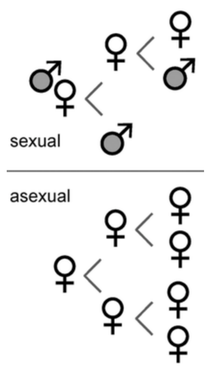
Quantifying the effects of parasites on the maintenance of sex

Sang Woo Park and Ben Bolker

McMaster University, Hamilton, Ontario, Canada

Evolution of sex

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



Gibson *et al.* [1]

Red Queen Hypothesis

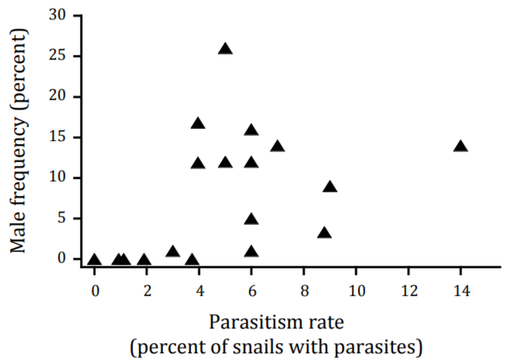


Figure: The snail population in a New Zealand lake [2] follows the prediction made by Lively [3]. Proportion of male snails is used as a measure of proportion of sexual snails in a population.

- snail population living in lakes in New Zealand coexist in both sexual and asexual forms
- the snail population serve as an important host for parasites called trematodes
- hypothesis: sexually reproducing snails can produce snails with rare genes that are resistant to trematode infection [4] (**Red Queen Hypothesis**)
- Lively [3] predicted that population with more infected snails will have higher proportion of 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 be simulated to generate data
3. found parameters of the model that made simulated data similar to the observed data

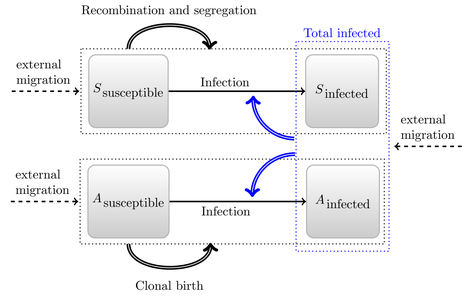


Figure: Graphical representation of the model.

Results

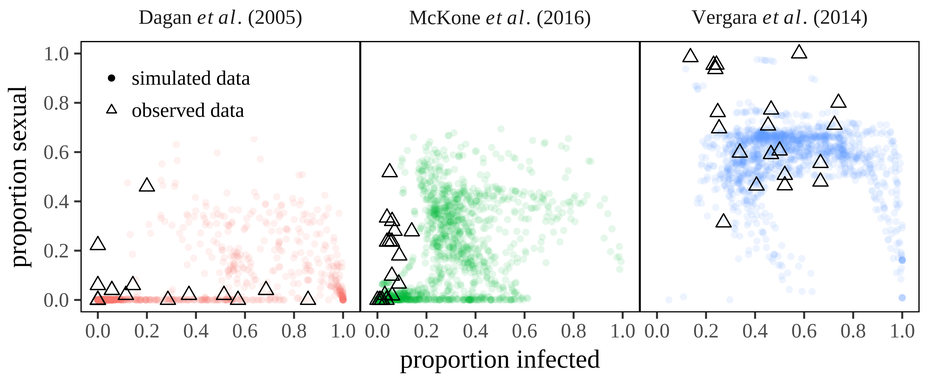


Figure: Simulated data v.s. observed data. (triangle) each point represents an observation from a study site in one year (circle) proportion of sexual hosts and proportion of infected hosts in a simulated population averaged over 100 generations. 50 simulations are plotted and each simulation consists 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 balance between sexual and asexual reproduction (hump in the intermediate zone) and eventually decrease in advantage of sexual reproduction

Discussion

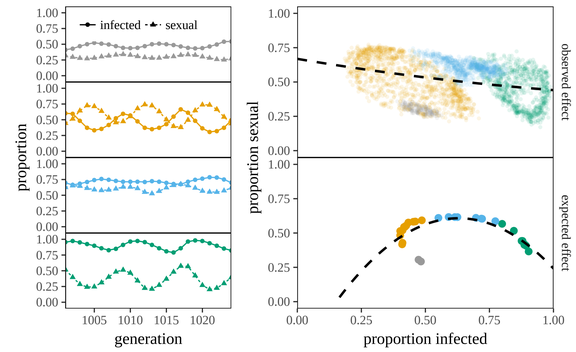


Figure: Closer look at Red Queen dynamics. (left) interaction between parasites and sexual hosts can create various oscillations. (right) we expect to see a downward curved trend but accounting for oscillations in each population predicts an oppsite trend

- 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.