Quantifying the effects of parasites on the maintenance of sex

Sang Woo Park and Ben Bolker

McMaster University, Hamilton, Ontario, Canada

Evolution of sex

- **two modes of reproduction**:
  - **sexual** females require a male partner to produce an offspring
  - **asexual** females produce offspring alone
- sexual population grows slower because males cannot produce offspring; **why then do organisms reproduce sexually**?

cost.png

Gibson *et al.* [1]

Red Queen Hypothesis

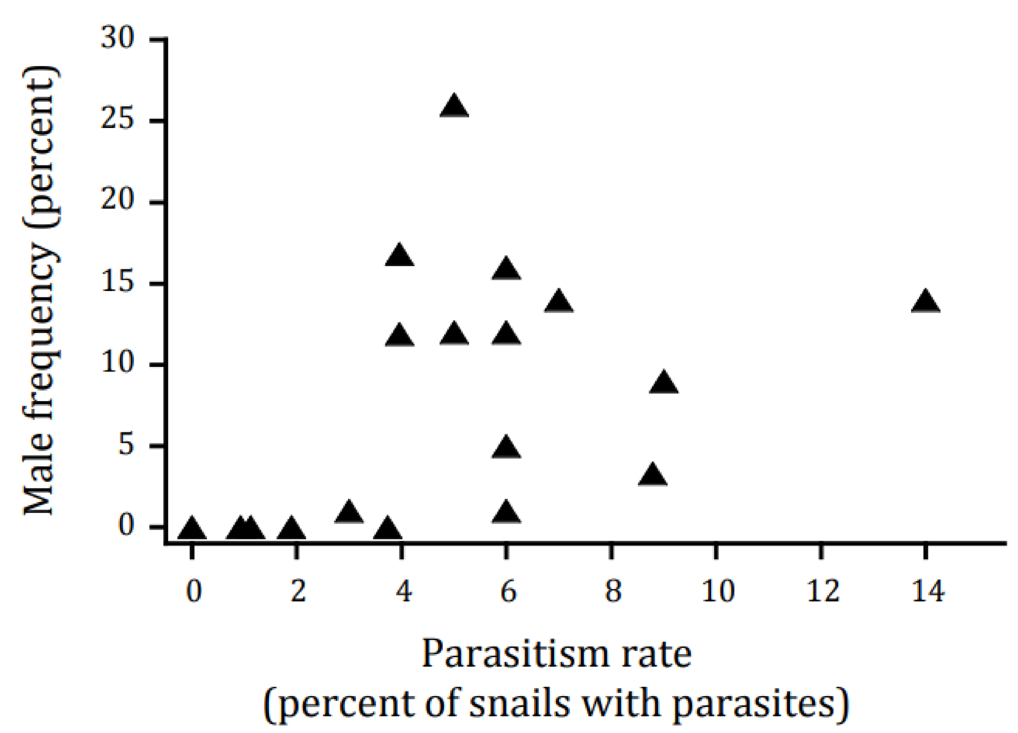

Figure : The snail population in a New Zealand lake [2] supports Lively's [3] prediction of positive correlation between proportion ♂, representing proportion of sexual snails, and parasite prevalence.

- asexual and sexual snail populations (*Potamopyrgus antipodarum*) coexist in New Zealand lakes
- snails are an important host for trematode parasites
- hypothesis: sexually reproducing snails → rare genotypes that resist trematode infection [4] (the **Red Queen Hypothesis**)
- Lively [3] predicted that populations with more infection will have more sexual snails; **how likely is it to observe this trend in nature?**

Methods

1. developed a mathematical model that represent the evolution of the snail population
   - each population is composed of both asexual (A) and sexual (S) hosts
   - infected hosts can infect others
   - hosts reproduce within their population but some can move to other populations
2. the model can generate "data" analogous to field observations
3. identify parameters that make simulated data similar to observed data

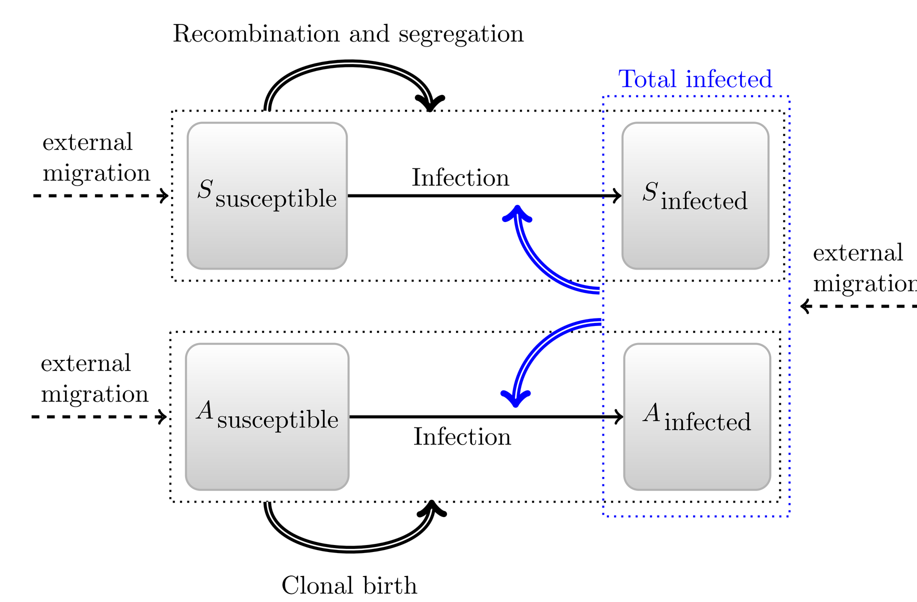

Figure : Graphical representation of the model.

Results

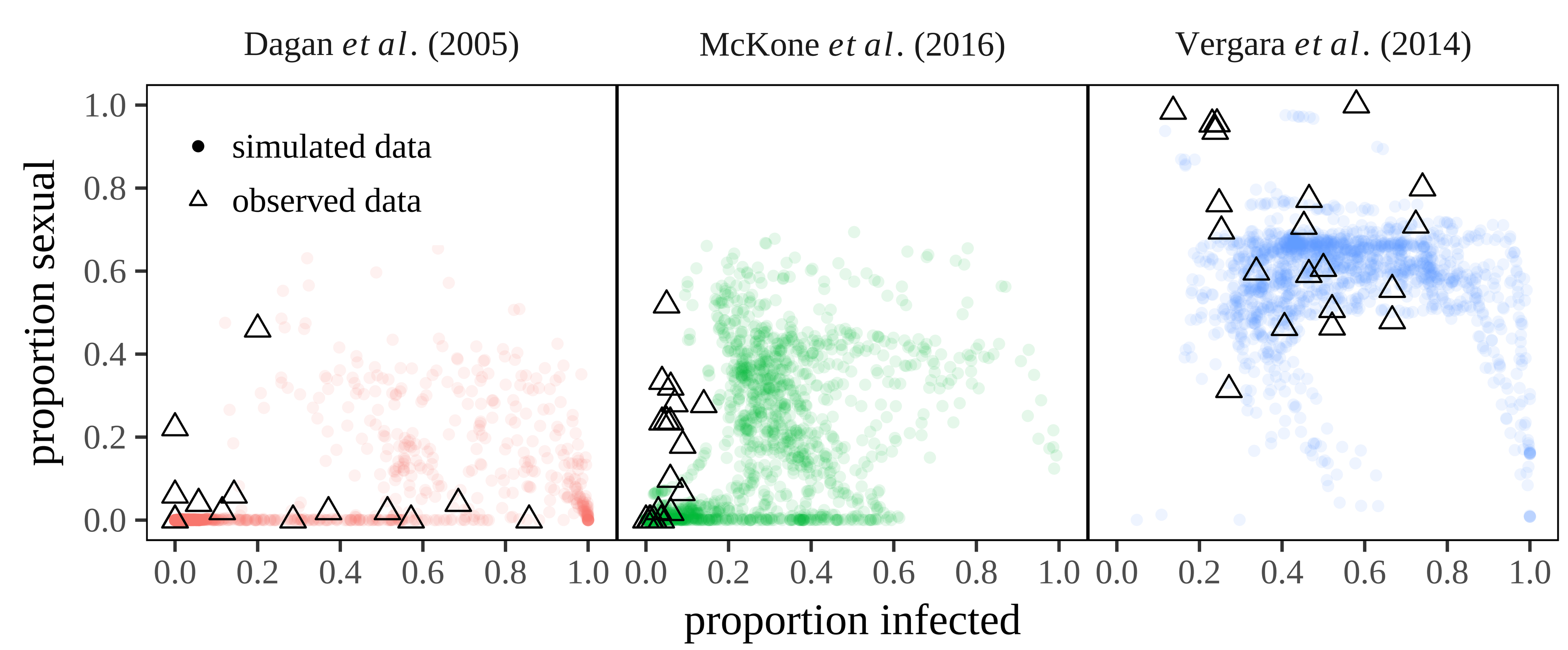

Figure : Simulated "data" vs. observed data. (△) observations from a study site in one year (◯) proportion of sexual hosts and infected hosts in a simulated population averaged over 100 generations. 50 simulations are plotted; each simulation consists of 30 populations.

