Studying Evolutionary Ecology 3: Mathematical Models

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Biol 417: Evolutionary Ecology

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Review

Review

So far we have covered experimentation and comparative methods as tools for studying evolutionary ecology.

Those approaches have proven highly informative, but there is an elephant in the room that limits their flexibility.

Experimentation and comparative methods rely on **observed** outcomes. What happens if we want to study the evolutionary consequences of conditions that haven't yet occurred in the Earth's history?

Today we will learn about mathematical and computational approaches for studying evolutionary ecology.

What is modelling?

Hypothesis vs. model

Hypothesis: An idea, supposition, or otherwise unproven theory used as the basis for further investigation.

Model: A generalised description of some phenomenon.

$$\text{Model} \neq \text{Hypothesis}$$

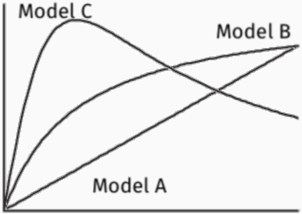
One hypothesis, many models

A single hypothesis can be represented by multiple models.

Hypothesis: Number of offspring R increases with body size M

Models:

- $R = aM$ Model A: Number of offspring is proportional to mass
- $R = \frac{aM}{1+bM}$ Model B: Number of offspring saturates as mass increases
- $R = aMe^{-bM}$ Model C: Number of offspring first increases and then decreases as mass increases



Source: Hilborn & Mangel (1997)

General points about modelling

The equation of a model is a very specific expression of the hypothesis. In other words, models help us clarify verbal descriptions of nature and the mechanisms involved.

Once we've transformed a verbal hypothesis into a mathematical model, the mathematical analysis maps the consequences of the assumptions.

This help us understand which parameters and processes are important, and which ones are not.

No model is correct

No model is correct … but some models are useful.

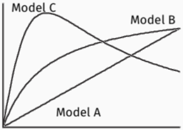
Components of a model

Model Components

Models are comprised of two main components:

Deterministic part: Describes the shape of the relationship (i.e., your hypothesis).

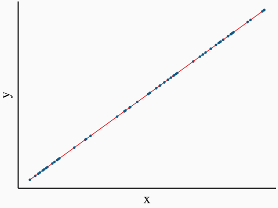
- Model A: $R = aM$
- Model B: $R = \frac{aM}{1+bM}$
- Model C: $R = aMe^{-bM}$



Stochastic part: Describes the randomness of the process (i.e., the noise in a system).

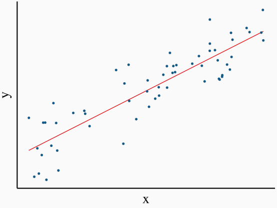
Deterministic models

- No components are uncertain
- Outcome is always the same
- $y_i = \beta_0 + \beta_1 x_i$



Stochastic models

- Some components are uncertain and characterised by probability distributions
- Outcome is variable
- $y_i = \beta_0 + \beta_1 x_i + \varepsilon_i$



Modelling in Evolutionary Ecology

Consider a population of individuals competing for resources, with two possible phenotypes: Doves (never fight) Hawks (always fight).

Questions: Which strategy is optimal? What proportions of the different strategies should we expect to see in a population?

Assumptions:

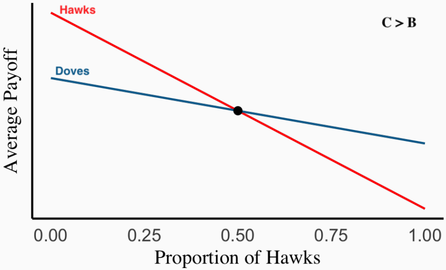
- When two doves meet, they will simply share the resource and the payoff to each dove is $\frac{B}{2}$.
- When a hawk meets a doves, the hawk always takes the resource and the payoffs are: ‘hawk’ $\rightarrow B$, dove is $\rightarrow 0$.
- When two hawks meet, they fight and the average payoff to each hawk is $\frac{B-C}{2}$.

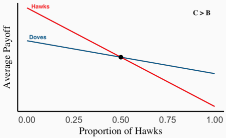
Game theory: Hawk-Dove cont.

	Hawk	**Dove**
Hawk	$\frac{B-C}{2}, \frac{B-C}{2}$	B, 0
Dove	B, 0	$\frac{B}{2}, \frac{B}{2}$

The optimal strategy will depend on who you are competing against, and the B and C.

We can calculate mean individual payoffs depending on the composition of the population, B, and C.





The optimal strategy will depend on who you are competing against, and the B and C.

In a population of doves, no individual ever receives the full resource, B, so this system is always open to exploitation.

In a population of hawks, all of the animals suffer the cost of competing, C. If $C > B$, hawks costs outweigh benefits on average and doves can persist.

The ESS for the proportion of hawks and doves in a population ultimately depends on B and C.

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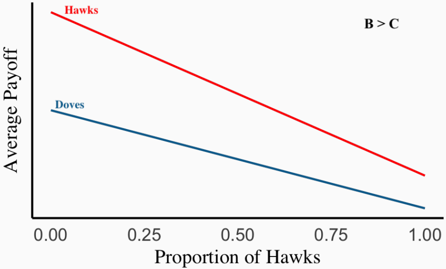
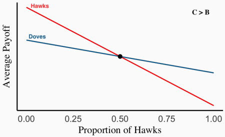
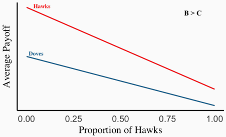
When $B > C$, doves are never favoured on average.



Game theory: Hawk-Dove cont.

	Hawk	Dove
Hawk	$\frac{B-C}{2}$, $\frac{B-C}{2}$	B, 0
Dove	B, 0	$\frac{B}{2}$, $\frac{B}{2}$





Based on this simple model of competition we were able to understand what resources are worth fighting for.

It also lets us predict what proportions of phenotypes might be expected in any given population.

We were able to do this without any empirical data.

Take home messages

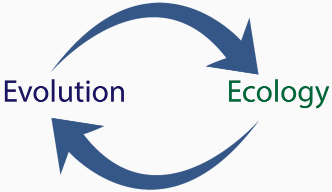
Models force us to be explicit about verbal hypotheses and are themselves are tests of whether verbal descriptions are sound.

Models have the ability to advance the field by introducing new predictions.

Models can outline the parameter space in which an evolutionary phenomenon can occur (e.g., hawks/doves).

Models allow us to circumvent real-world complications in order to tackle virtually any problem.

Take home messages cont.



	Dynamic	Static
Proximate (How)	Ontogeny (development)	Mechanism (causation)
Ultimate (Why)	Phylogeny (evolution)	Function (adaptation)

References

Hilborn, R. & Mangel, M. (1997). *The ecological detective: confronting models with data*. vol. 28. Princeton University Press.