Individual-based modelling of a predator's hawk-dove strategy in a closed bottle

Matthew Malishev, School of Botany, University of Melbourne, Victoria, Australia

Bob W. Kooi; Sebastiaan A. L. M. Kooijman
Faculty of Biology, Vrije Universiteit, Amsterdam, The Netherlands

1COIN
1PLAY
♥X3
008500
PRESS
START

Select trait

Hawk (ρ)

Dove ($1-\rho$)

Abilities

- Always beat dove
- If competing with a hawk, incur a cost C, and a 0.5 probability of gaining prey G.
- Always share prey with another dove.

Aim

Find prey and grow in biomass. You win by using **individual-based modelling (IBM)** to replicate a stochastic predator-prey model [1].

But watch out for competitors! They follow classic **game theory** rules for **competition** [2] (Figure 1).

The journey of game dynamics on the fast time scale

$$\begin{pmatrix} \frac{(G-C)}{2} & G \\ 0 & \frac{G}{2} \end{pmatrix}$$

Figure 1. Game theory payoff matrix. How do you fare against your competitor?

LEVEL 1

Time 310

*Our story starts with our hero in a **closed predator-prey food chain** ...*

As a predator, you switch between three behavioural states:

searching S
handling H
and fighting F

These occur on the **fast time scale.** The energetic costs and gains of handling prey follow a mechanistic framework for individual food uptake underpinned by the **Dynamic Energy Budget (DEB) theory** [3].

But beware! Your prey intake rate depends on handling time and the number of prey in the system. This is the **Holling Type II functional response** [4] (Fig 2).

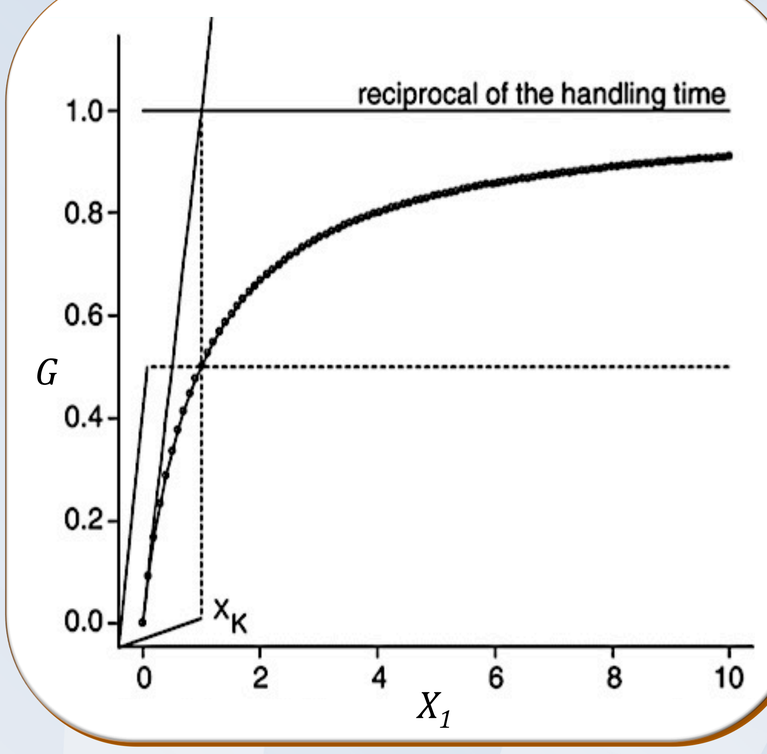

Figure 2. Beware of the Holling Type II functional response. Your prey X_1 intake is limited by its half saturation coefficient X_K [5].

LEVEL 2 Fight to grow

Competition is fierce. By now, some predators are doing better than others and the demography of the predator level is changing. Can our hero survive?

Your metabolic products, like **assimilation** of prey items, **maintenance** of your body's cells, and eventually **growth** are instantaneously recycled in the food chain. Thus, **energy and mass is conserved over continuous time,** following the DEB theory. You now begin **growing in biomass on the slow time scale.**

LEVEL 3

The wrath of the replicator dynamics

Our hero has reached the final stage of modelling the system using IBM.

Suddenly, disaster strikes! The separate time scales means the proportion of fighting predators doesn't link to the population level as a trait!

You need to find an evolutionary stable strategy using the two time scales. Quick, use **replicator dynamics** to link the frequency of the game dynamics to the predator population level!

