Annual RAC meeting

Vibishan B.

20163448

8th July, 2021

Outline

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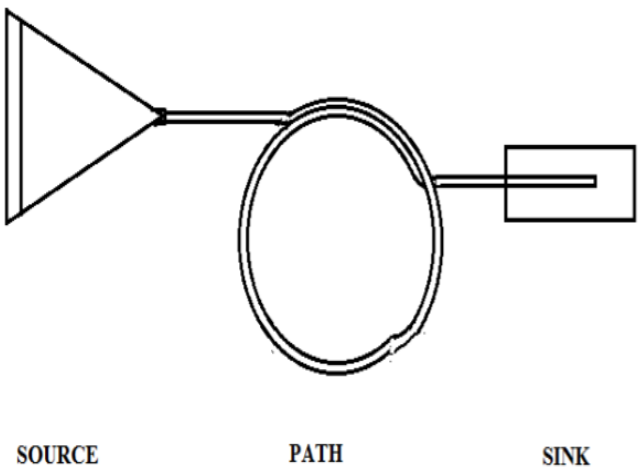
Background



- Existing setup for dispersal selection
- Large outbred population of *Drosophila melanogaster*

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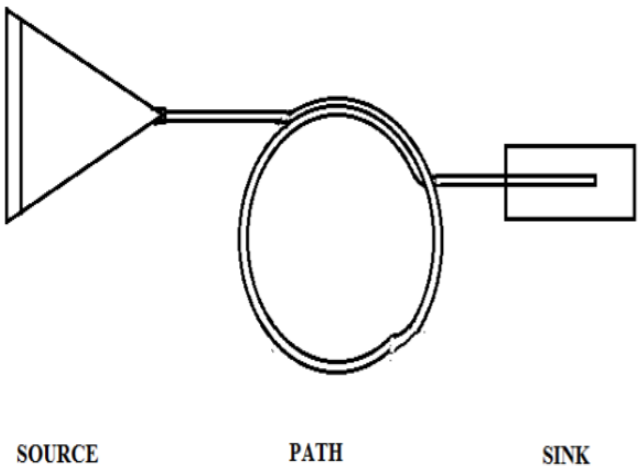

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Tradeoffs against dispersal

- Previous work in normal food showed largely cost-free selection response.

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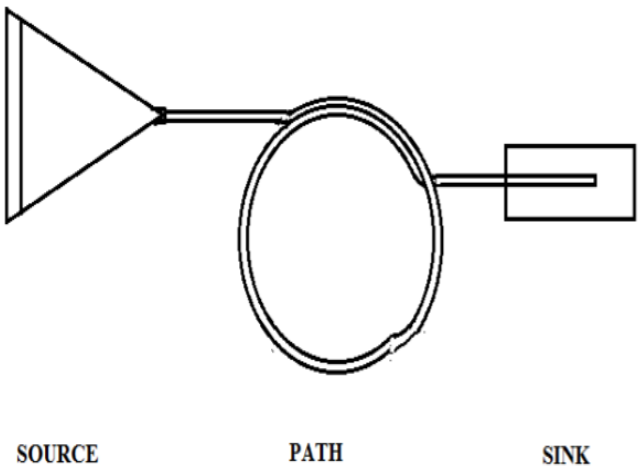

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Tradeoffs against dispersal

- Previous work in normal food showed largely cost-free selection response.
- *Could costs be detected in a nutritionally-deprived context?*

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- Malnutrition $\Longrightarrow$ development in food with one-third yeast concentration

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Selection line populations

- **MD**-Malnourished Dispersers
- **MC**-Malnourished Control

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- Malnutrition $\Longrightarrow$ development in food with one-third yeast concentration

Response at generation 42

- Dispersal response seen-MD were more likely to initiate dispersal and dispersed over longer distances than MC.
- Locomotor activity higher in MD than in MC, but no costs in body weight or fecundity

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Lockdown and suspension of selection

