The Abdus Salam International Centre for Theoretical Physics

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School on Modelling Tools and Capacity Building in Climate and Public Health

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Longitudinal modelling of helminth infections

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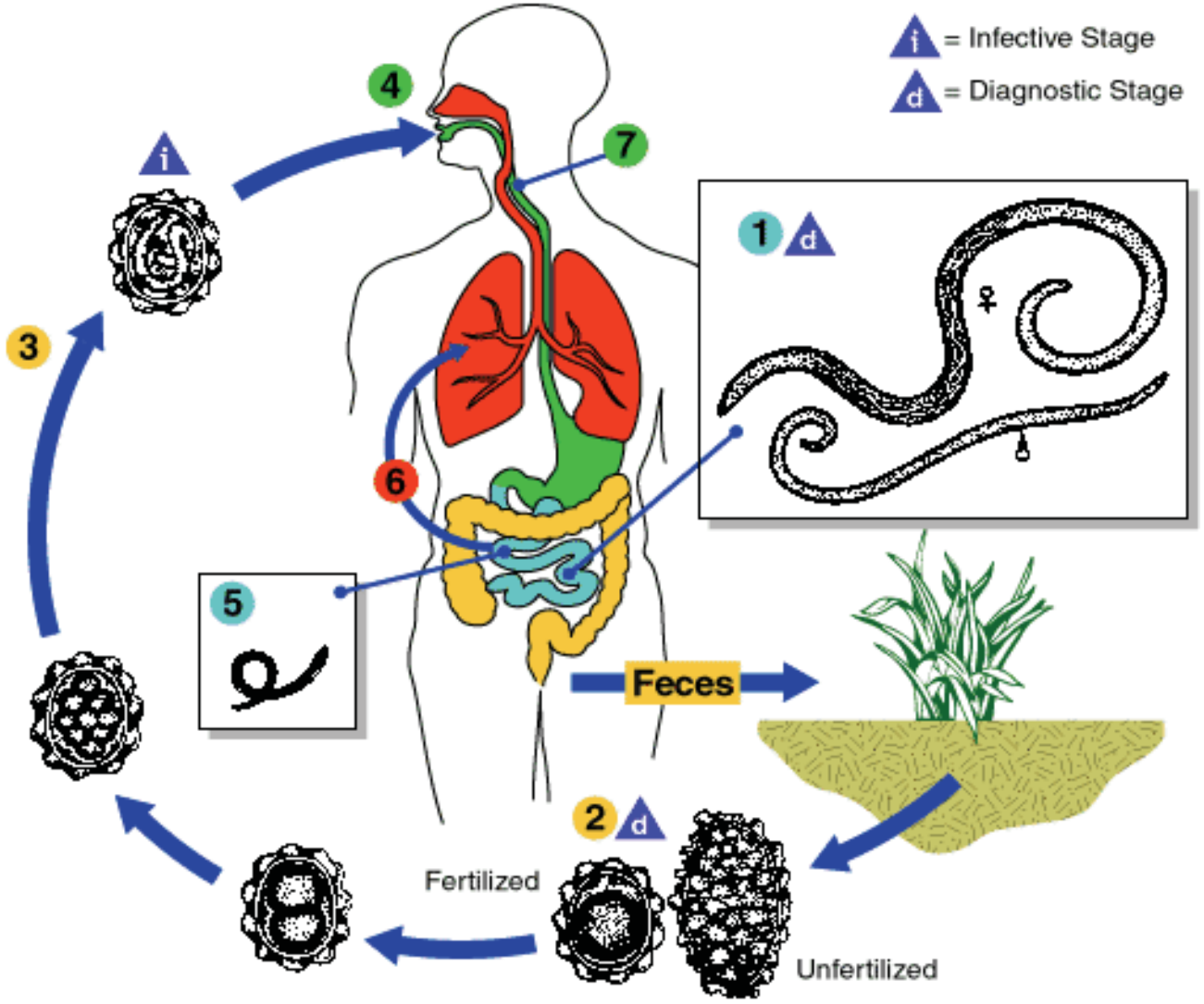
Longitudinal modelling of helminth infections

Direct life cycle parasites

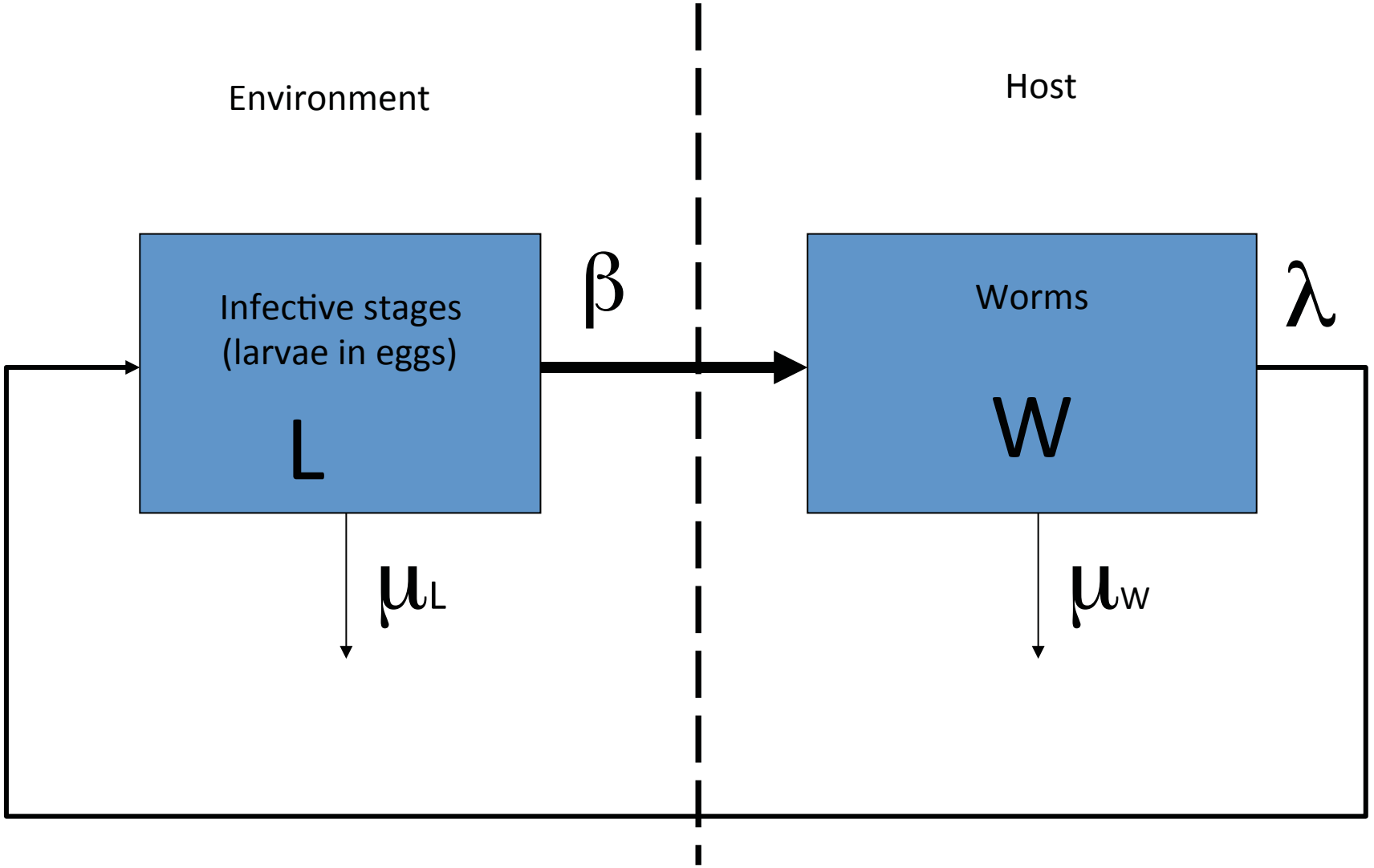
- *Ascaris lumbricoides*
- *Trichuris trichiura*
- Hookworms (*Ancylostoma duodenale*, *Necator americanus*)