This finds an equilibrium* between gain G and your trait ρ based on the size of the predator population, X_2 (Fig. 3).

$$\rho^* = \begin{cases} \frac{G}{C} & \text{if } G < C \\ 1 & \text{if } G > C \end{cases}$$

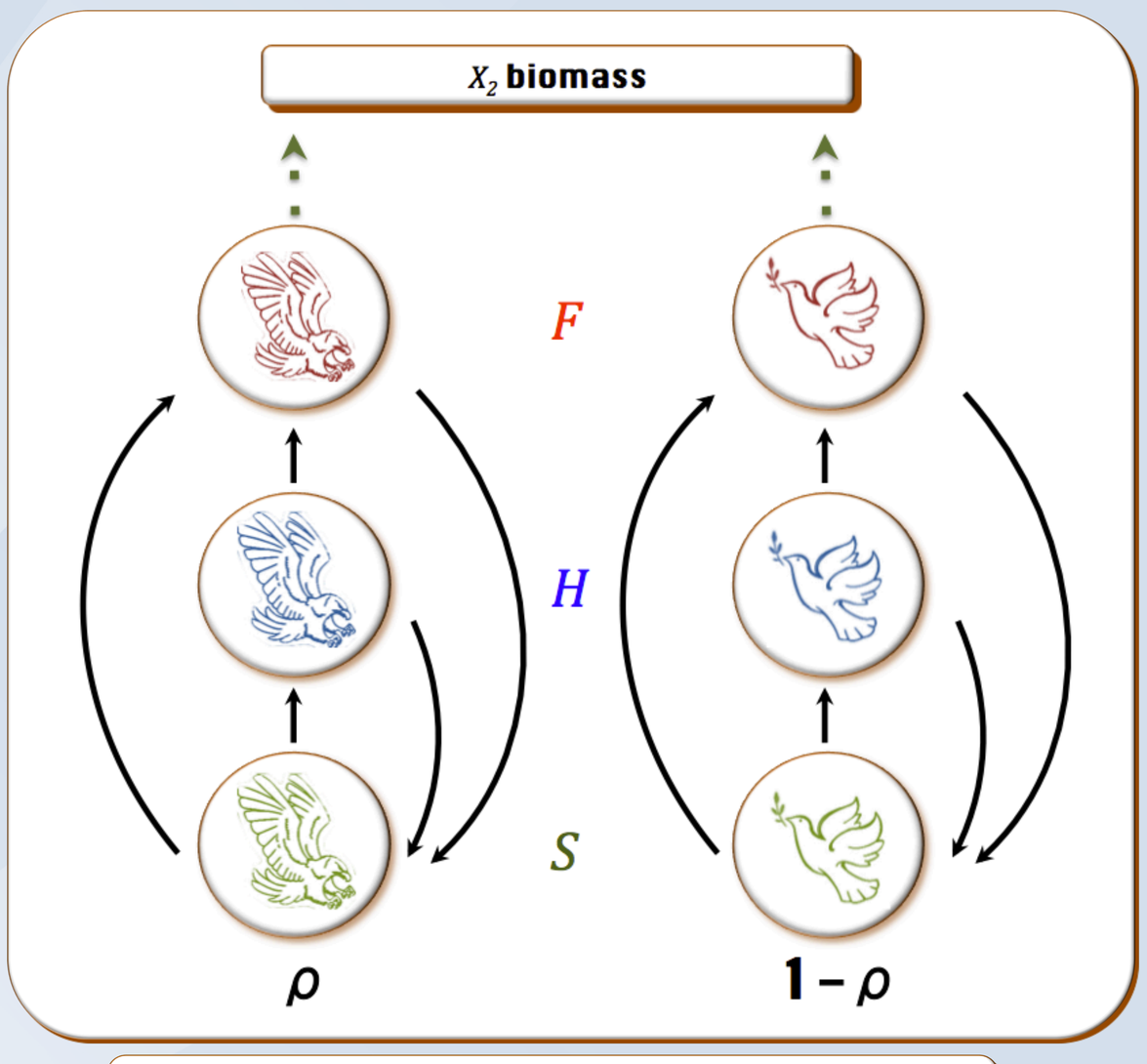

Figure 3. Fluxes of predators switching between behavioural states. Replicator dynamics link the fast time scale game (black arrows) with slow time scale growth (green arrows) [6].

YOU WIN!!!

You found enough prey to survive under a stabilised food chain with two time scales and your energy and mass was modelled using energetics theory.

You can now use IBM to model this system using a finite number of predators. This favours the **first principles approach of individual energetics** and is useful for **bottom-up analysis** of the predator-prey model.

TOP SCORE
900000100

matthew.malishev@gmail.com

HALL OF FAME

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