A NEW WAY TO CALCULATE THERMAL SUMMATION CONSTANTS FOR FORENSICALLY USEFUL INSECTS USING FUZZY REGRESSION

Szymon Matuszewski, Jędrzej Wydra

Laboratory of Criminalistics, Adam Mickiewicz University, Poznań, Poland
Wielkopolska Centre of Advanced Technologies, Adam Mickiewicz University, Poznań, Poland

How to make time of development more reliable?

Thermal summation constants are usually calculated using Ikemoto and Taki's method. These values are useful to estimate time of development for a given insect, for instance premature insects sampled on a death scene. What is surprising, the accuracy of this procedure is extremely small. We checked it for Necrodes littoralis L. (Silphidae) and Creophilus maxillosus L. (Staphylinidae) using data from the previous studies.

When you create an interval of development times (D) in given temperature (T) according to following formula

$$\left[\frac{k-s_e}{T-t_0}, \frac{k+s_e}{T-t_0}\right]$$

(where k is thermal summation constant, s_e is its standard error, t_0 is the development threshold) it will appear that its error rate id about 51% in case of N. littoralis; and 75% in case of C. maxillosus. Moreover, computer simulations show that in most cases such error rates could be even worse, above 90%.

Development models

The Authors would like to propose a new way to estimate aforementioned constants. Instead of linear function, we used a hyperbolic function $D(T) = \frac{k}{T-t_0}$, where k and D are as above, T is the temperature of development and t_0 is the development threshold. And instead of linear regression, we used fuzzy regression. In effect, we get k and t_0 in the form of intervals that are more meaningful and accurate than intervals yielded by conventional methods.