Each infection has a free living stage affected by environmental conditions

Life cycle of Ascaris



Compartmental model of Ascaris life cycle



Basic *Ascaris* life-cycle dynamics

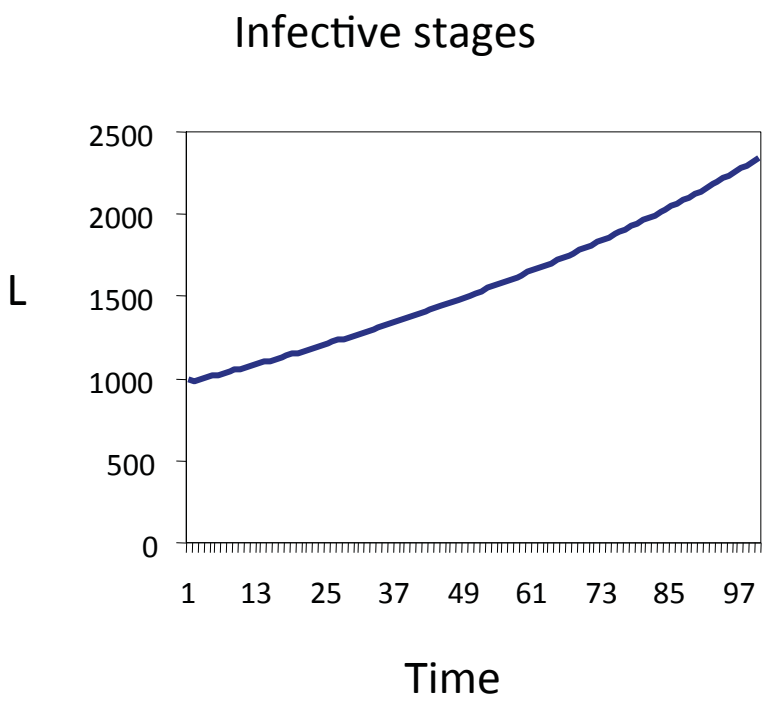
Rate of change of adult worm population

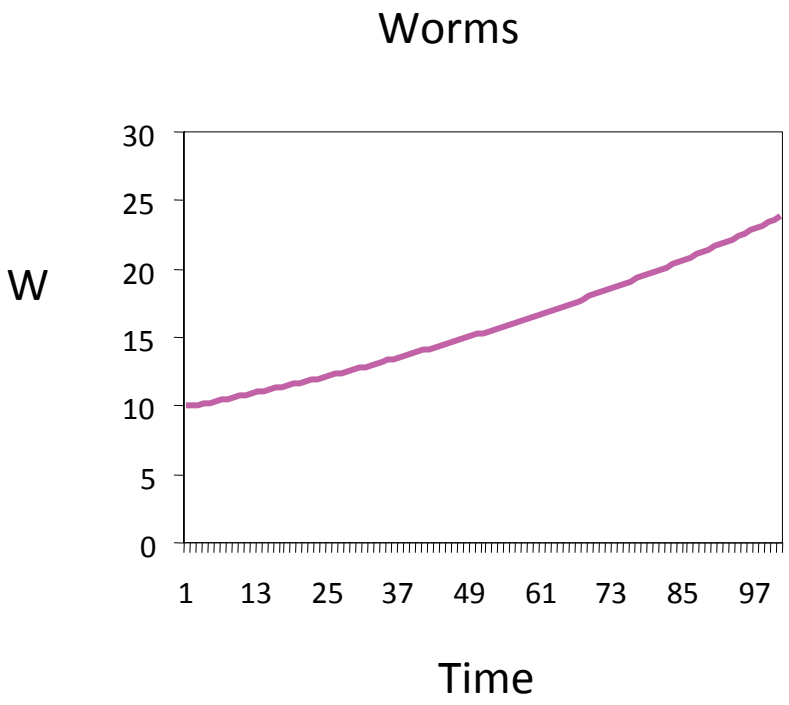
$$\frac{dW}{dt} = \beta L - \mu_w W$$

Rate of change of infective population

$$\frac{dL}{dt} = \lambda W - \beta L - \mu_L L$$

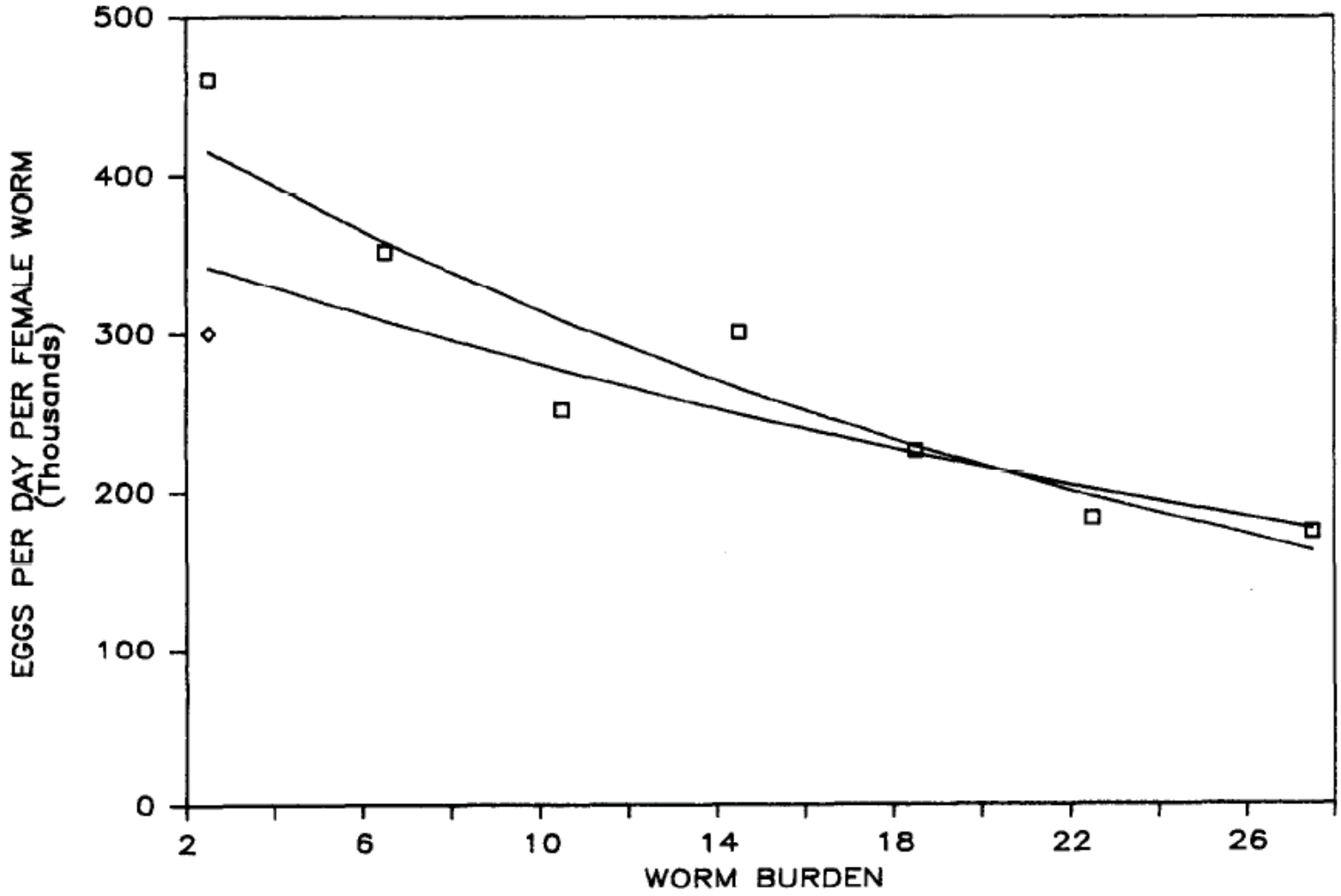
Growth curves in the absence of density dependence