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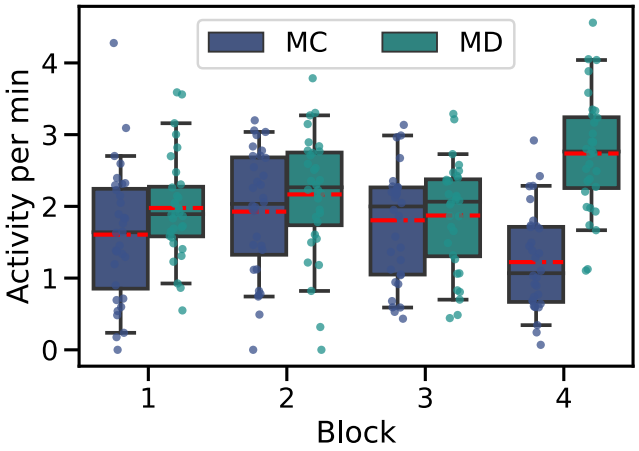
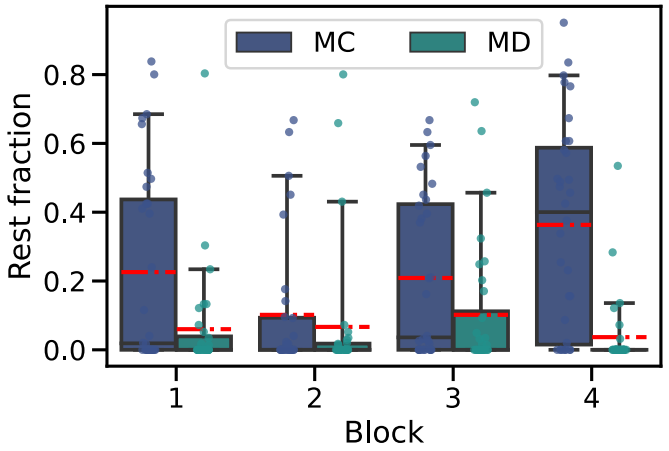
- Two assays to assess loss of phenotype before continuing selection-*dry body weight and locomotor activity*

Lockdown and suspension of selection

Locomotor activity

Activity (Two-way mixed-effects ANOVA); Population main effect: $F_{1,6} = 4.938; p = 0.068$
Rest (linear mixed-effects binomial model); Population main effect: $z = -3.990; p = 6.61e-05$

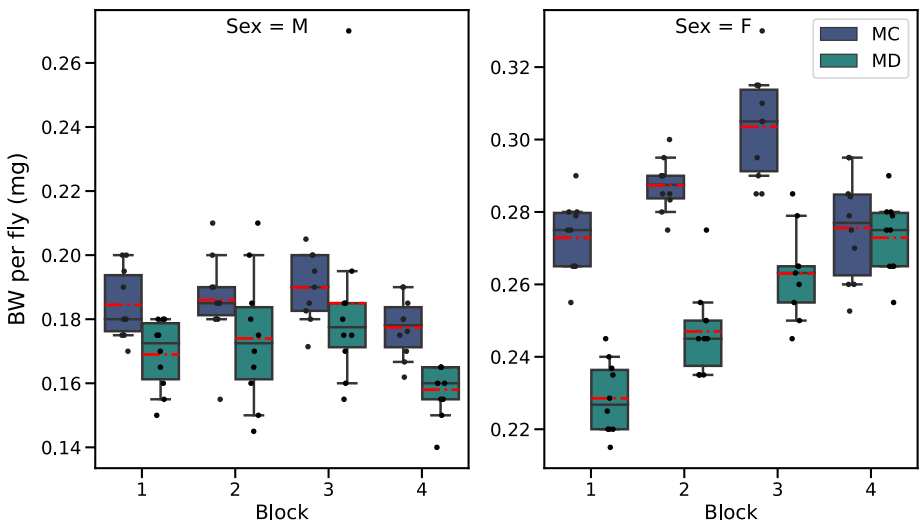




Lockdown and suspension of selection

Dry body weight

Three-way mixed-effects ANOVA
Population main effect: $F_{1,150} = 73.186; p = 1.233e-14$
Sex main effect: $F_{1,150} = 1189.076; p < 2.2e-16$
Popn-sex interaction: $F_{1,150} = 12.778; p = 0.0004713$



Resuming selection

- Locomotor phenotype is still detectable, body weight trends are unclear.
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- I plan to conduct smaller experiments for the time being-exploration and male-male aggression, and kit-based estimation of total glucose and triglyceride content.

