Schisto IBM

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Contents

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Model from Civitello et al 2018 Bioenergetic theory predicts infection dynamics of human schistosomes in intermediate host snails across ecological gradients

Overview

IBM of snail and schistosome ecology, including resources and environmental temperature, driven by energetic consequences.

Population model of individual hosts (snails) and parasites (schistosomes) in a lake system. Host and parasite population sizes and production of different parasite life stages are driven by a population model. Parasites are released into the habitat according to reproduction rules of a full energy and mass budget model based on Dynamic Energy Budget (DEB) theory. Hosts feed on resource patches in the habitat and are exposed to schistosomes depending on the type of resource patch they feed on.

The host population is size and age structured, where parasite loading varies depending on the biomass of the host. Host biomass, including energy reserves, maintenance, and reproductive potential, is modelling through a DEB model.

The energetics model determines the intake and production of parasites. The simulation runs over a year and emulates a lake system in Kenya where schistosomes are found.

The energy reserves, somatic maintenance, and growth of hosts. The reproductive capacity of hosts is the parasite biomass prodcuted.

Environment

Resources

$$\frac{dR}{dt} = r\left(1 - \frac{R}{K}\right)R - \sum -i_M L^2 f_H$$

$\sum -i_M L^2 f_H$ = feeding by snails

Miracidia

$$\frac{dM}{dt} = M(t) - \sum uptake - death$$

$M(t)$ = miracidia in environment
$\sum uptake$ = infection of hosts by miracidia. **Not a DEB parameter**

Cercariae

$$\frac{dC}{dt} = \sum \frac{dRp}{dt} - death$$

$\sum \frac{dRp}{dt}$ = cumulative release of cercariae (parasite reproduction)

Individual

Host

Host length

$$\frac{dL}{dt} = \frac{gY_{VE}}{3\chi} \cdot \left(\frac{\kappa^* a_M e - (m_V + m_R E_M \delta)\chi L}{e+g} \right)$$

Host reserve

$$\frac{de}{dt} = (f_H - e)\frac{a_M}{\chi E_M L} - p\left(\frac{i_{PM} f_P}{E_M}\right)$$

Host development (maturity)

$$\frac{dD}{dt} = \begin{cases} \text{if } D < D_R, & (1-\kappa^*)C - m_D D \\ \text{if } D D_R, & 0 \end{cases}$$

Host reproduction

$$\frac{dR_H}{dt} = \begin{cases} \text{if } D < D_R, & 0 \\ \text{if } D D_R, & (1-\kappa^*)C - m_D D \end{cases}$$

Parasite

Parasite biomass (growth)

$$\frac{dP}{dt} = P(Y_{PE} i_{PM} f_P (1 - r_P) - m_P)$$

Parasite reproduction

$$\frac{dR_P}{dt} = \gamma_{RP} Y_{PE} i_{PM} f_P r_P$$

Damage density

$$\frac{d\delta}{dt} = \frac{\Theta}{\chi L^3} \cdot \frac{dR_P}{dt} + k_R(1-e) - k_R\delta - \frac{3\delta}{L} \cdot \frac{dL}{dt}$$

$\frac{3\delta}{L} \cdot \frac{dL}{dt}$ = growth dilution. Growth of host reduces damage density
$\frac{\Theta}{\chi L^3}$ = damage intensity
k_R = damage repair rate (via reserve depletion)

Cumulative hazard for host

$$\frac{dH}{dt} = h_b + h_\delta \ max(\delta - \delta_0,\ 0)$$

δ_0 = linear damage density function
h_b = background hazard rate
h_δ = hazard coefficient

References

Civitello et al 2018 Bioenergetic theory predicts infection dynamics of human schistosomes in intermediate host snails across ecological gradients