Each population will continue to grow indefinitely due to a lack of constraints

A. Lumbricoides density dependent fecundity



Haswell Elkins et al 1986 TRSTMH

Density dependence

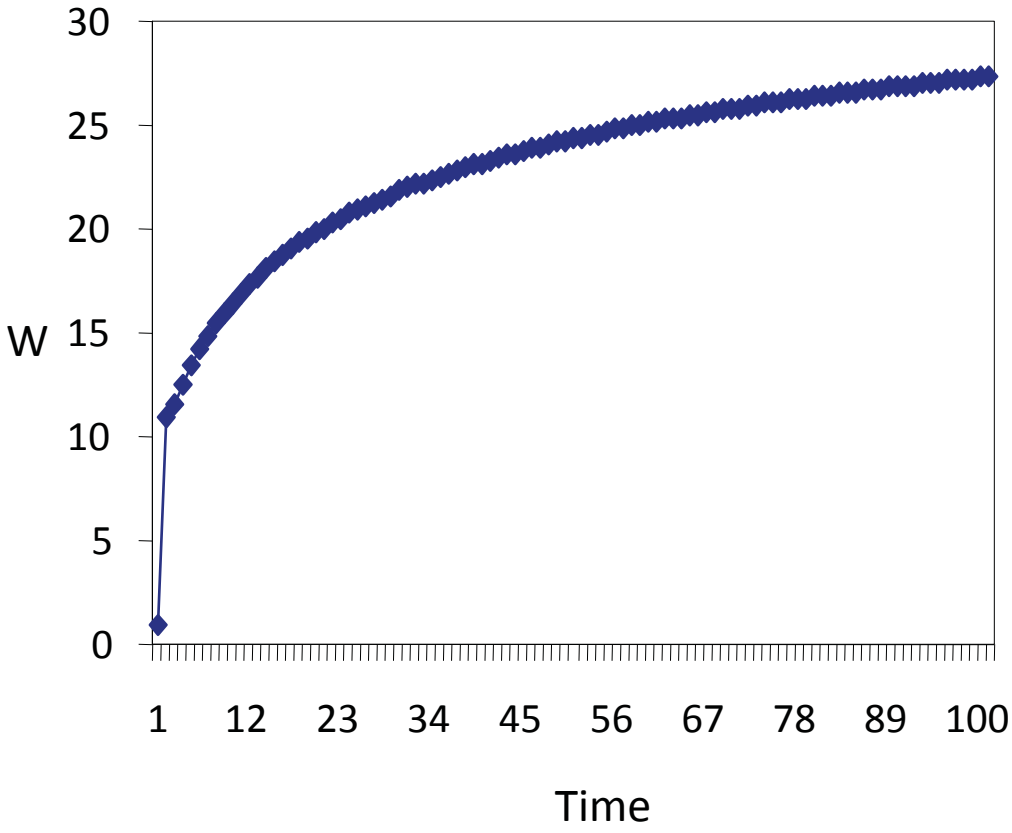
The reproductive potential of each worm-pair is limited by the average number of worms in the host:

$$f = \lambda e^{-\gamma W}$$

Where:

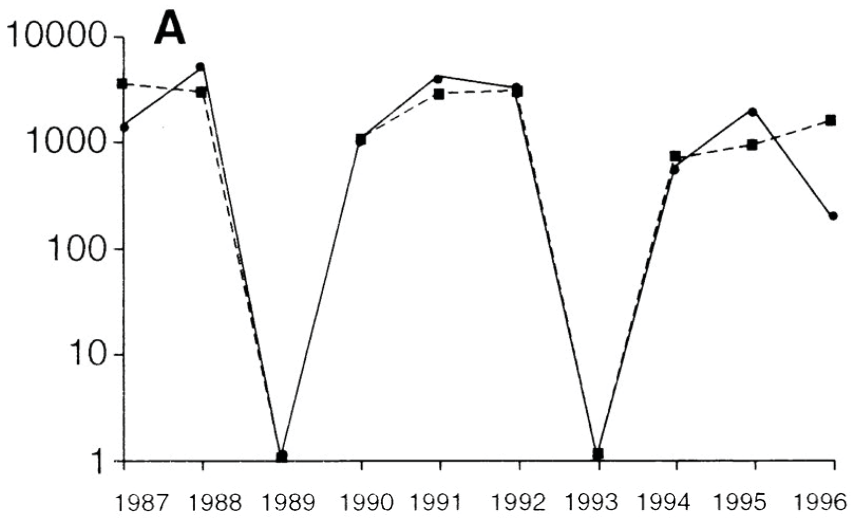
f = number of eggs produced by each worm-pair

γ = density dependence parameter

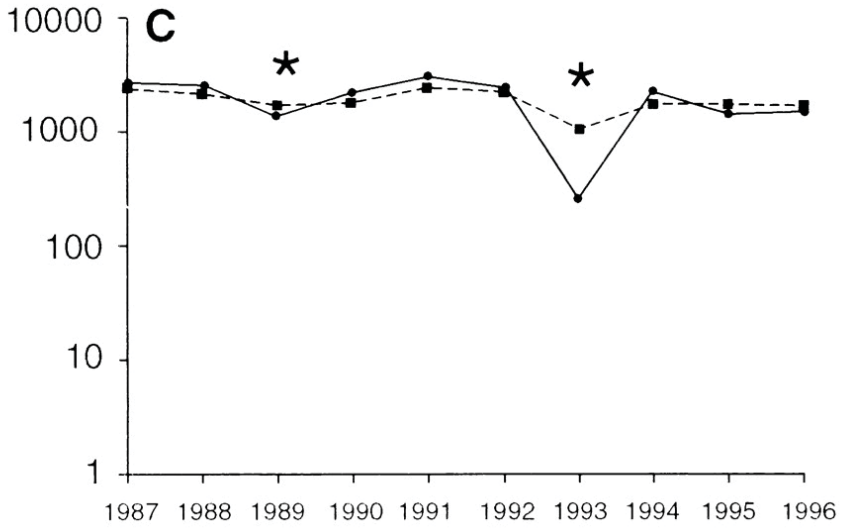


Host mortality as density dependence

Untreated



Treated



Trichostrongylid parasites of grouse control populations of both hosts and parasites

WHO recommends……

category		prevalence
I	high prevalence	≥ 50%
II	moderate prevalence	≥20% < 50%
III	low prevalence	< 20%

For communities in **category I,** universal treatment is recommended. The whole community is treated irrespective of age, sex, infection status, or other social characteristics. Treatment campaigns must be conducted once a year. The efficacy of the measure is higher if the whole population is treated simultaneously.

In areas where the prevalence of high intensity infection (visible haematuria for *S. haematobium*) is over 15% schoolchildren may be given treatment twice a year for added benefit.

For communities in **category II,** targeted treatment is recommended. The groups identified for treatment are school-age children, and the treatment can be organized every 1-2 years.

For communities in **category III,** screening schoolchildren is the recommended measure, and positive cases must be selected for treatment by haematuria or urine filtration. The treatment can be organized every two years.

In all categories, information, education and communication (IEC) strategies and improving sanitation have a great impact and should be extensively applied.

Chemotherapy options are based on prevalence estimates.

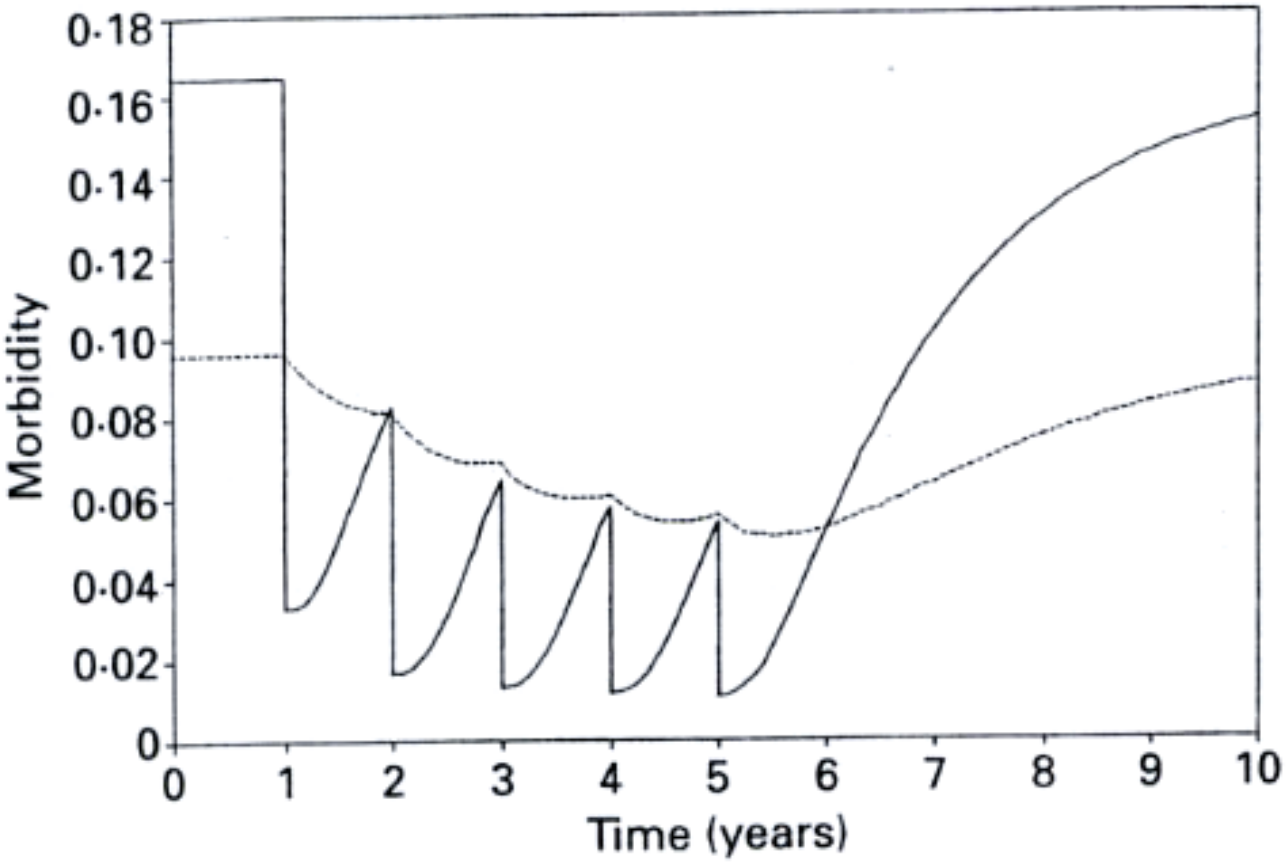
Mass treatment every year in high transmission areas….

