Acta Biotheoretica

Developmental models for estimating ecological responses to environmental variability: structural, parametric, and experimental issues

Julia L Moore, Justin V Remais*
*Department of Environmental Health, Rollins School of Public Health, Emory University, 1518 Clifton Rd Room 2023, Atlanta, GA 30322, USA. E-mail: justin.remais@emory.edu

Online Resource 1: Non-linear models

This supplementary file details several common non-linear models. Equations and parameter definitions are given in Table A1.1, and the results of fitting these models to experimental data are shown in Table A1.2 and Figure A1.1.

Table A1.1: Parameters for several non-linear developmental models

Parameter	Definition	Reference
Sharpe	$$\rho = \frac{Te^{\left[\left(\phi - (\Delta H_A^{\pm}/T)\right)/R\right]}}{1 + e^{\left[\left(\Delta S_L - (\Delta H_L/T)\right)/R\right]} + e^{\left[\left(\Delta S_H - (\Delta H_H/T)\right)/R\right]}}$$	Sharpe and DeMichele 1977
T	Absolute temperature (Kelvin)	
K	Boltzmann constant	
h	Planck's constant	
R	Gas constant	
ε_e	Relative enzyme concentration	
$\Delta H_A^{\pm}$	Enthalpy of activation	
ΔH_L	Difference in enthalpy of activation between first inactive and active enzyme states at equilibrium	
ΔH_H	Difference in enthalpy of activation between active and second inactive enzyme states at equilibrium	
$\Delta S_A^{\pm}$	Entropy of activation	
ΔS_L	Difference in entropy of activation between first inactive and active enzyme states at equilibrium	
ΔS_H	Difference in entropy of activation between active and second inactive enzyme states at equilibrium	
ϕ	Simplying parameter, equal to $\Delta S_A^{\pm} + \ln(K\varepsilon_e/h)$	
Logan	$$\rho = \psi \cdot \left(e^{rT} - e^{\left(rT_{\max} - (\delta_{\max} - T)/\Delta T\right)}\right)$$	Logan et al. 1976
T	Air temperature – minimum temperature threshold	
δ_{max}	Lethal maximum temperature	
ΔT	Difference between maximum and optimal temperatures	
ψ	Developmental rate at a given base temperature above the minimum developmental temperature	
r	Rate increase up to optimal temperature	
Holling	$$\rho = \psi \cdot \left(\frac{T^2}{T^2 + D^2} - e^{\left((\delta_{\max} - T)/\Delta T\right)}\right)$$	Hilbert and Logan 1983
T	Air temperature – minimum temperature threshold	
δ_{max}	Lethal maximum temperature	
ΔT	Difference between maximum and optimal temperatures	
ψ	Developmental rate at a given base temperature above the minimum developmental temperature	
D	Fit parameter	
Lactin	$$\rho = e^{rT} - e^{\left(rT_{\max} - (\delta_{\max} - T)/\Delta T\right)} + \lambda$$	Lactin et al. 1995
T	Air temperature – minimum temperature threshold	
δ_{max}	Lethal maximum temperature	
ΔT	Difference between maximum and optimal temperatures	
r	Rate increase up to optimal temperature	
λ	Fit parameter	

Table A1.2: Goodness of fit of models to empirical *N. bisignatus* developmental data, using two metrics of model fit: R^2, the coefficient of determination or nonlinear regression, for linear or nonlinear models, respectively, and RSS, the residual sum of squares. High R^2 and low RSS indicate good model fit. Model fit analysis conducted by Kontodimas et al. (2004).

