 | 0.000 | 16.83 | 19.05 |
| *B* | 82.3 | 0.72 | 114.6 | 0.000 | 80.7 | 84.0 |
| *C* | -0.253 | 0.00645 | -39.14 | 0.000 | -0.267 | -0.238 |

**Table SM2.** Parameter estimates providing the best fit to the data for the rates of pupal development (fig. 3, main text) for male and female *G. m. morsitan*s maintained in the laboratory. Parameter estimates, values of *t*, P and the 95% confidence intervals were calculated using Stata’s non-linear least squares programme.

1. Fits to all data for *T* ≥16°C and ≤32°C, using the model shown in Equation (5).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | Standard  error | t | P>|t| | 95% Confidence Interval | |
| Males | *R*2 = 0.9997 | N =14 |  |  |  |  |
| *k* | 0.0529 | 0.0010 | 52.48 | 0.000 | 0.0506 | 0.0551 |
| *a* | 5.29 | 0.16 | 32.12 | 0.000 | 4.93 | 5.65 |
| *b* | -0.238 | 0.00906 | -26.22 | 0.000 | -0.258 | -0.218 |
| Females | *R*2 = 0.996 | N =14 |  |  |  |  |
| *k* | 0.0570 | 0.0012 | 48.51 | 0.000 | 0.0544 | 0.0596 |
| *a* | 5.46 | 0.19 | 28.89 | 0.000 | 5.04 | 5.88 |
| *b* | -0.245 | 0.010 | -23.85 | 0.000 | -0.267 | -0.222 |

1. Fits to data for *T* <16°C, using the model shown in Equation (6).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | Standard  error | t | P>|t| | 95% Confidence Interval | |
| Males | *R*2 = 0.9973 | N = 4 |  |  |  |  |
| *K*1 | 0.000635 | 0.00016 | 3.95 | 0.059 | -0.00006 | 0.0013 |
| *K*2 | 0.175 | 0.0200 | 8.75 | 0.013 | 0.0888 | 0.261 |
| Females | *R*2 = 0.999 | N =12 |  |  |  |  |
| *K*1 | 0.000656 | 0.000037 | 17.8 | 0.003 | 0.00050 | 0.00081 |
| *K*2 | 0.169 | 0.00445 | 37.90 | 0.001 | 0.149 | 0.188 |

**Table SM3.** Parameter estimates providing the best fit to the data for pupal duration (fig. 1b, main text) for male and female *G. m. morsitan*s maintained in the laboratory at temperatures of 8, 10, 12 and 14°C. Data were fitted using the model shown in Equation (7).Parameter estimates, values of *t*, P and the 95% confidence intervals were calculated using Stata’s non-linear least squares programme.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | Standard  error | t | P>|t| | 95% Confidence Interval | |
| Males | *R*2 = 0.989 | N = 6 |  |  |  |  |
| *B* | 107.4 | 11.64 | 9.23 | 0.001 | 75.1 | 139.8 |
| *C* | -0.152 | 0.017 | -8.99 | 0.001 | -0.198 | -0.105 |
| Females | *R*2 = 0.999 | N = 6 |  |  |  |  |
| *B* | 101.3 | 1.86 | 54.5 | 0.000 | 96.1 | 106.4 |
| *C* | -0.171 | 0.003 | -61.4 | 0.000 | -0.179 | -0.163 |

**Table SM4.** Parameter estimates providing the best fit to the data for daily rates of fat consumption by pupae of *G. m. morsitan*s maintained in the laboratory at constant temperatures between 16 and 32°C. Data fitted using the logistic function (Equation 8).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | | Standard  error | | t | | P>t | | 95% Confidence  Intervals | | |
| Males |  |  | |  | |  | |  | |  |
| *a* | 0.137 | 0.022 | | 6.11 | | 0.001 | | 0.087 | | 0.186 |
| *b* | 0.149 | 0.024 | | 6.22 | | 0.001 | | 0.096 | | 0.203 |
| *c* | 25.9 | 2.4 | | 10.6 | | 0.001 | | 20.5 | | 31.3 |
| Females |  |  | |  | |  | |  | |  |
| *a* | 0.162 | 0.024 | | 6.86 | | 0.001 | | 0.109 | | 0.204 |
| *b* | 0.142 | 0.017 | | 8.48 | | 0.001 | | 0.105 | | 0.179 |
| *c* | 27.4 | 2.2 | | 12.5 | | 0.001 | | 22.6 | | 32.3 |

**Table SM5.** Parameter estimates providing the best fit to the data shown in fig. 6b (main text) using the model shown in Equation (11). *T*1 and *T*2 were set at 16 and 320C, respectively: their values are arbitrary and chosen simply to ensure that *K*1 and *K*2 take values in a convenient range. *R*2 = 0.98

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | Standard  error | t | P>t | 95% Confidence  Intervals | |
| *K*0 | 0.0588 | 0.0119 | 4.94 | 0.001 | 0.0319 | 0.0858 |
| *K*1 | 0.675 | 0.0341 | 19.83 | 0.000 | 0.599 | 0.7529 |
| *K*2 | 1.118 | 0.139 | 8.04 | 0.000 | 0.805 | 1.432 |
| *K*3 | 0.557 | 0.034 | 16.4 | 0.000 | 0.480 | 0.634 |
| *K*4 | 1.312 | 0.214 | 6.14 | 0.000 | 0.828 | 1.796 |

**Table SM6.** Parameter estimates providing the best fit to the data for instantaneous daily rates of pupal mortality in female *G. m. morsitan*s maintained in the laboratory at constant temperatures between 16 and 32°C. Data were fitted using the model shown in Equation (14).