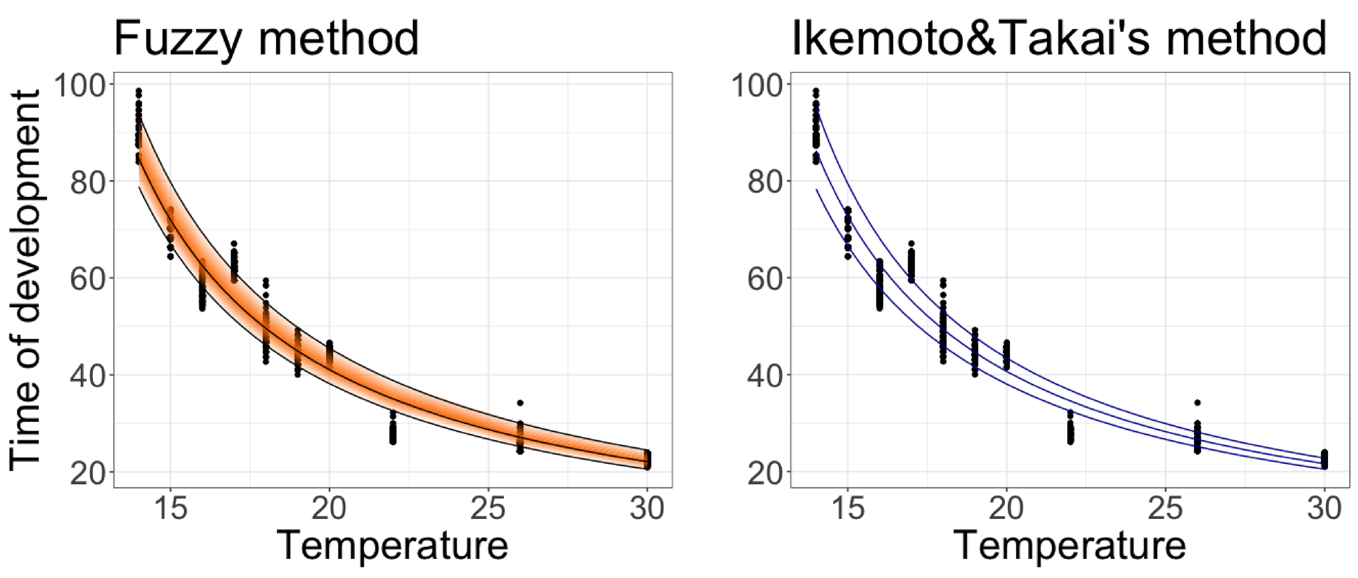


Figure 1. N. littoralis

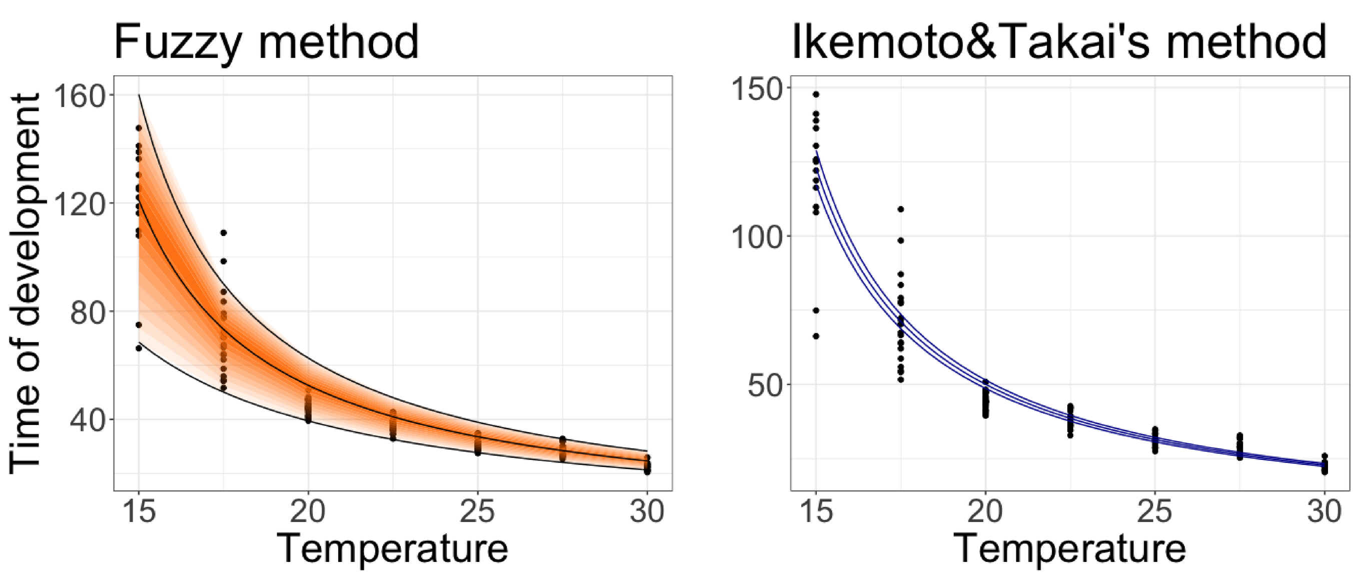


Figure 2. C. Maxillosus

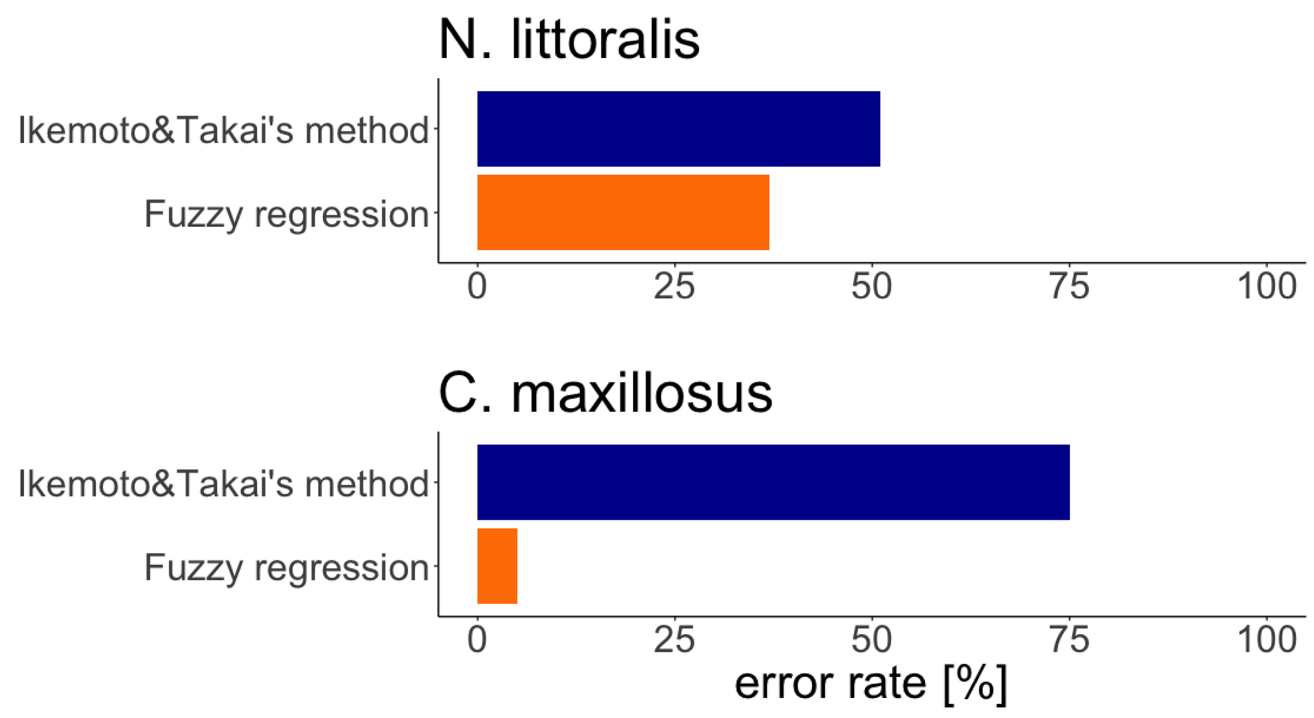
Definition of error rate

The error rate is complement of coverage probability i.e. $1-P(S_1 < X < S_2)$, where S_i, $i = 1, 2$ are limits of given interval and X is random variable. The estimator of the coverage probability is ratio between the number of observations contained in given interval and number of all observations (Ob):

$$\hat{P}(S_1 < X < S_2) = \frac{|\{x|S_1 < x < S_2, x \in Ob\}|}{|Ob|}$$

Error comparison

The new method was tested with developmental data for beetle species N. littoralis and C. maxillosus. The error rate decreased to 37% in the case of N. littoralis and 5% in the case of C. maxillosus. Computer simulations indicate that decreases below 10% may be common in the other species useful in forensic entomology.



References

[1] Joanna Gruszka and Szymon Matuszewski. Estimation of physiological age at emergence based on traits of the forensically useful adult carrion beetle necrodes littoralis l.(silphidae). *Forensic Science International*, 314:110407, 2020.

[2] Takaya Ikemoto and Kenji Takai. A new linearized formula for the law of total effective temperature and the evaluation of line-fitting methods with both variables subject to error. *Environmental Entomology*, 29(4):671–682, 2000.

[3] Ali Furkan Kalay. Uq beamerposter template. *Overleaf Poster Templates*, 2021.

[4] Szymon Matuszewski and Katarzyna Frątczak-Łagiewska. Size at emergence improves accuracy of age estimates in forensically-useful beetle creophilus maxillosus l.(staphylinidae). *Scientific reports*, 8(1):1–9, 2018.