Link to publication

University of Bath

Alternative formats
If you require this document in an alternative format, please contact:
openaccess@bath.ac.uk

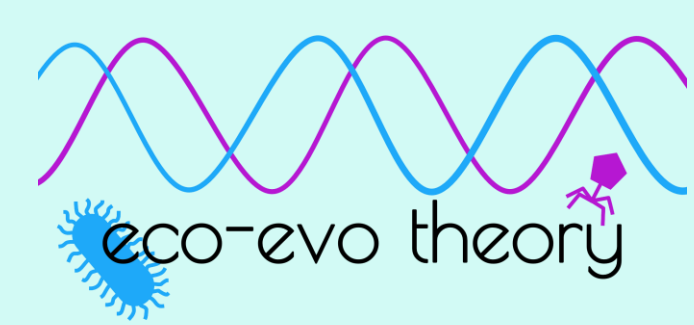# Trade-offs and the evolution of age-specific resistance to infectious disease

Lydia Buckingham[1,2], Emily Bruns[3], Ben Ashby[1,2,4]

1. Department of Mathematical Sciences, University of Bath, Bath. UK
2. Milner Centre for Evolution, University of Bath, Bath. UK
3. Department of Biology, University of Maryland, College Park, Maryland. US.
4. Department of Mathematics, Simon Fraser University, Burnaby. Canada

eco-evo theory

UNIVERSITY OF BATH

Sometimes adults are more resistant to disease than juveniles.

Sometimes juveniles are more resistant to disease than adults.
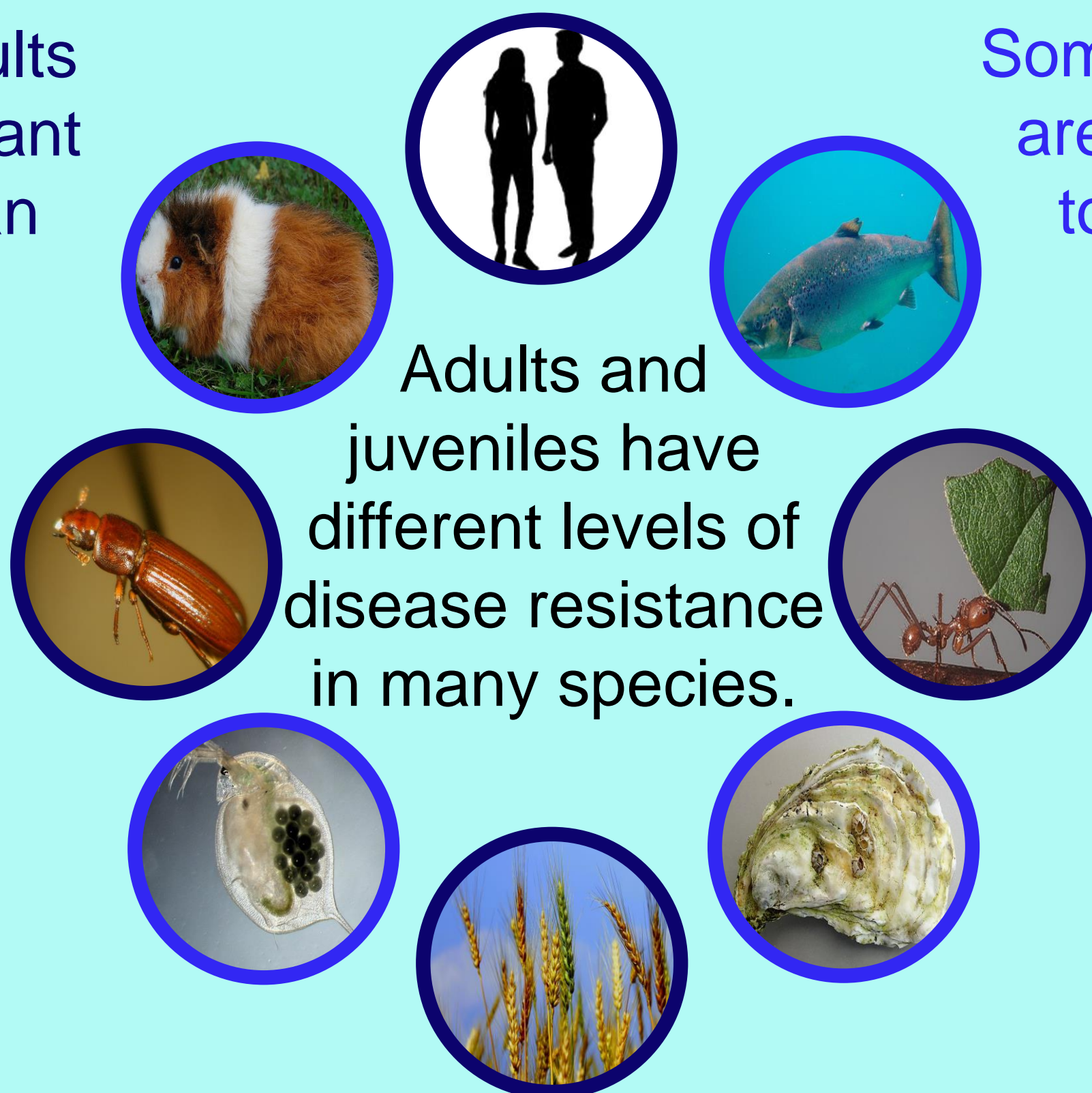
Adults and juveniles have different levels of disease resistance in many species.

