Quantifying the effects of parasites on the maintenance of sex

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Summary

Why must **sexual reproduction** persist in nature given its **two-fold cost**? The **Red Queen Hypothesis** predicts sexually reproducing individuals to overcome the cost of sex by escaping infection more easily under strong parasite selection. Here, we tried to quantify the effect of the Red Queen and perform a power analysis.

Evolution of sex

- **two modes of reproduction**: sexual and asexual
  - an asexually reproducing female reproduces alone
  - a sexually reproducing female requires a male partner to reproduce
- sexual population grows slower than asexual population because males cannot give birth
- if sexual reproduction is worse, why do so many organisms reproduce sexually?

Red Queen Hypothesis

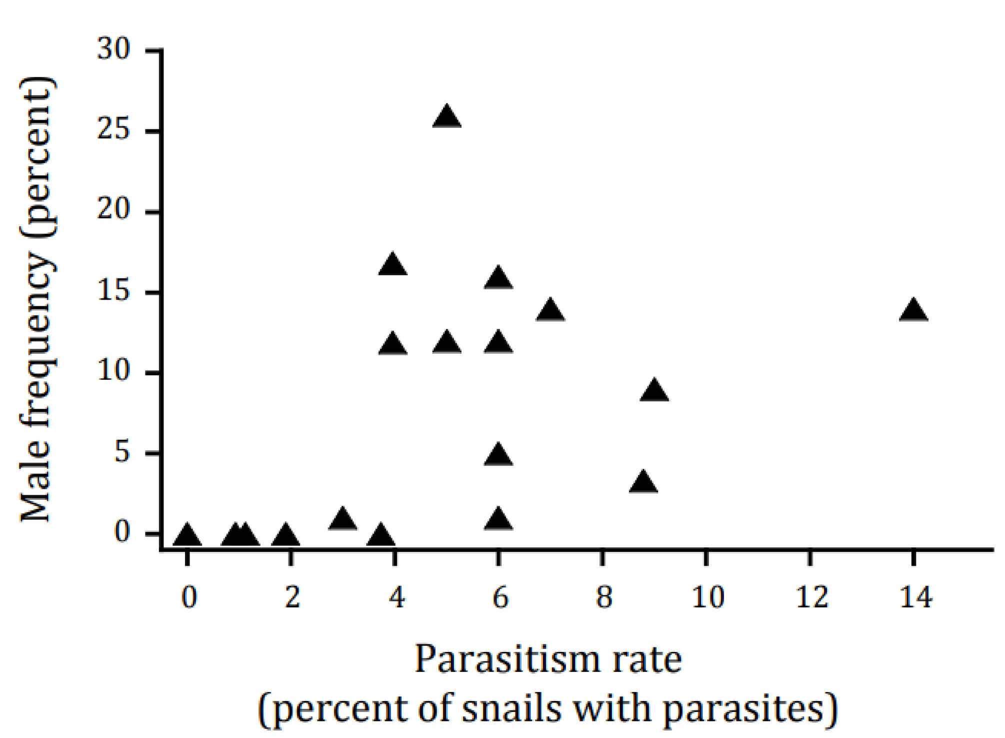

Figure 1: Parasitism rate is positively correlated with male frequency [1].

- snail population living in lakes in New Zealand coexist in both sexual and asexual forms
- it is hypothesized that sexual reproduction is maintained in the snail population to [2]
- sexual reproduction combines parent genes and can create new genes
- prevalence of sex should be **positively correlated** with prevalence of infection [3]
- unable to detect any correlation in a similar snail-trematode system. Why? [4]