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | | Standard  error | | t | | P>t | | 95% Confidence  Intervals | | |
| *k*0 | 0.00202 | 0.00040 | | 5.13 | | 0.001 | | 0.00113 | | 0.00292 |
| *k*1 | 0.00534 | 0.00115 | | 4.64 | | 0.001 | | 0.00274 | | 0.00795 |
| *k*2 | 1.552 | 0.975 | | 1.59 | | 0.146 | | -0.653 | | 3.758 |
| *k*3 | 0.02972 | 0.00114 | | 26.1 | | 0.001 | | 0.02714 | | 0.03230 |
| *k*4 | 1.217 | 0.120 | | 10.2 | | 0.001 | | 0.946 | | 1.489 |

**Modelling rates of pupal development as a function of temperature**

Phelps & Burrows (1969a) modelled the rate of pupal development (*r*(*T*)) using the function:

*r*(*T*) = *k*/(1 + exp(*a* + *bT*) (S1)

In the absence of sophisticated computer software to fit the data they used an iterative procedure due to Aitchison & Silvey (1960): a slightly better fit (*i*.*e*., with a lower residual sums of squares) was achieved using Stata’s non-linear fitting routine (Figure S1). The parameter values arising from the two different fitting methods are shown in Table SI1.



**Figure SI1.** Development rates for pupae of *G. m. morsitan*s incubated in the laboratory at constant temperatures (*T*). Data for *T* ≥ 160C fitted using Equation (S1). A. Using the parameters provided by Phelps & Burrows (1969a). B. Fit achieved using Stata. See Table SI1 for parameter estimates.

**Table SI1.** Parameter values

The means and standard errors obtained by Phelps & Burrows (1969a) [see their Table 3] are shown, in bold type and in square parentheses, below the present estimates. The total residual sums of squared deviations between the observed and predicted development rates for males and females were 9.79 x 10-6 and 14.57 x 10-6, respectively, using the parameter values quoted by Phelps & Burrows (1969a) – and 7.02 x 10-6 and 8.73 x 10-6, respectively, using the parameter values from the Stata fit

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Mean | Standard Error | *t* (*P* > *t*) | 95% confidence intervals | Mean | Standard Error | *t* (*P* > *t*) | 95% confidence intervals |
| *k* | 0.05385  **[0.05415]** | 0.00113  **[0.00138]** | 47.60\*\*\* | 0.0514  - 0.0563 | 0.05763 | 0.00109 | 52.73\*\*\* | 0.0553  -0.0600 |
| *a* | 5.0682  **[4.8184]** | 0.139  **[0.0820]** | 36.48\*\*\* | 4.768  - 5.368 | 5.3043 | 0.142 | 37.38\*\*\* | 4.998  - 5.611 |
| *b* | -0.2259  **[-0.2149]** | 0.0082  **[0.0041]** | -27.41\*\*\* | -0.244  - -0.208 | -0.2368 | 0.0082 | -28.88\*\*\* | -0.255  - -0.219 |

**Attempts to model pupal durations at all temperatures as a single function**

In fig. 1b of the main text, the predicted pupal durations for temperatures between 8 and 320C are calculated using a composite function: for *T* ≥ 160C values were calculated using Equation (1): for *T* <160C using Equation (7). When we fitted all of the data using Equation (1) we obtained an apparently very good fit, particularly for females, over the whole range of values of temperatures 8 - 320C (Figure SI2, Table SI2). Closer examination of the data showed, however, that the fit to data for temperatures greater than 150C were now not as good as when we used the composite function. In particular, the fitted function shown in Figure S1 consistently under-estimated the observed pupal duration by as much as 5.9 days (27.9%) for males and 4.0 days (20.5%) days for females, when the flies were kept at 320C.



**Figure SI2.** Pupal duration in male and female *G. m. morsitan*s as a function of the constant temperature (*T*) at which the pupae were maintained in the laboratory. For *T* = 16-320C pupal durations were measured directly: for *T* < 160C durations were inferred by maintaining pupae at constant temperatures for 24 hour periods, the periods alternating between the test temperature and 250C. All data were given identical weight in the modelling.

The essential problem is that the pupal durations for temperatures less than 160C have been derived by a circuitous route and will clearly be subject to much greater error than for the durations at higher temperatures, which were measured directly. Phelps & Burrows provided, however, no estimates of the error of estimation of either approach. In the absence of such information we gave all the points equal weight and this effectively meant that the sums of squares was dominated by the data for long pupal durations associated with lower temperatures.

**Table SI2.** Parameter estimates providing the best fit to the data for pupal duration (Figure S1) for male and female *G. m. morsitan*s maintained in the laboratory at constant temperatures between 16 and 320C, or at temperatures <160C for 24 hour periods, alternated with a temperature of 250C. All data were fitted using the model shown in Equation (1) in the main text.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Coefficient | Standard  error | t | P>|t| | 95% Confidence Interval | |
| Males | *R*2 = 0.982 | N =16 |  |  |  |  |
| A | 7.93 | 7.72 | 1.03 | 0.323 | -8.76 | 24.62 |
| B | 97.1 | 11.2 | 8.65 | 0.000 | 72.8 | 121.3 |
| C | -0.163 | 0.014 | -11.59 | 0.000 | -0.193 | -0.132 |
| Females | *R*2 = 0.998 | N =16 |  |  |  |  |
| A | 11.03 | 2.13 | 5.17 | 0.000 | 6.42 | 15.64 |
| B | 89.0 | 3.15 | 28.3 | 0.000 | 82.2 | 95.8 |
| C | -0.185 | 0.0044 | -41.97 | 0.000 | -0.194 | -0.175 |