Why are adults sometimes, but not always, more resistant to disease than juveniles?

Variation in the resource requirements of different organisms at different life stages may provide an explanation.

Allocating resources to reproduction (a), maturation (g) or juvenile mortality (b_J) may reduce juvenile resistance (r_J).

Allocating resources to reproduction (a) or adult mortality (b_A) may reduce adult resistance (r_A).

We model these relationships using trade-off functions.

Example trade-off

growth rate

resistance

maturation rate — none, resistance, full
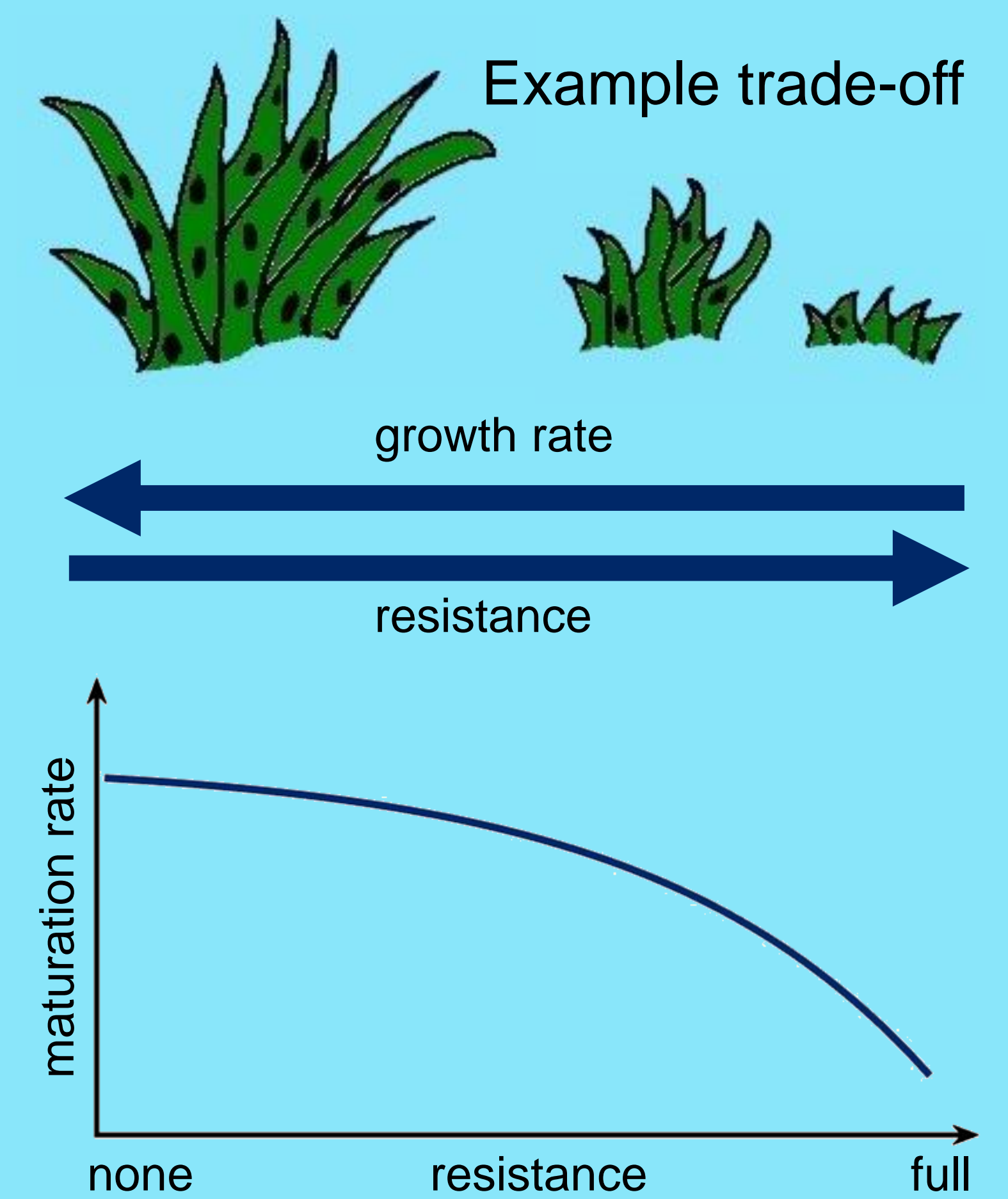
We describe these ecological interactions using the following system of ODEs:

$$\frac{dS_J}{dt} = a(1 - qN)(S_A + fI_A) - (b_J + g + \lambda_J)S_J$$

$$\frac{dS_A}{dt} = gS_J - (b_A + \lambda_A)S_A$$

$$\frac{dI_J}{dt} = \lambda_J S_J - (b_J + g + \alpha)I_J$$

$$\frac{dI_A}{dt} = gI_J + \lambda_A S_A - (b_A + \alpha)I_A$$

The juvenile and adult resistance traits are allowed to evolve independently between zero and one.

We use adaptive dynamics (evolutionary invasion analysis) and simulations to determine the evolutionary dynamics.

Consider a host-pathogen system with these ecological dynamics:

- q is density dependence
- f is relative reproduction of infected hosts
- S_J is density of susceptible juveniles
- S_A is density of susceptible adults
- I_J is density of infected juveniles
- I_A is density of infected adults
- N is total host density
- $\lambda_J \propto (1 - r_J)(I_J + I_A)$ is force of infection on juveniles
- $\lambda_A \propto (1 - r_A)(I_J + I_A)$ is force of infection on adults
- α is disease-induced mortality

$a(1 - qN)(S_A + fI_A)$ Reproduction

S_J — $b_J S_J$ Mortality — gS_J Maturation — S_A — $b_A S_A$ Mortality

$\lambda_J S_J$ Infection — $\lambda_A S_A$ Infection

I_J — $b_J I_J$ Mortality — gI_J Maturation — I_A — $b_A I_A$ Mortality

αI_J Mortality — αI_A Mortality

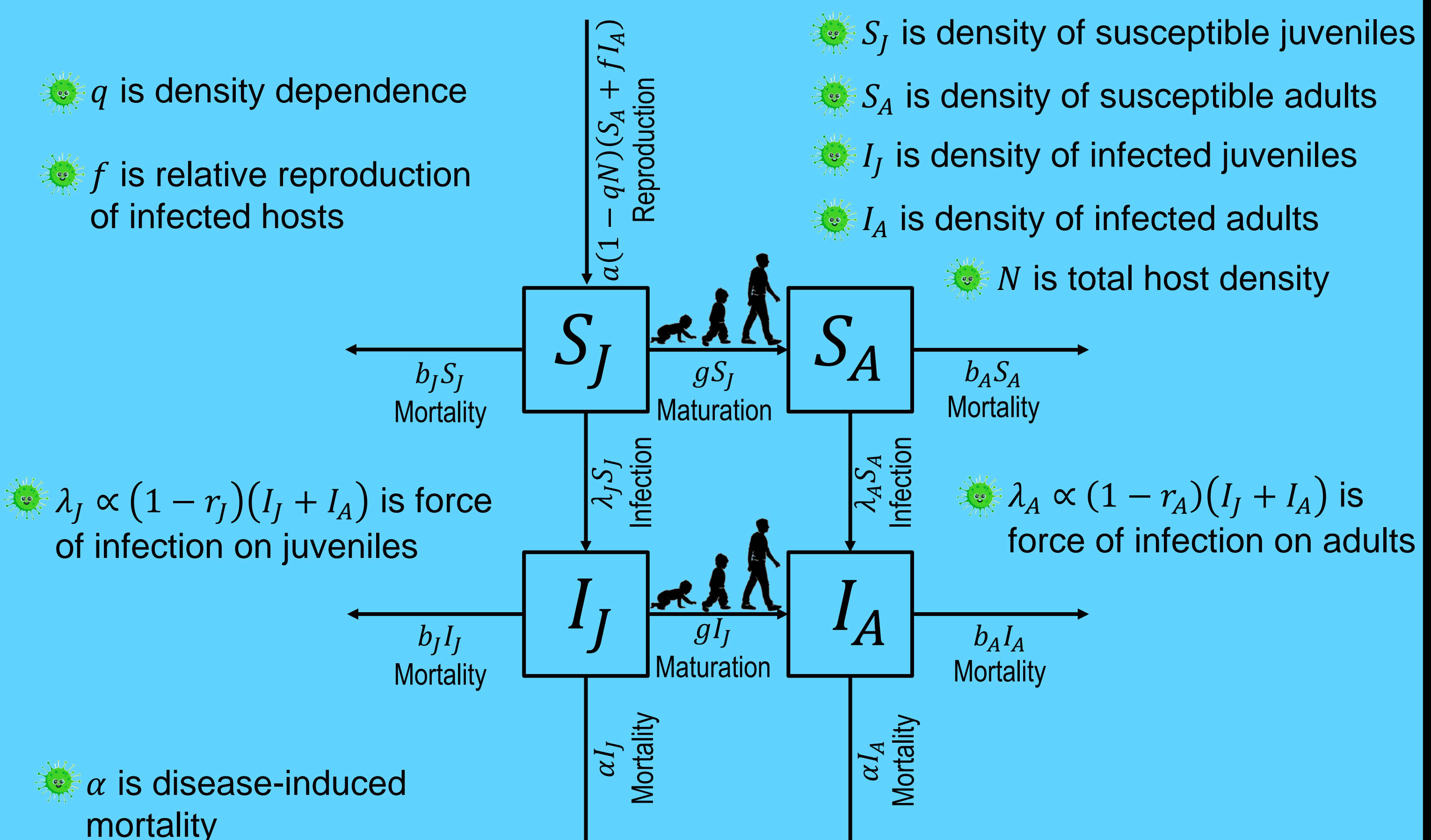We consider six different combinations of juvenile and adult resistance trade-offs.

For each combination, we calculate the difference between juvenile and adult resistance for many parameter sets. The box plots show the distributions of these differences.