- this model is not appropriate for studying the snail population in Israel (left panel; Dagan *et al.* [5]); need to consider other hypotheses for the maintenance of sex?
- when a population is dominated by asexual reproduction, stronger parasite infection leads to increase in sexual reproduction but decrease in proportion infected; opposite to Lively's prediction [3]
- even stronger infection leads to a balance between sexual and asexual reproduction (hump at intermediate prevalence) and an eventual decrease in proportion of sexual reproduction

Discussion

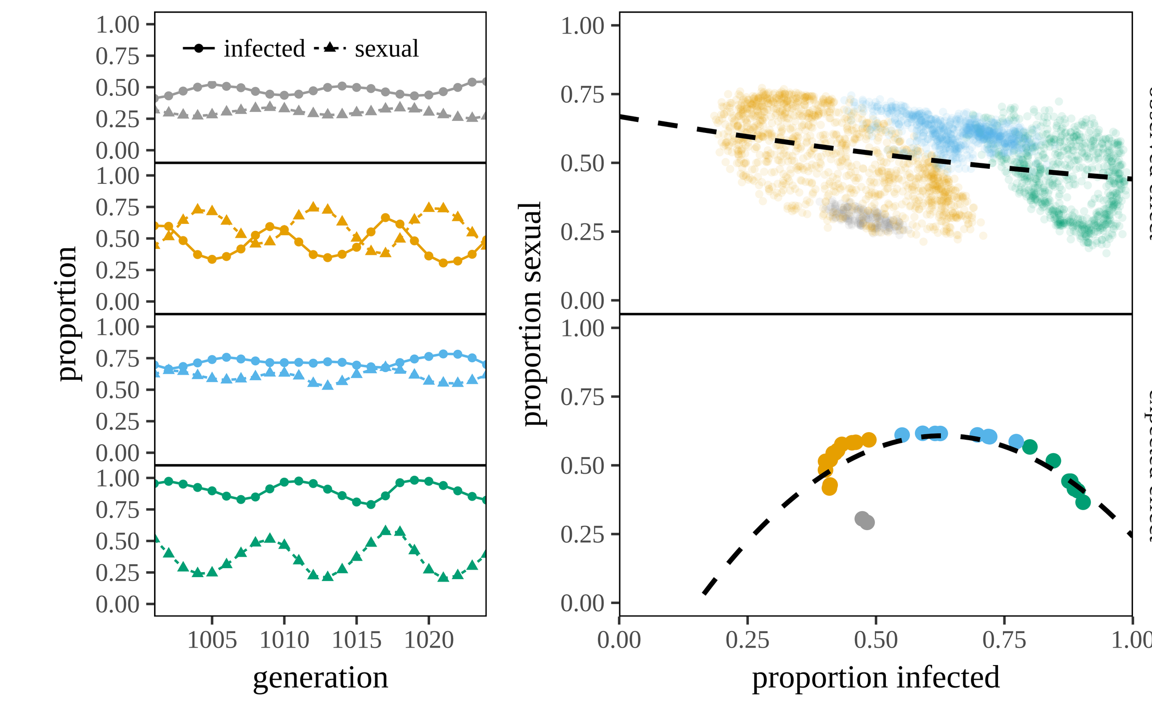

Figure : A closer look at Red Queen dynamics. (left) interaction between parasites and sexual hosts drives various types of oscillations. (right) we expect to see a downward curved trend; averaging out oscillations in each population predicts an opposite trend

- eventually parasites evolves to infect resistant snail and sexual reproduction decrease in the population; creates **oscillation between parasite and sexual population** (left panel)

Conclusion and further questions

- sexual populations "run away" (to escape infection) from parasites but parasites "chase" (to infect more) sexual populations, creating an oscillation; depending on where the population is in the cycle, we can observe a wide range of trends
- what kind of data and tests are needed to detect oscillation in the population?

Reference

[1] Amanda K Gibson, Lynda F Delph, and Curtis M Lively. The two-fold cost of sex: Experimental evidence from a natural system. *Evolution Letters*, 1(1):6–15, 2017.

[2] Mark J McKone, Amanda K Gibson, Dan Cook, Laura A Freymiller, Darcy Mishkind, Anna Quinlan, Jocelyn M York, Curtis M Lively, and Maurine Neiman. Fine-scale association between parasites and sex in *Potamopyrgus antipodarum* within a New Zealand lake. *New Zealand Journal of Ecology*, 40(3):1, 2016.

[3] Curtis M Lively. Trematode infection and the distribution and dynamics of parthenogenetic snail populations. *Parasitology*, 123(07):19–26, 2001.

[4] Daniela Vergara, Jukka Jokela, and Curtis M Lively. Infection dynamics in coexisting sexual and asexual host populations: support for the Red Queen hypothesis. *The American naturalist*, 184(S1):S22–S30, 2014.

[5] Y Dagan, K Liljeroos, J Jokela, and F Ben-Ami. Clonal diversity driven by parasitism in a freshwater snail. *Journal of evolutionary biology*, 26(11):2509–2519, 2013.