…twice *p.a.* in high morbidity areas

Children take priority in low transmission areas.

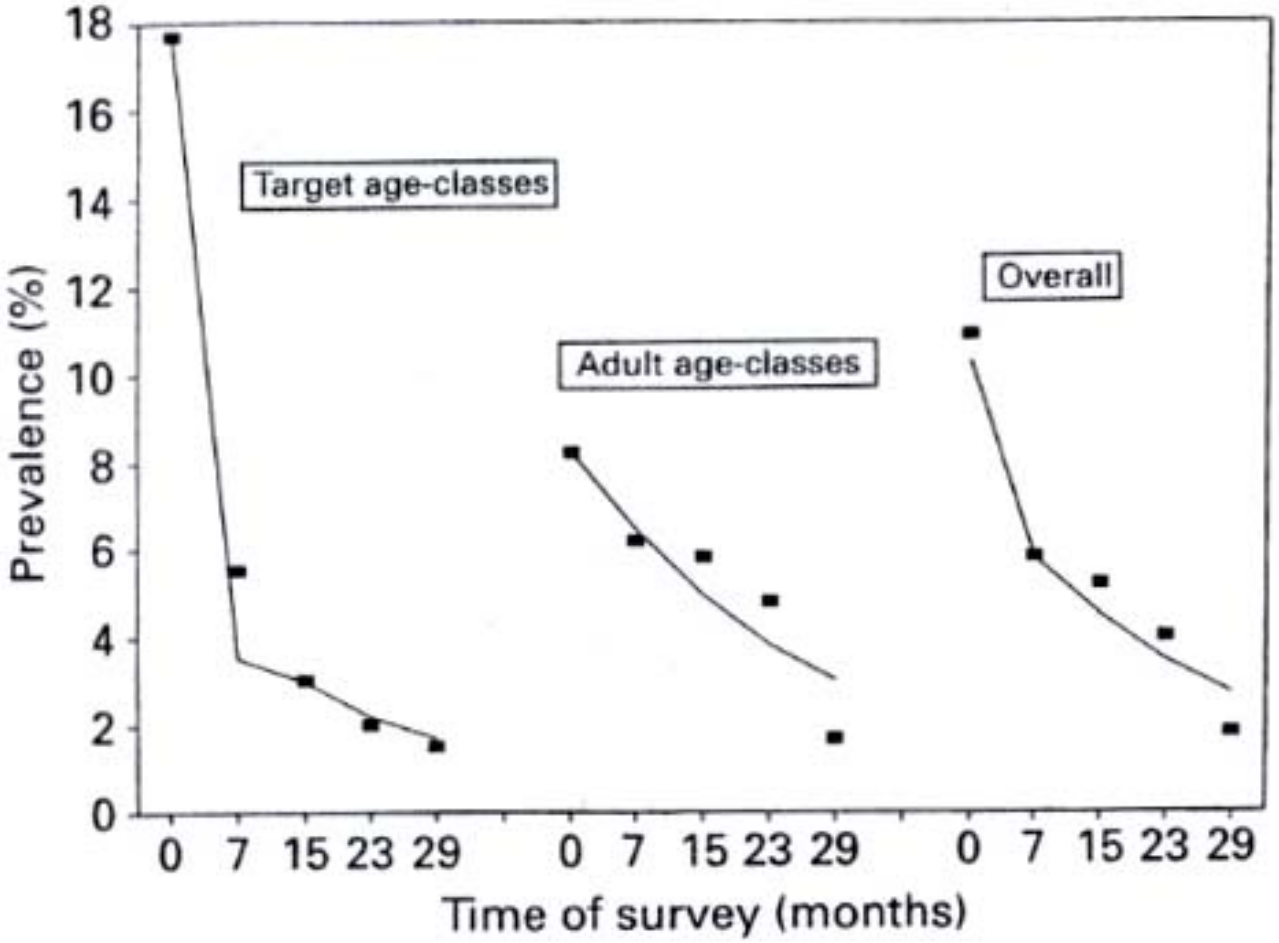
Use other strategies concurrently.

Model predictions

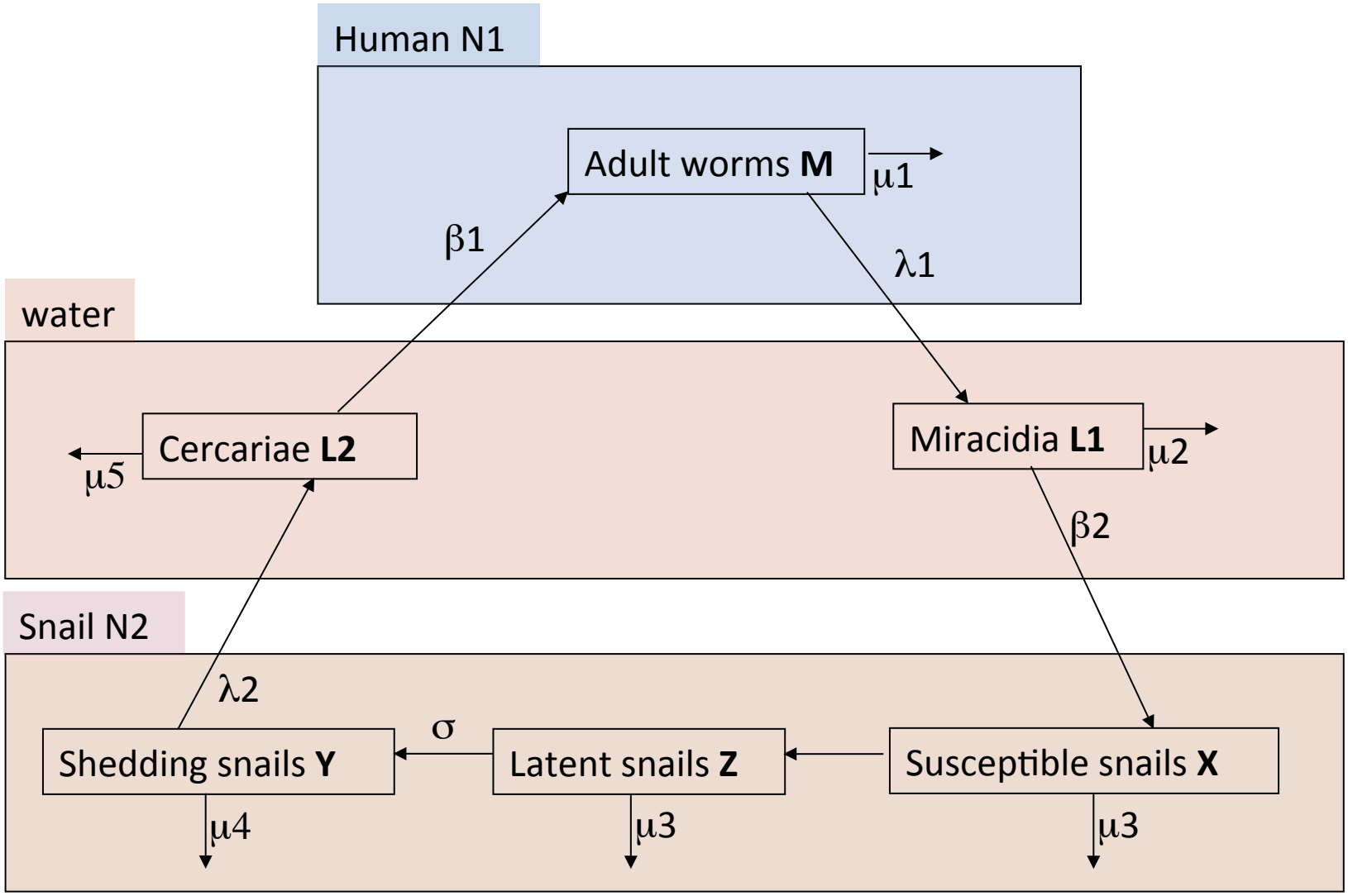


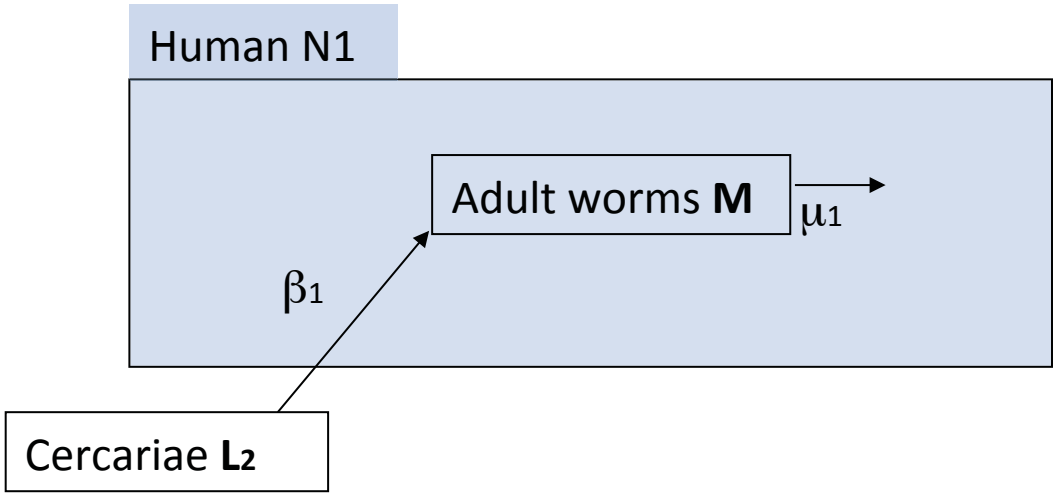
Morbidity = Prevalence of >20 worms. Adults are untreated.

Model validation



Compartmental model of schistosome life cycle





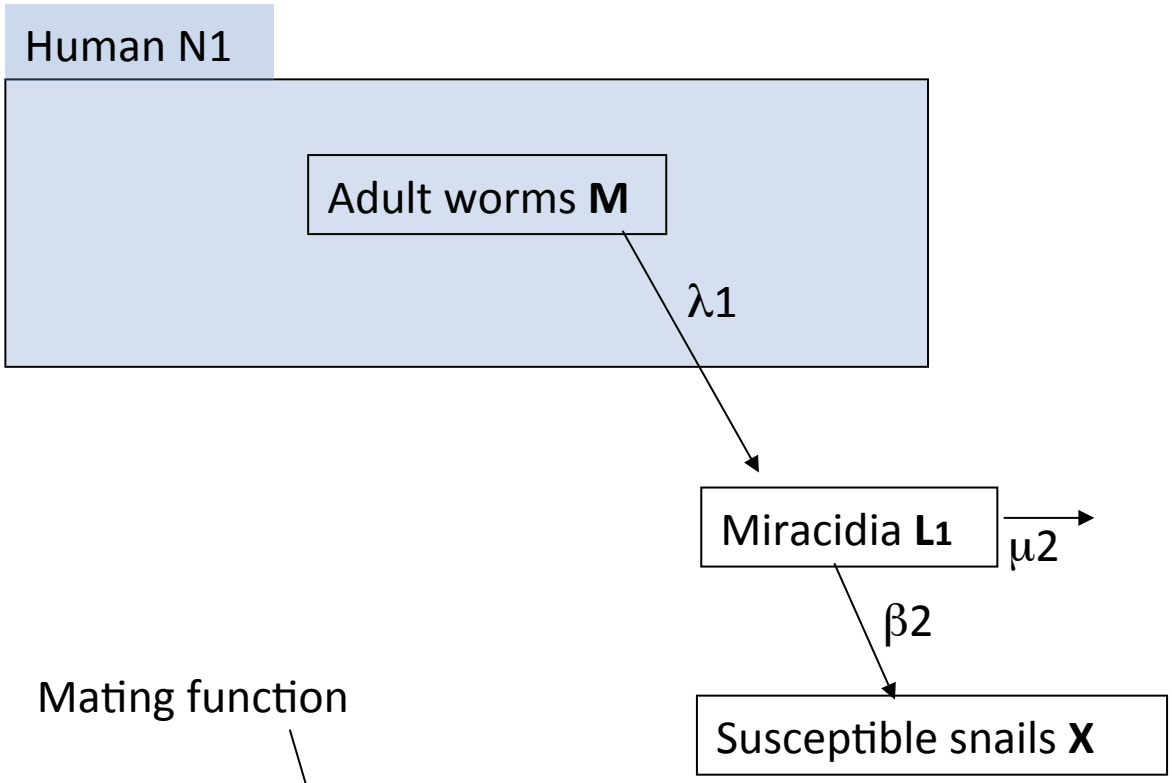
Rate of change of worm population

Adult worm population size at time t

$$dM/dt = \beta_1 L_2 - \mu_1 M$$

Proportion of larvae that become adults per unit time

Per capita death rate



Rate of change of miracidial population

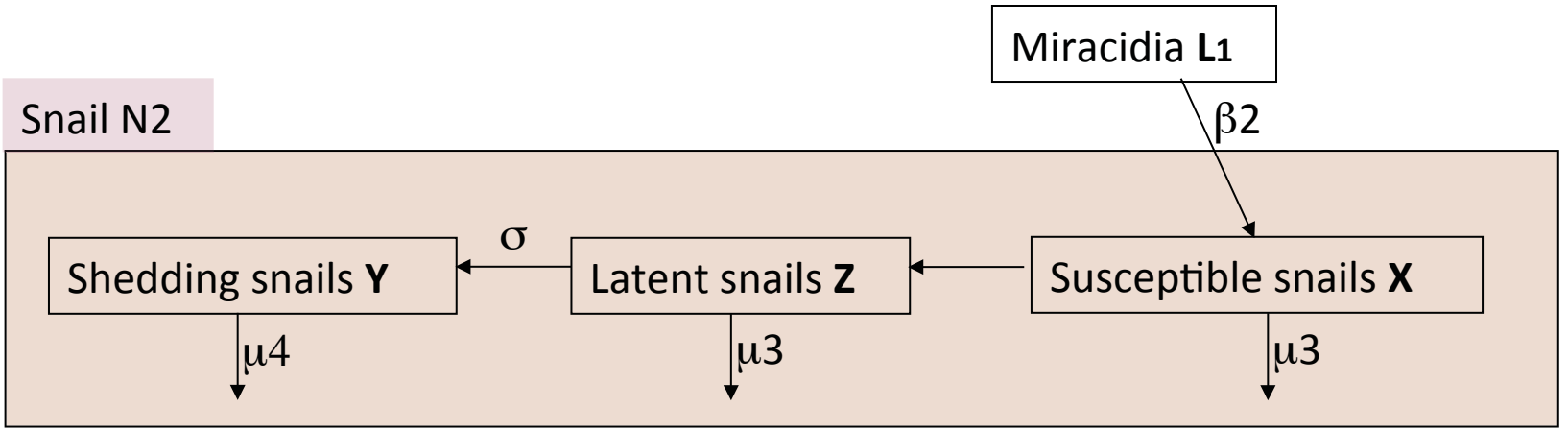
Mating function

$$dL_1/dt = \tfrac{1}{2}\lambda_1 M N_1 \phi - \mu_2 L_1 - \beta_2 N_2 L_1$$

No. of eggs hatching per unit time

No. of dead miracidia per unit time

No. of miracidia that infect snails per unit time

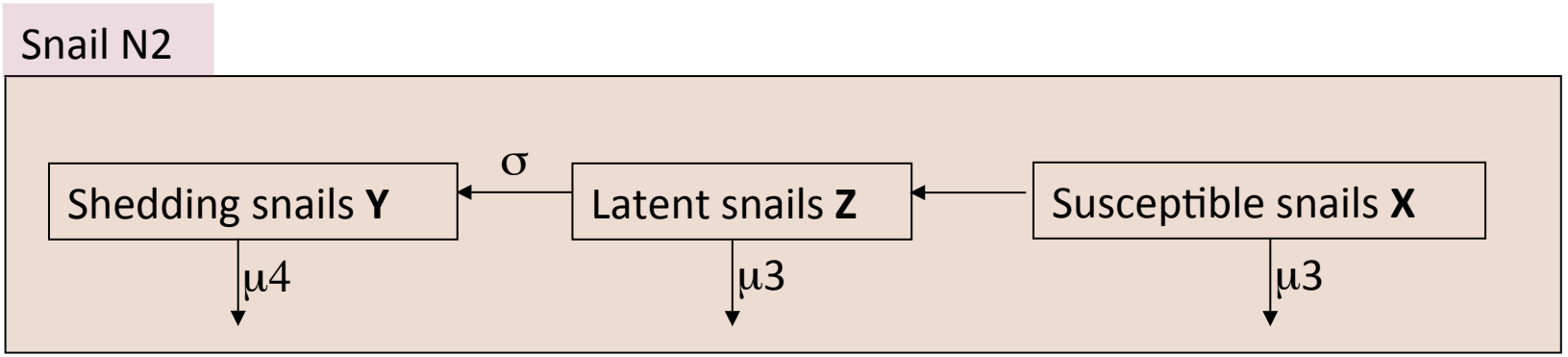


$$\frac{dX}{dt} = \mu_3(X+Z)+u_4Y-\beta_2XL_1$$

Rate of change of proportion of snail population that are uninfected

Propn of population that die per unit time (recyled into births)