Change in resistance (from juvenile to adult)
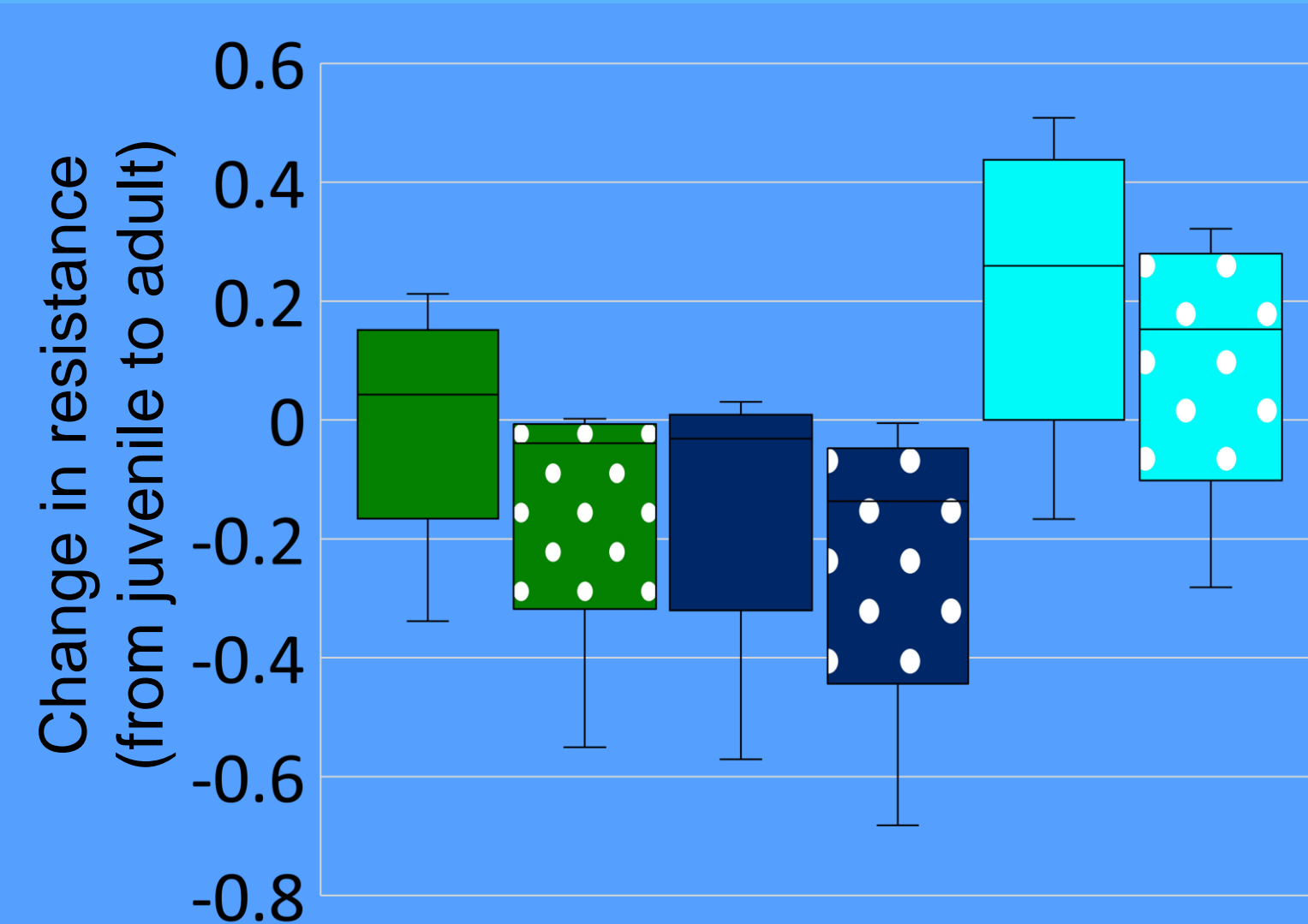
- Juvenile resistance trade-off with maturation
- Juvenile resistance trade-off with mortality
- Juvenile resistance trade-off with reproduction
- Adult resistance trade-off with mortality
- Adult resistance trade-off with reproduction

Juvenile resistance is generally higher than adult resistance when juvenile resistance trades off with reproduction but adult resistance is generally higher than juvenile resistance in all other cases.

Trade-offs between juvenile resistance and adult reproduction are inherently more costly than other trade-offs (e.g. with maturation or mortality).

Differences in the costs of resistance may therefore help to explain why adults are sometimes, but not always, more resistant to disease than juveniles.

References

Images are subject to Creative Commons Share Alike Licenses and are attributed to Hans-Petter Field (salmon), Peter Traub (ant), Shree Krishna Dhital (wheat), Dieter Ebert (Daphnia magna), Robelo Marques (humans ageing) or else are anonymous.

Contact

Email: ljb74@bath.ac.uk
LinkedIn: