Fitting Models to Data in Ecology and Evolution

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Mechanistic vs. Phenomenological models

What does "modelling data" mean to you?

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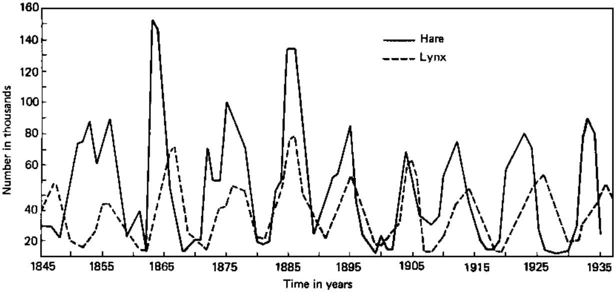
Mechanistic vs. Phenomenological model fitting



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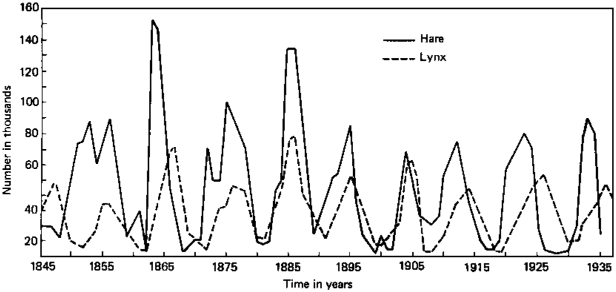

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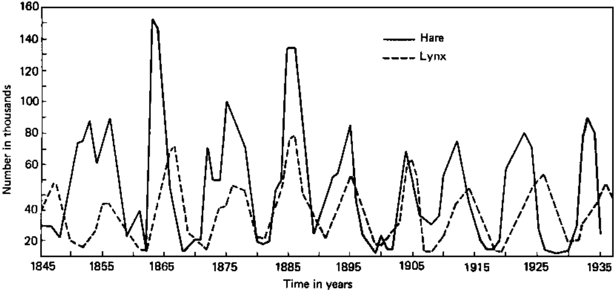

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- **Phenomenological model**: The Lynx and Hare Cycles have a significant asynchrony (period shift) of xx years

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- *Ultimately, successful, EMPIRICALLY-GROUNDED mechanistic models are the best path towards a THEORY in any scientific discipline (including ecology and evolution)*

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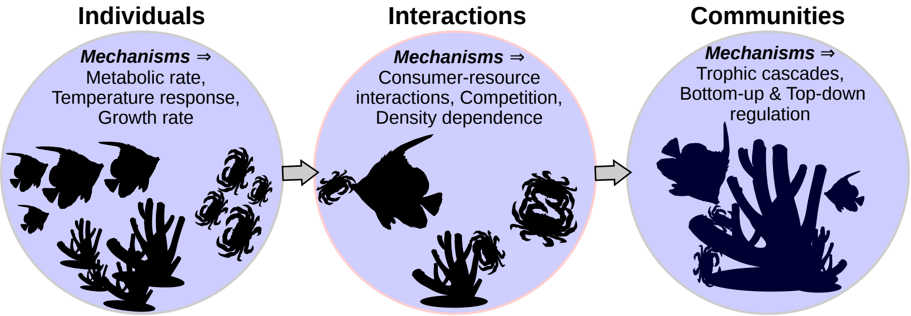

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  - For example, disease outbreaks: Do we really need to care about the underlying mechanisms if we can predict a future event using phenomenological modelling (e.g., Machine-learning of time series patterns)?

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- But is this REALLY mechanistic? What are r and k really?

Example of a fundamental mechanism: metabolic rate

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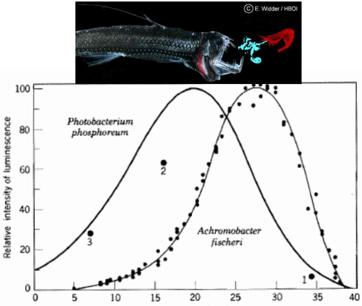

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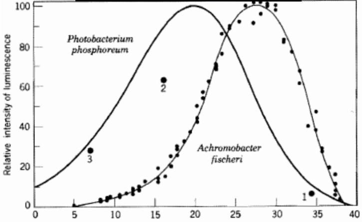

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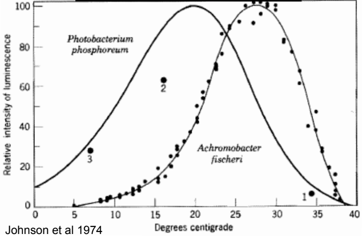

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- Surely there is more to thermal responses?
- *What about alternative models?*

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MODELS: HOW TO BUILD THEM?

- It's an art, takes practice
- Build models one mechanism at a time — in biology, it means start at the right level of organization!
- Always consider an alternative that is more parsimonious, even if it is phenomenological (the thermal performance curves example: Sharpe-Schoolfield, Briere, or Polynomial?)!
- For example, the Boltzmann-Arrhenius model is a good first try describe and uncover mechanisms underlying individual level rates (e.g., vector fecundity or development rate)
- The next step would be to include species interactions with temperature dependence of individuals (or go in an evolutionary direction)

Fitting models to data

Multiple ways to do it:

- Least Squares methods
  - Linear
  - Non-linear
- Likelihood-based methods
  - Maximum Likelihood Estimation (MLE)
  - Bayesian
- Artificial intelligence and Machine learning
  - Focus in on maximizing ability to discover pattern and predict at the cost of mechanistic insights

METHODS YOU CAN USE IN THE MINIPROJECT

- Least squares: along with Linear Model fitting, Non-linear Least Squares (NLLS) fitting is a particularly versatile and powerful approach because many mechanisms in biology and inherently non-linear

- MLE/Bayesian methods: more robust if you are able to calculate the likelihood function — you will learn this in Term 2, so not recommended

- AI/machine Learning: most versatile for large amounts of noisy data — you will be introduced to these at the end of term 2, so definitely not recommended

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- This is an advance over the traditional “null hypothesis” approach in Biology
- Necessary for developing the advancement of Biology from from an observational and axiomatic discipline to one with general theories.
- Necessary for understanding the mechanisms underlying biological patterns/phenomena

READINGS

- Levins, R. (1966) The strategy of model building in population biology. Am. Sci. 54, 421–431.
- Johnson, J. B. & Omland, K. S. (2004) Model selection in ecology and evolution. Trends Ecol. Evol. 19, 101–108.
- Bolker, B. M. et al. (2013) Strategies for fitting nonlinear ecological models in R, AD Model Builder, and BUGS. Methods Ecol. Evol. 4, 501–512 .

- Some illustrative examples of (non-linear) model fitting to ecological/evolutionary data `https://groups.nceas.ucsb.edu/non-linear-modeling/projects`
- Additional readings in the git repository