Model	R^2	RSS ($x10^{-6}$)
Linear	0.9965	1.152
Sharpe	0.9998	0.8661
Logan	0.9983	0.6503
Holling	0.9985	5.7955
Lactin	0.9997	1.0767

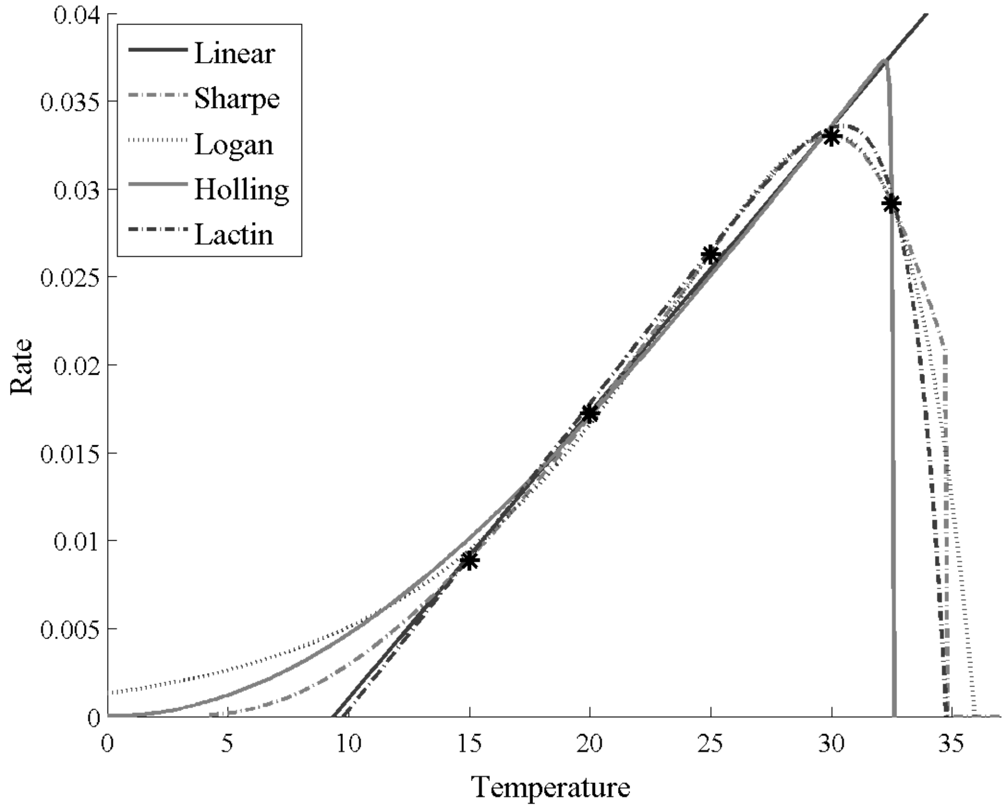

Figure A1.1 Representative plots of the linear and several non-linear devepmental models, with points indicating empirical developmental data of *N. bisignatus*. All parameter values and data were obtained from Kontodimas et al. (2004). Additionally, Kontodimas et al. (2004) assessed the goodness of fit for these models using two metrics (R^2 and RSS). Their results are shown in Table A1.2.

References

Hilbert D, Logan J (1983) Empirical model of nymphal development for the migratory grasshopper, *Melanoplus-sanguinipes* (Orthoptera, Acrididae). Environ Entomol 12(1):1–5

Kontodimas D, Eliopoulos P, Stathas G, Economou L (2004) Comparative temperature-dependent development of *Nephus includens* and *Nephus bisignatus* preying on *Planococcus citri*: Evaluation of a linear and various non-linear models using specific criteria. Environ Entomol 33(1):1–11

Lactin D, Holliday N, Johnson D, Craigen R (1995) Improved rate model of temperature-dependent development by arthropods. Environ Entomol 24(1):68–75

Logan J, Wollkind D, Hoyt S, Tanigoshi L (1976) An analytic model for description of temperature-dependent rate phenomena in arthropods. Environ Entomol 5(6):1133–1140

Sharpe P, DeMichele D (1977) Reaction-kinetics of poikilotherm development. J Theor Biol 64(4):649–670