Mathematical model

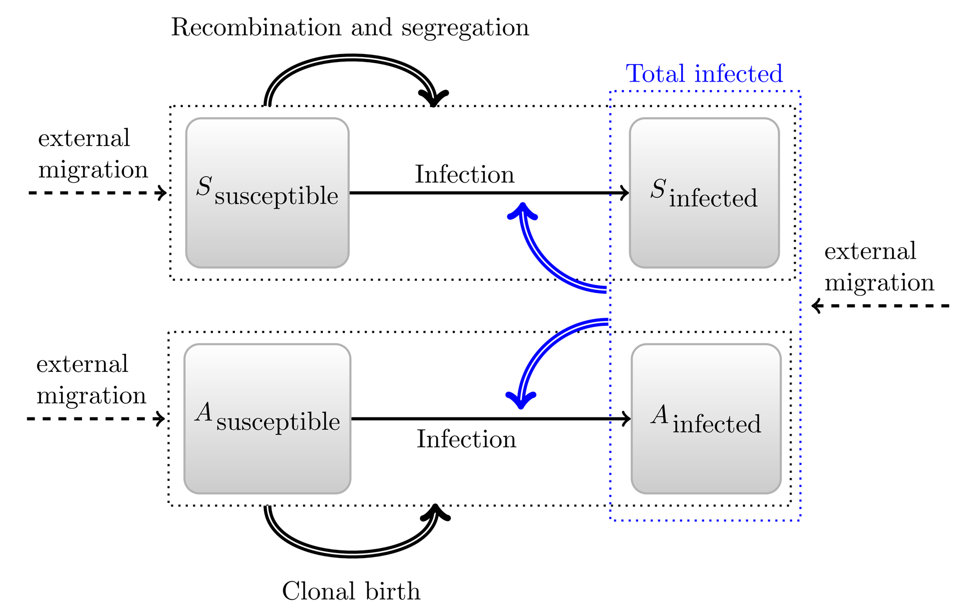

Figure 2: Graphical representation of the model. Double lined arrows represent dynamics that are affected by mixing betwee habitats.

- competition between obligate sexual (S) and clonal (A) population under parasite selection is represented by a mathematical model [5]
- hosts stay within their habitats and can mix with hosts in different habitats
- varying transmission rates across habitats
- relies on stochastic computer simulations

Approximate Bayesian Computation (ABC)

- a random sample of parameters is drawn
- simulated data is compared to the observed data
- if the difference is small enough, the parameter sample that generated the data is *accepted*
- repeated until enough sample is obtained

