a **b**

Supplementary material to:

*Modeling winter moth (*Operophtera brumata*) egg phenology: nonlinear effects of temperature and developmental stage on developmental rate*

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Table A1. Description of the experimental set-up: wild-caught females moths were allocated to one of four groups (A-D) and their eggs were split among eight or four experimental treatments. Each experimental treatment was exposed at a given transfer date to either colder (5 °C) or warmer (15 °C) temperature for a period of four weeks. Per each group, one control treatment was kept at 10 °C constant temperature.

Group	Weeks from the start of the experiment	Transfer date	Temp (°C)
A	1	1 st December	5
A	2	8 th December	5
B	3	15 th December	5
A	4	22 nd December	5
A	5	29 th December	5
B	6	5 th January	5
A	7	12 th January	5
A	8	19 th January	5
B	9	26 th January	5
A	10	2 nd February	5
C	1	1 st December	15
C	2	8 th December	15
D	3	15 th December	15
C	4	22 nd December	15
C	5	29 th December	15
D	6	5 th January	15
C	7	12 th January	15
C	8	19 th January	15
C	9	26 th January	15
C	10	2 nd February	15
A	eggs not transferred (*)	-	10
B	eggs not transferred (*)	-	10
C	eggs not transferred (*)	-	10
D	eggs not transferred (*)	-	10

(*)In control treatments eggs were kept at 10°C constant until egg hatching

Table A2. Number of temperature treatments of the experimental data-sets used in the optimization and validation procedure. a) Experimental data-set used to estimate the model parameters; b) experimental data-set and c) field data-set used to validate the models. The year during which the experiment was performed and the number and the type of temperature treatments used in each experiment is indicated. Sample size indicates the number of egg clutches (originated by different mothers) used. When the number of treatments is larger than 1, each egg clutch was split over more treatments (to a maximum of 8 treatments).

Experiment		Year	Number of temperature treatments	Sample size	Temperatures treatments
a)	1	2004	23	22	Constant artificial temperature treatments
	2	2009	7	38	
	3	2012	7	88	
	4	2000	3	70	Natural fluctuating temperature treatments (mimicking real years)
	5	2005	3	132	
	6	2010	3	91	
	7	2002	3	73	
	8	2003	3	59	
b)	9	2005	44	26	Constant artificial temperature treatments
	10	2007	24	11	
c)	11	2000	1	163	Natural fluctuating temperature treatments (mimicking real years)
	12	2001	1	109	
	13	2002	1	192	
	14	2003	1	175	
	15	2004	1	220	
	16	2005	1	521	
	17	2006	1	301	
	18	2007	1	158	
	19	2008	1	181	
	20	2009	1	442	
	21	2010	1	254	
	22	2011	1	276	
	23	2012	1	406	

Table A2. Analysis of total warmth sum at egg hatching (T_{sum}) for a long-term field study (2000-2012). Estimates, standard error, t values, p values and AIC are given for three separate linear models. AIC values of the full model (frost days + mean temperature) and the model including only mean temperature are comparable (difference ≤ 2), thus the simplest and most parsimonious model should be preferred. Number of frost days per year was calculated as the number of days, from the 1st of December till the 1st of April, with a minimum temperature equal or below 0 °C. Mean temperatures were calculated as daily mean for the period from the 15th of December till the 1st of April.

	estimate	std.error	t value	p	AIC
lm(warmth sum~ n frost days + mean temp)					
intercept	818.7	94.2	8.7	<0.0001	
number of frost days	-1.8	0.9	-1.9	0.08	
mean temperatures	44.6	12.9	3.5	<0.01	
					126.7
lm(warmth sum~ n frost days)					
intercept	113.7	29.5	38.6	<0.0001	
number of frost days	-4.7	0.7	-7.1	<0.0001	
					134.9
lm(warmth sum~ mean temp)					
intercept	645.9	32.6	19.8	<0.0001	
mean temperatures	66.2	7.1	9.4	<0.0001	
					128.8

Fig. A1. Sensitivity analysis of the seven parameters estimated in the developmental stage-dependent model. a) scaling factor; b) temperature threshold (°C); c) developmental threshold; d) developmental rate (day⁻¹) at reference temperature ; e) activation enthalpy (kJ mol⁻¹); f) enthalpy change (kJ mol⁻¹); g) reference temperature (°C). On the y-axis is the difference between the predicted egg hatching dates by the model when using the optimal parameter value and when varying the parameter value. Each parameter value was varied of ± 25 , 50 or 75 % with exception of b), c) and g) where biologically meaningful values were chosen. Note that in two cases the exact optimal parameter value is not used: c) developmental threshold=0.48; g) reference temperature= 13.8°C.

Fig. A2. Analysis of the relationship between predicted warmth sum at egg hatching and (a) number of frost days and (b) mean temperatures from a long-term field study (2000-2012). Black solid lines are the linear regression estimates. Warmth sum at hatching was calculated using the degree-day model for the period from the 15th of December till egg hatching. Temperature profiles used in the model were collected with temperature loggers. Number of frost days per year was calculated as the number of days, from the 1st of December till the 1st of April, with a minimum temperature equal or below 0 °C. Mean temperatures were calculated as daily mean for the period from the 15th of December till the 1st of April.