Propn of susceptible snails becoming infected per unit time



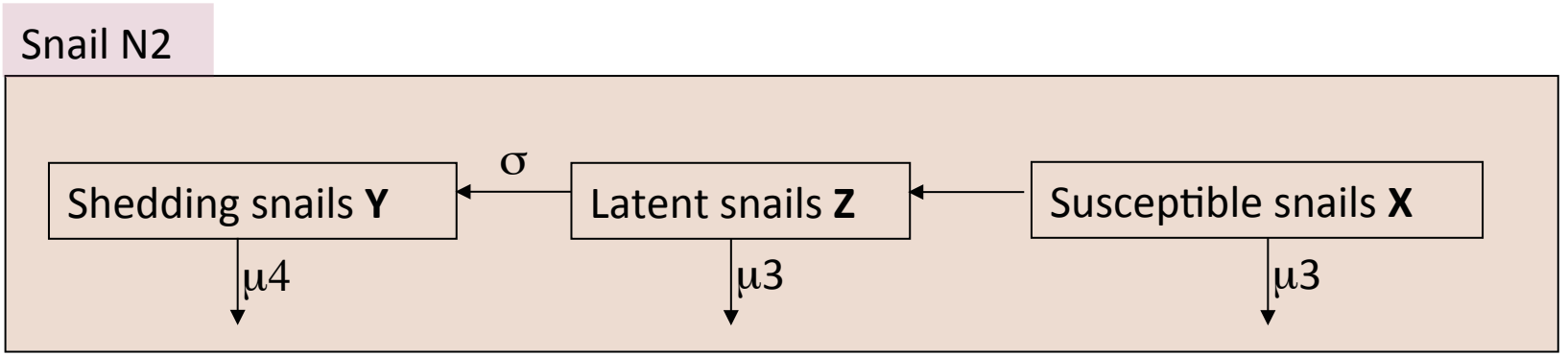
$$\frac{dZ}{dt} = \beta_2 X L_1 - \sigma Z - \mu_3 Z$$

Rate of change of propn. of snail population that are infected but not shedding

Propn. of snails becoming infected per unit time

Propn. of latent snails that start shedding

Propn. of latent snails that die

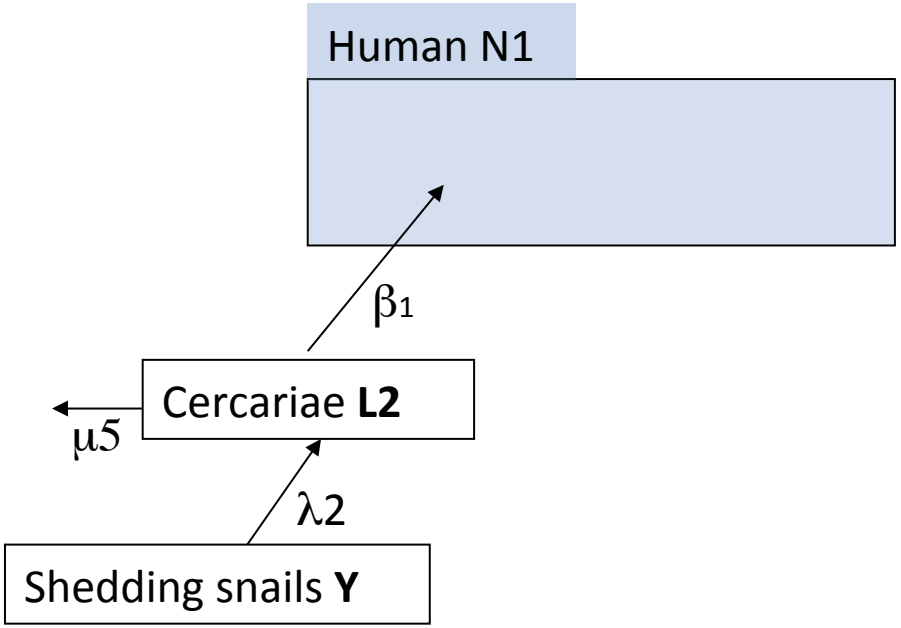


$$\frac{dY}{dt} = \sigma Z - \mu_4 Y$$

Rate of change of propn. of snail population that are shedding

Propn. of latent snails that start shedding

Propn. of shedding snails that die



$$\frac{dL_2}{dt} = \lambda_2 Y N_2 - \mu_5 L_2 - \beta_1 N_1 L_2$$

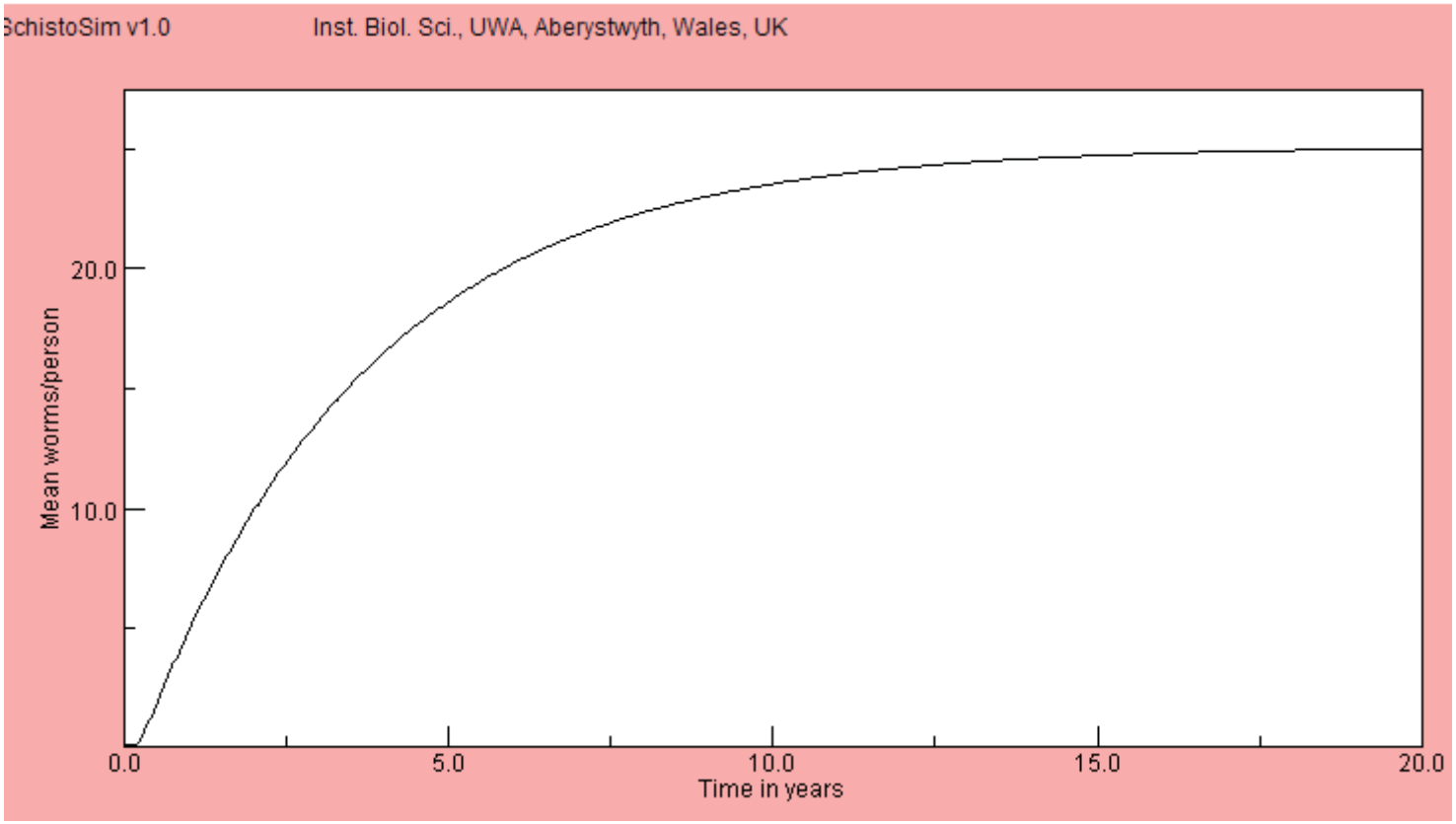
Rate of change of cercarial population

Total no. of cercariae produced per unit time

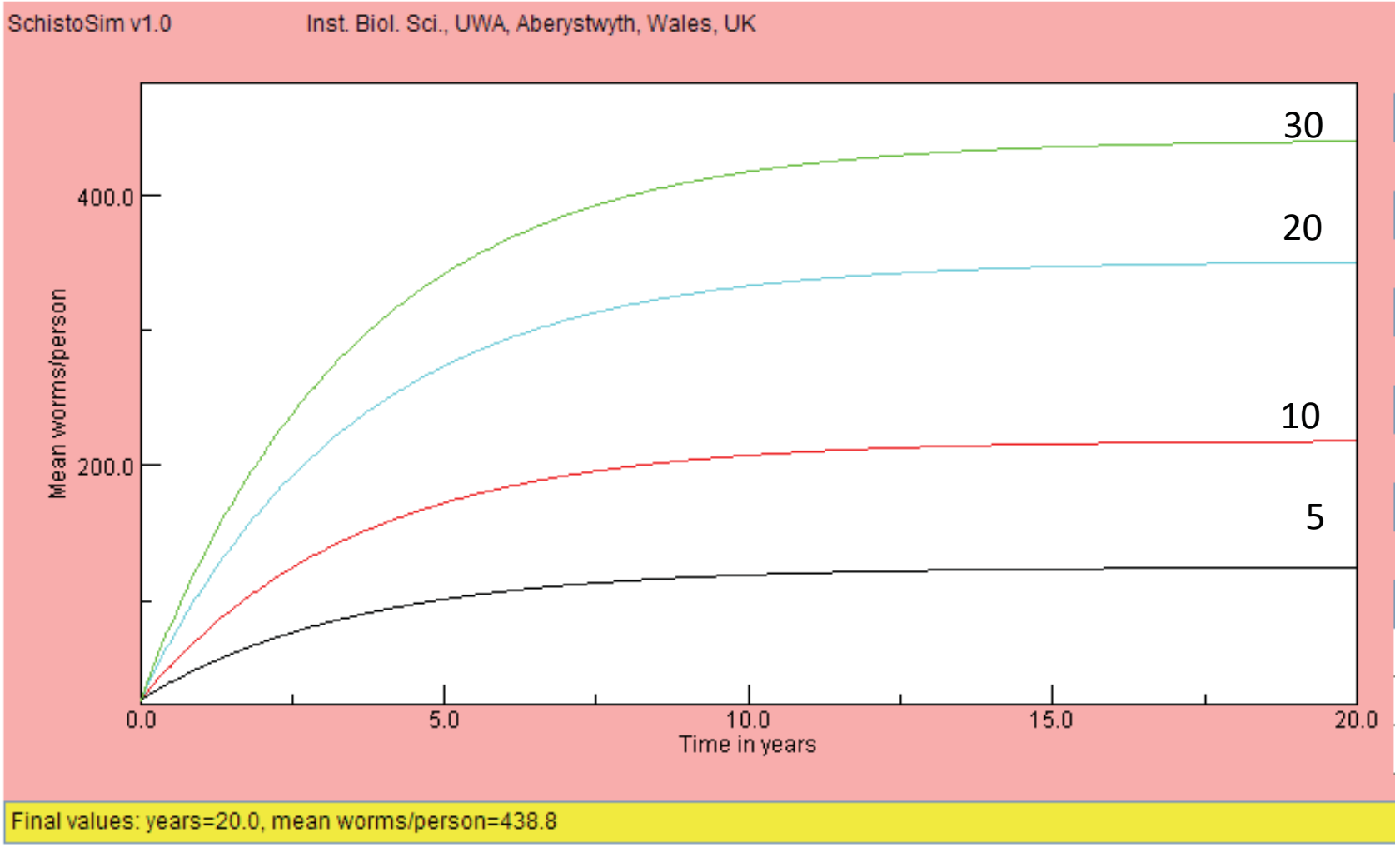
No. of cercariae dying per unit time

No. of cercs that penetrate definitive host per unit time

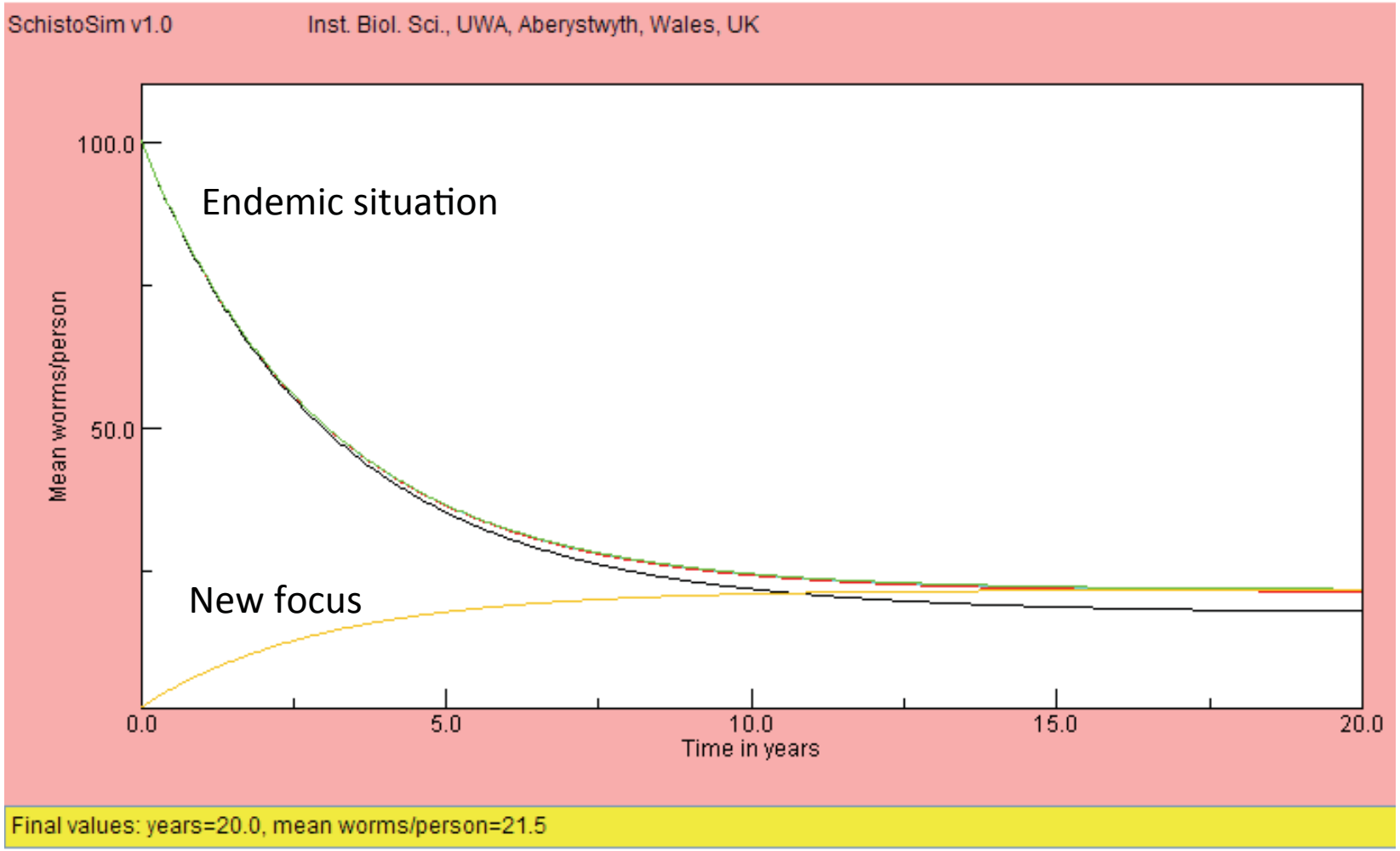
Schistosome model output



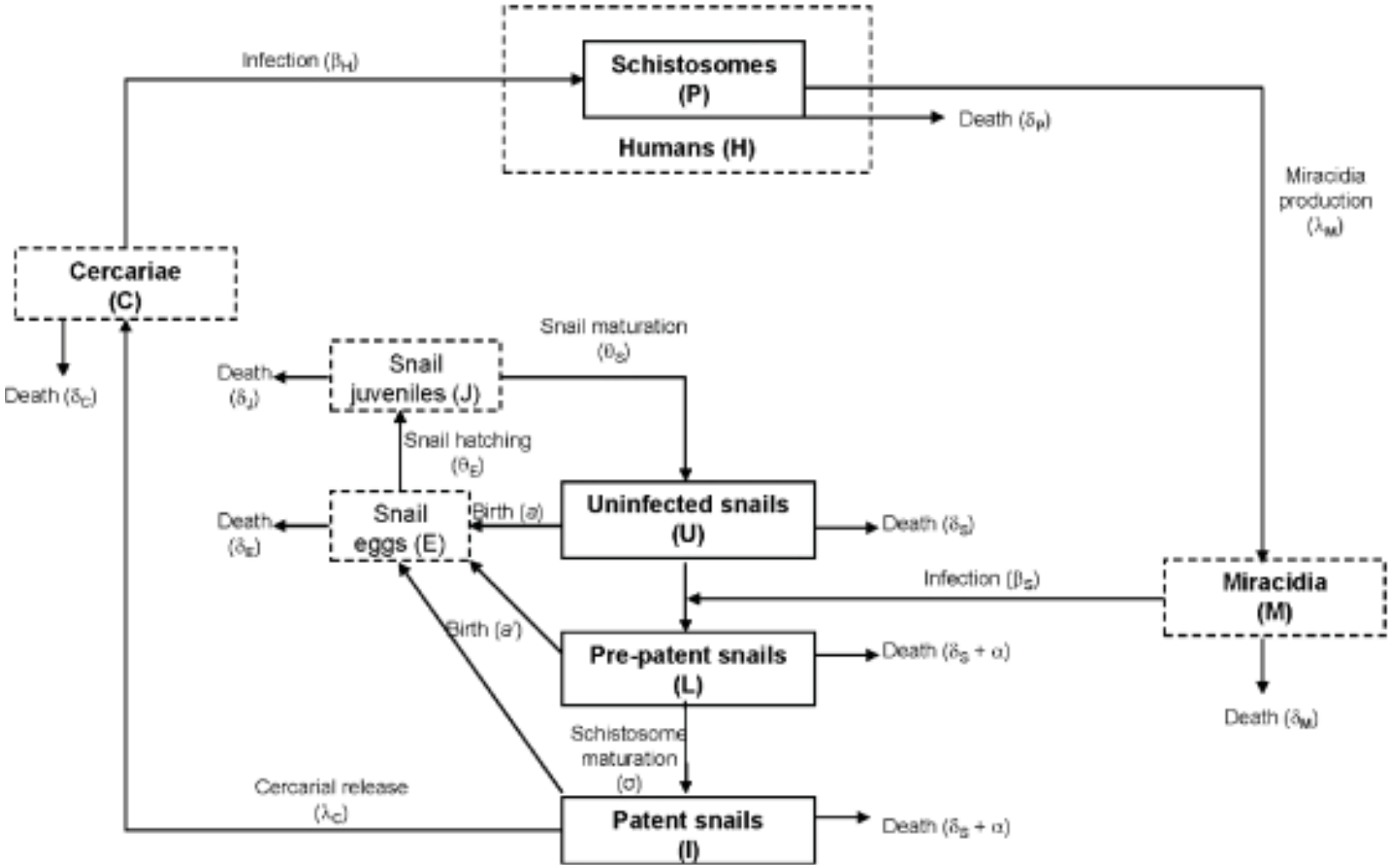
Varying snail longevity



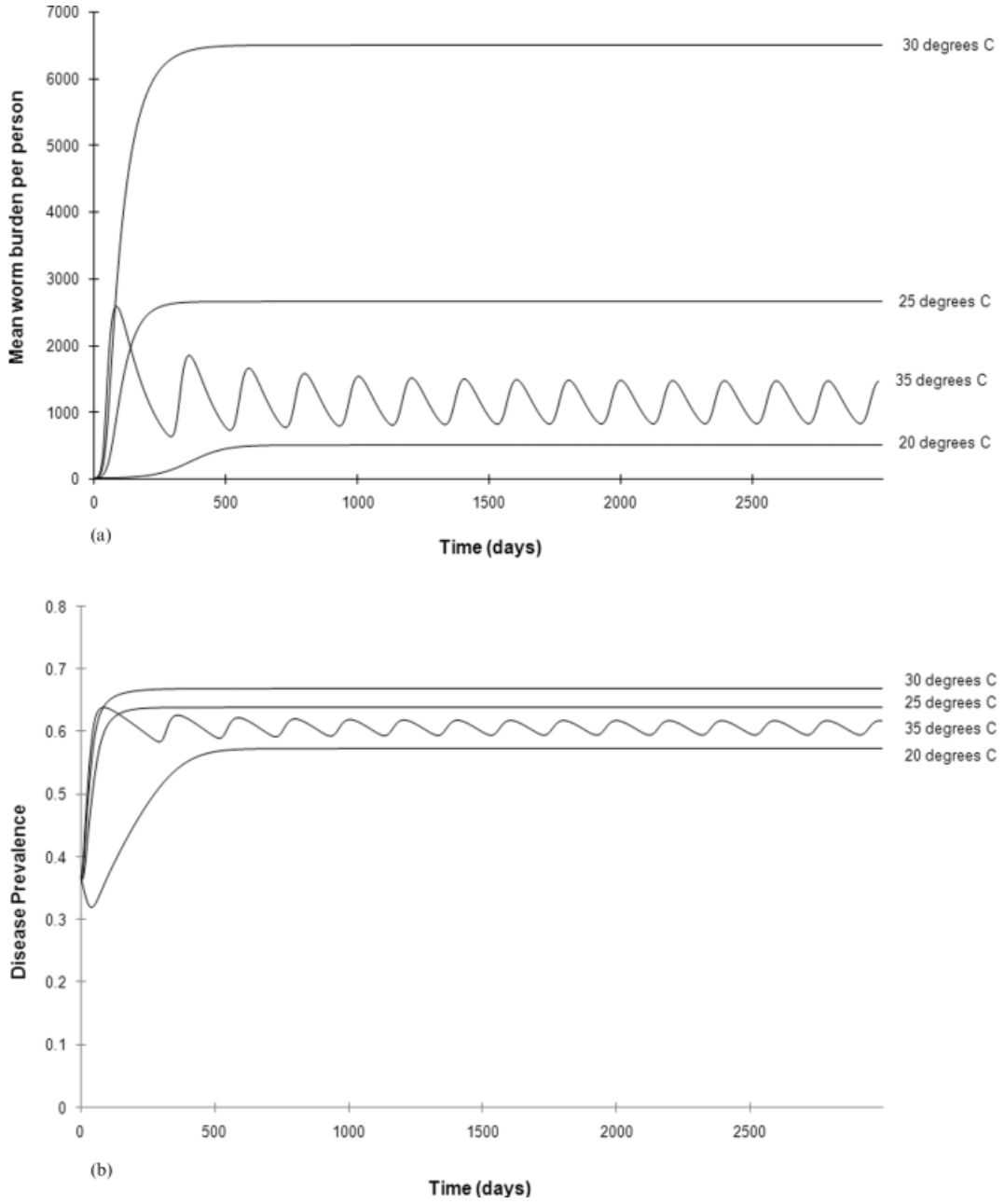
low fecundity, short worm longevity



Modelling the impact of long-term temperature changes on schistosome transmission



Mangal *et al* PLoS One. 2008 Jan 16;3(1):e1438



Temperature increases result in higher mean worm burdens until about 35 degrees before the system becomes 'unstable'

Mangal *et al* PLoS One. 2008 Jan 16;3(1):e1438

Challenges

The social dimension - who does what and why?

Population growth / migration – how far will people go to seek prosperity?

Extreme weather events – how frequent, how intense?

Governmental policies – will they offer mitigation or adaptation to climate change?

Evolution – rapid generation times may lead to adaptation of both snails and parasites

Scale – infections act locally, climate change acts globally

IN DEPTH | 22 April 2013

Worm therapy: Why parasites may be good for you

By Rachel Nuwer

Health | Disease | Medicine | Science & Environment | Biology

Is this the future?