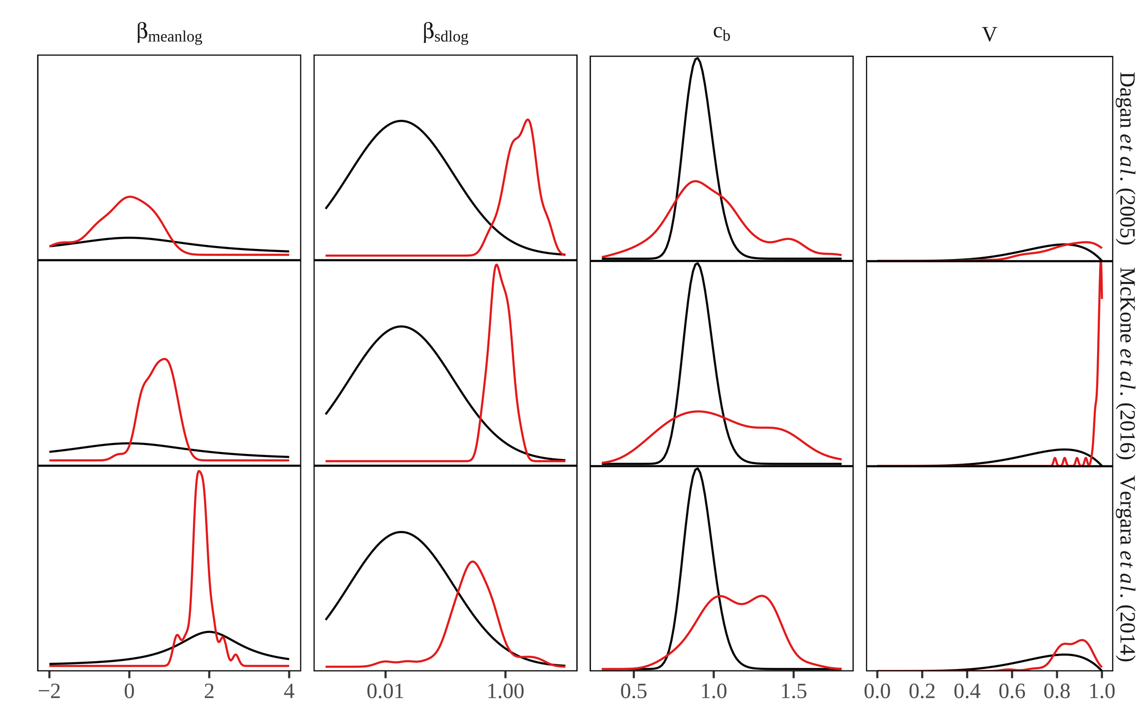

Figure 3: (black) prior distributions where parameters sampled from and (red) posterior distributions obtained from ABC

Discussion

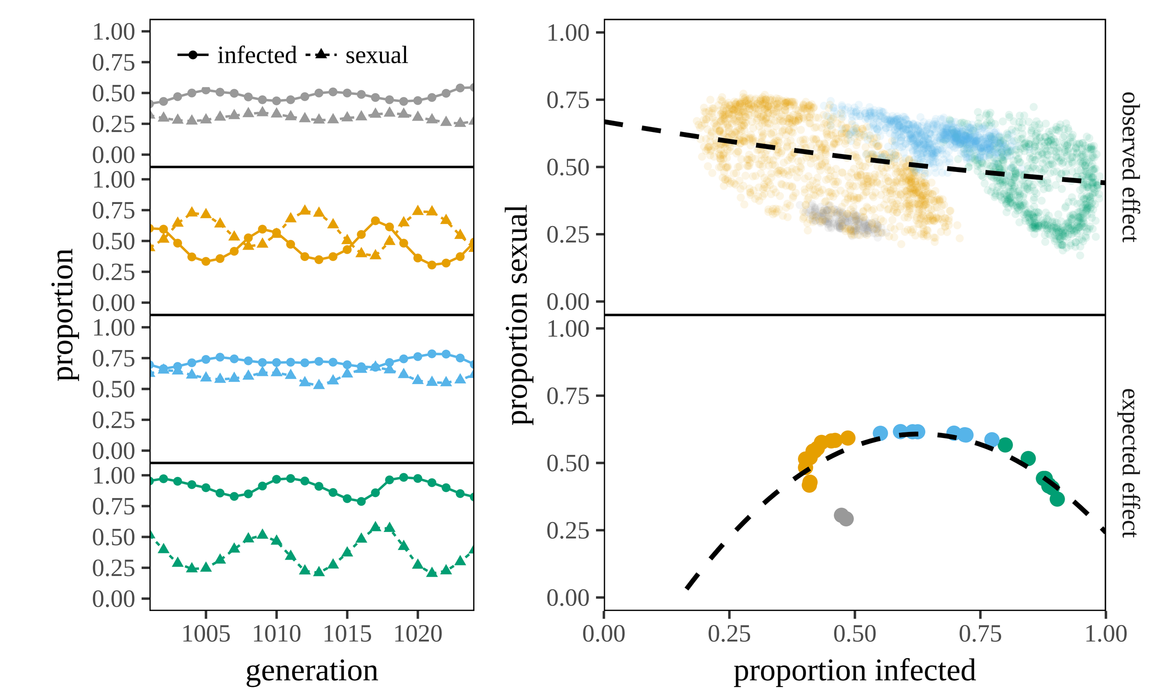

Figure 6: A sample data from a posterior sample. (left) type of cycles present in a simulated data (right) observed relationship v.s. expected relationship. (dashed line) quadratic regression.

- 'expected effect' is masked by different cycles (explains low power)
- high asexual diversity [4] and different environment (e.g., seasonal flood [6] and highly interconnected but diverse [4]) may not be appropriate for the Red Queen Hypothesis?
- unusual sampling problems in nature ([2] v.s. [7])

Results

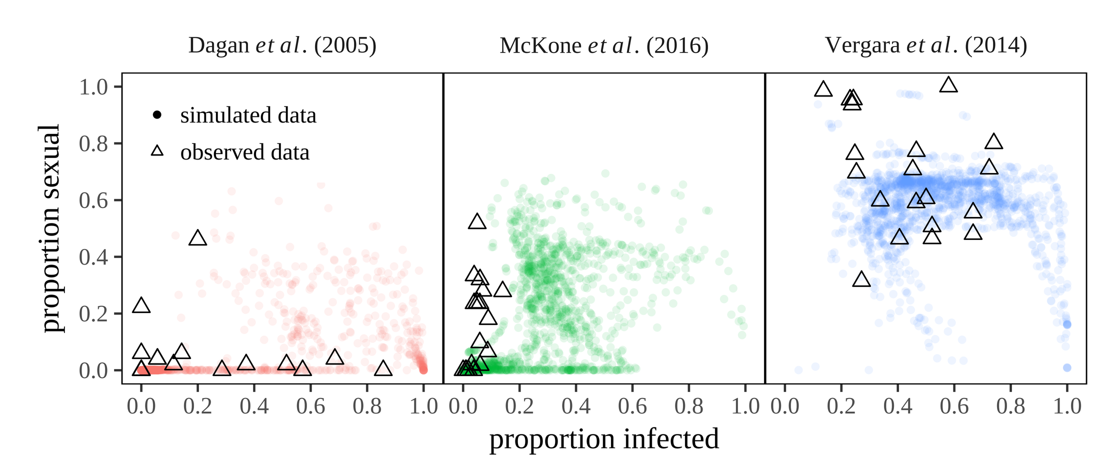

Figure 4: Simulated data v.s. observed data. Each point represents mean proportion infected and sexual at each site.

- fitted result does not match Dagan *et al.* [4]
- overestimates proportion infected when fitted to McKone *et al.* [1]
- spatial structure allows high level of infection to be maintained even at high virulence (middle panel)
- initially increasing prevalence of sexual reproduction pulls back infection (consistent with [3]) and causes prevalence of infection to decrease; quadratic overall?

- better to increase number of sites than number of samples
- Spearman's rank correlation has higher power for detecting a positive correlation than Pearson correlation
- a negative correlation is observed from simulated data fitted to Vergara *et al.*
- very low power for detecting a negative quadratic curvature

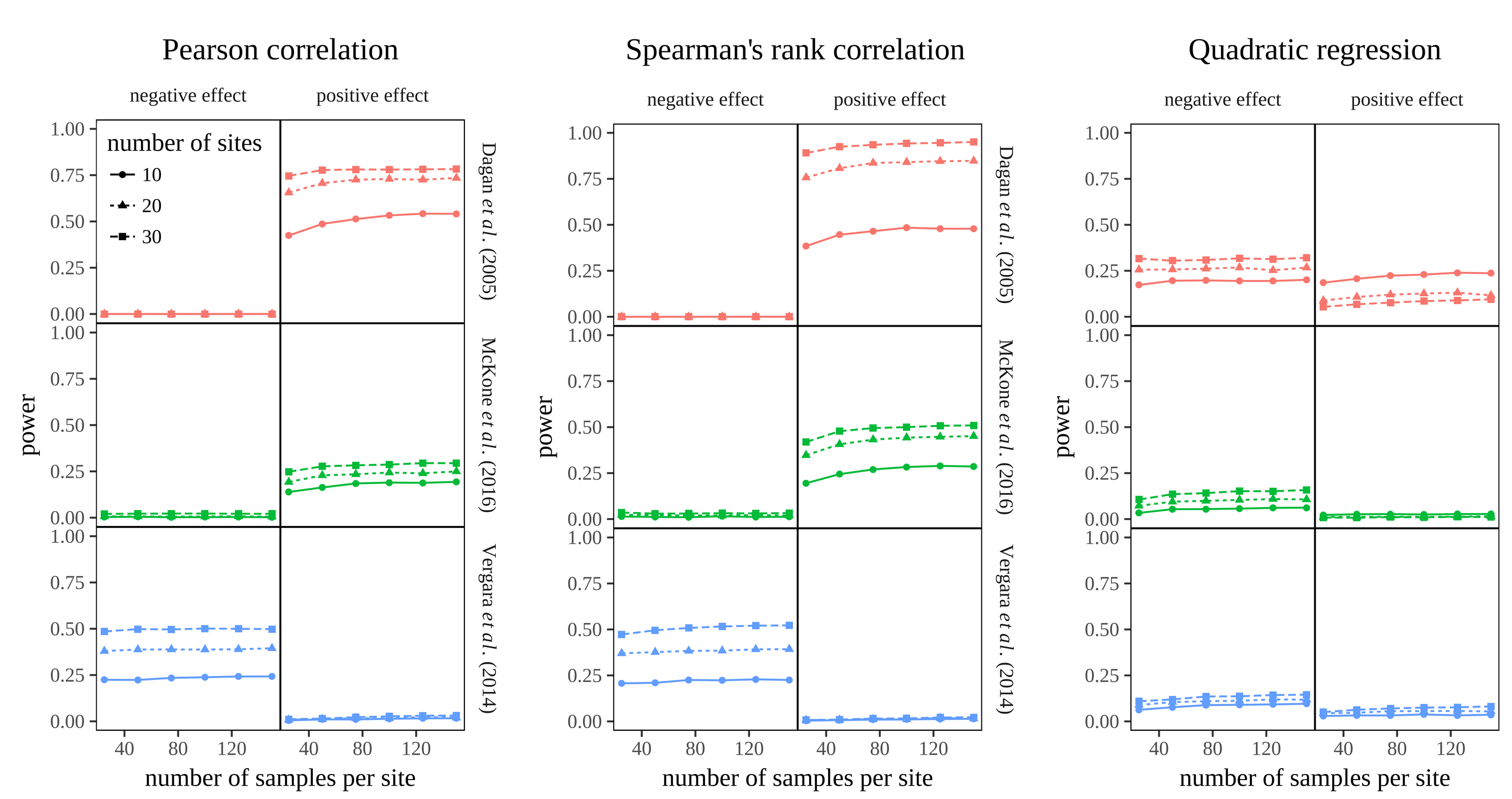

Figure 5: Power analysis for detecting a correlation and negative quadratic curvature.

Conclusion and further questions

- spatial data provides limited information; only Vergara *et al.* [2] had spatiotemporal data
- is there a way to detect the Red Queen cycles from a spatiotemporal data?
- consider pluralistic approach (Red Queen hypothesis + other mechanisms for maintaining sex)

Reference

[1] 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.

[2] 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.

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

[4] 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.

[5] Curtis M Lively. An epidemiological model of host–parasite coevolution and sex. *Journal of evolutionary biology*, 23(7):1490–1497, 2010.

[6] Frida Ben-Ami and Joseph Heller. Temporal patterns of geographic parthenogenesis in a freshwater snail. *Biological journal of the Linnean Society*, 91(4):711–718, 2007.

[7] Daniela Vergara, Curtis M Lively, Kayla C King, and Jukka Jokela. The geographic mosaic of sex and infection in lake populations of a new zealand snail at multiple spatial scales. *The American Naturalist*, 182(4):484–493, 2013.