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- Standardisation-consumption rate based on coloured dye uptake and recording-based approaches to measure time to starvation or dessication

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Conventional vs adaptive therapy

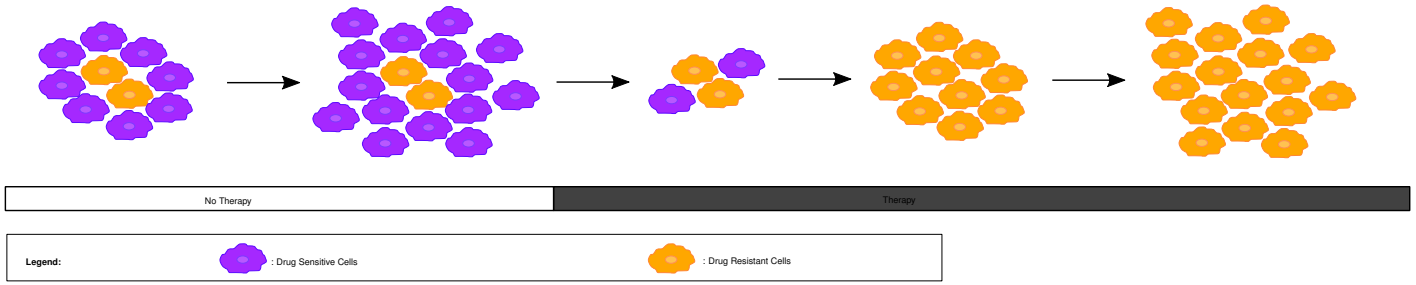

Figure 1: Drug at maximum dose-competitive release of resistant cells[1]

[1] Image courtesy: Harshavardhan BV

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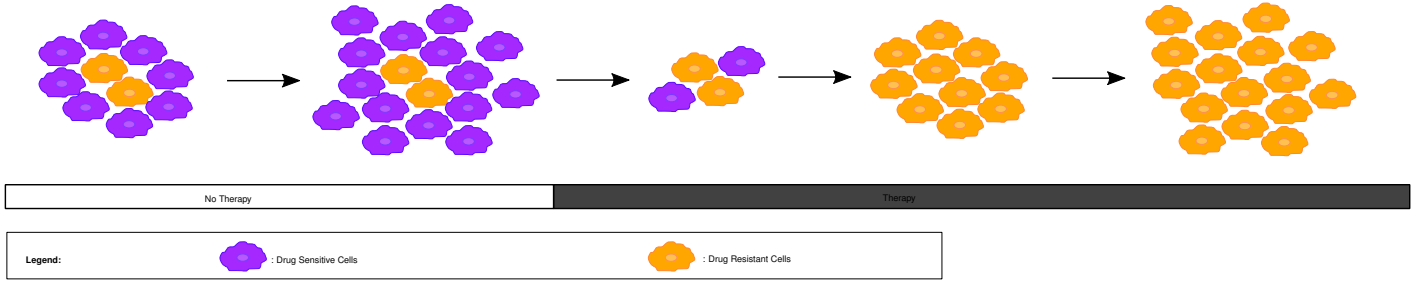

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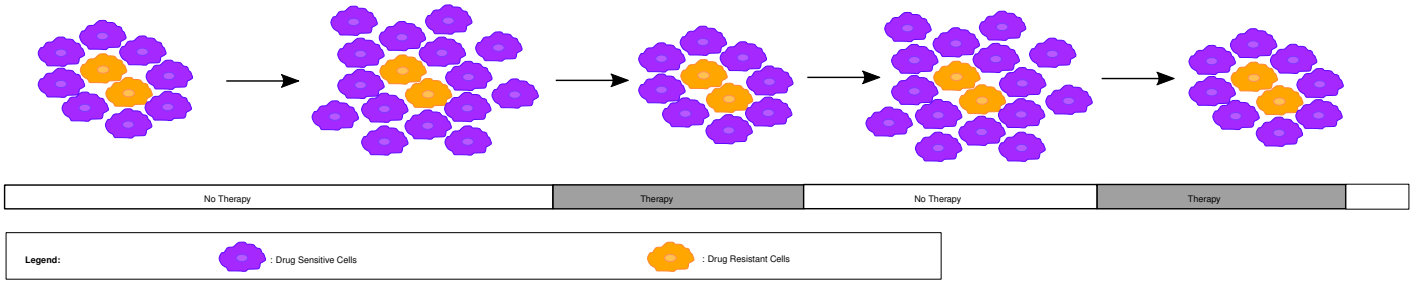

Figure 2: Adaptive therapy and *control through competition*[1]

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Ecological interactions in castration-resistant prostate cancer

- Early prostate cancer cells-dependent on testosterone supply for growth-treated by chemical castration

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- Early prostate cancer cells-dependent on testosterone supply for growth-treated by chemical castration
- Some cells acquire testosterone synthesis $\Longrightarrow$ castration resistance-treated with specific inhibitors
- Other cells become testosterone-independent in growth $\Longrightarrow$ resistant to inhibitors-treatment?

Ecological interactions in castration-resistant prostate cancer

Three cell types and two resources

- Oxygen-externally-supplied resource
- Testosterone-produced internally
- T^+-testosterone-dependent, but not producing
- T^p-testosterone-dependent, also producing as a public good
- T^--testosterone-independent

This work was done with Harsha, a Master's student in the lab.

A mathematical framework

For $i \in \{T^+, T^p, T^-\}$

$$\frac{dy_i}{dt} = r_{i,max} y_i (1 - \frac{\sum_j y_j}{1 + K_{i,max} f_i(O_2) f_i(T)}) - \delta_i y_i \quad (1)$$

For $R \in \{O_2, T\}$

$$f_i(R) = \begin{cases} 1 & \text{if } ul_{R,i} \leq R \\ \frac{R - ll_{R,i}}{ul_{R,i} - ll_{R,i}} & \text{if } ll_{R,i} < R < ul_{R,i} \\ 0 & \text{if } R \leq ll_{R,i} \end{cases} \quad (2)$$

$$\frac{dO_2}{dt} = p_{O_2} - \sum_i \mu_{O_2,i} y_i - \lambda_{O_2} O_2 \quad (3)$$

$$\frac{dtest}{dt} = p_{test}(abi) y_{T^p} - \sum_i \mu_{test,i} y_i - \lambda_{test} test \quad (4)$$

A mathematical framework

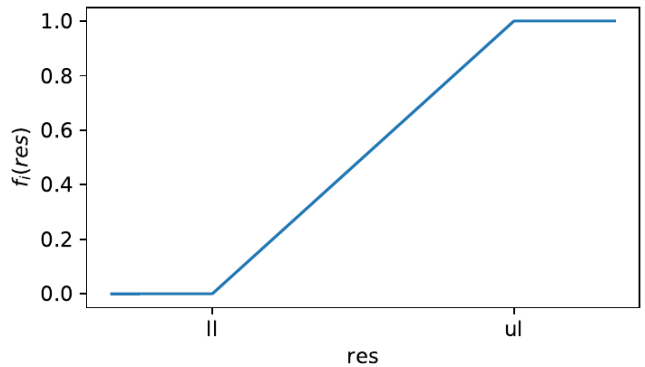
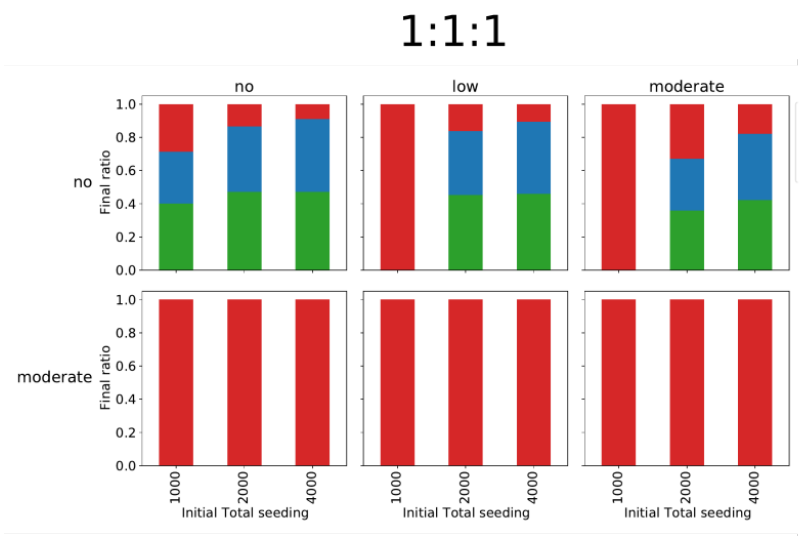


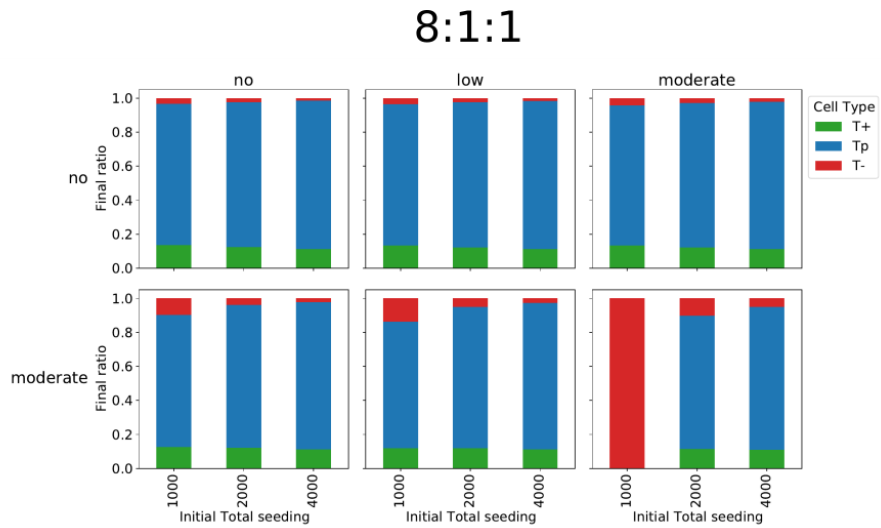
Figure 3: Response function for change in carrying capacity against resource concentration

Parameterisation

Doubling times, consumption rates for oxgen and testosterone, and testosterone production rate for T^p were all derived from literature sources reporting empirical measurements in cell lines.

Competition is tuned by resource limitation





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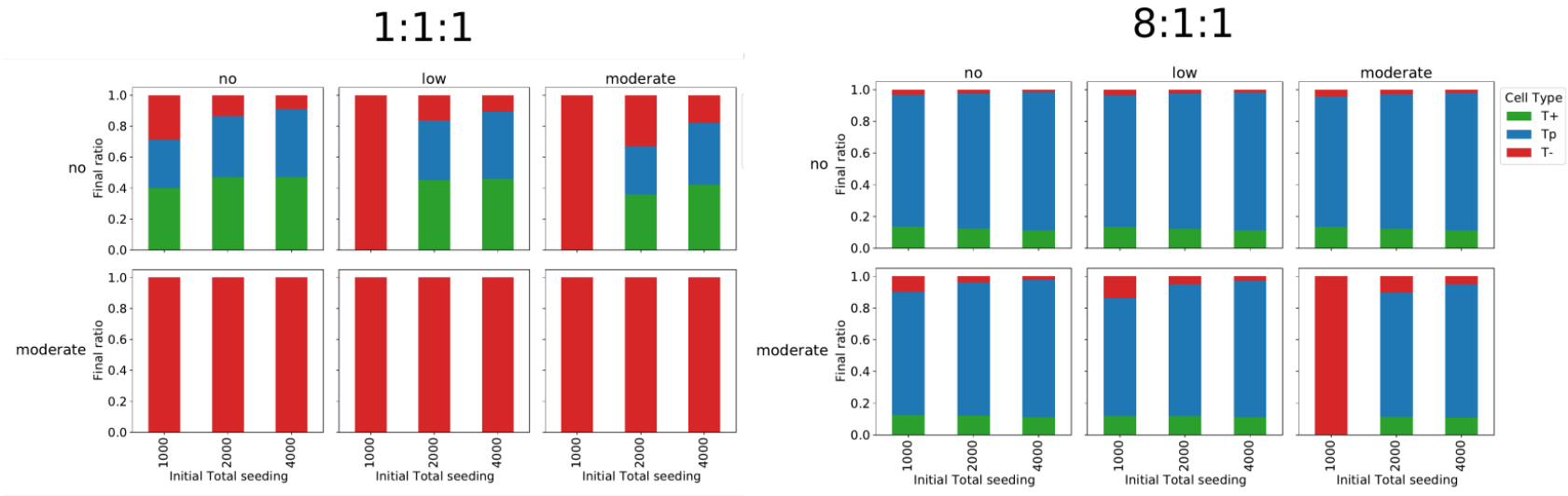

- Doubling rates scale as T^-<T^+<T^p, but T^- doesn't win by default.
- Resource limitations can be used to tune co-existence.

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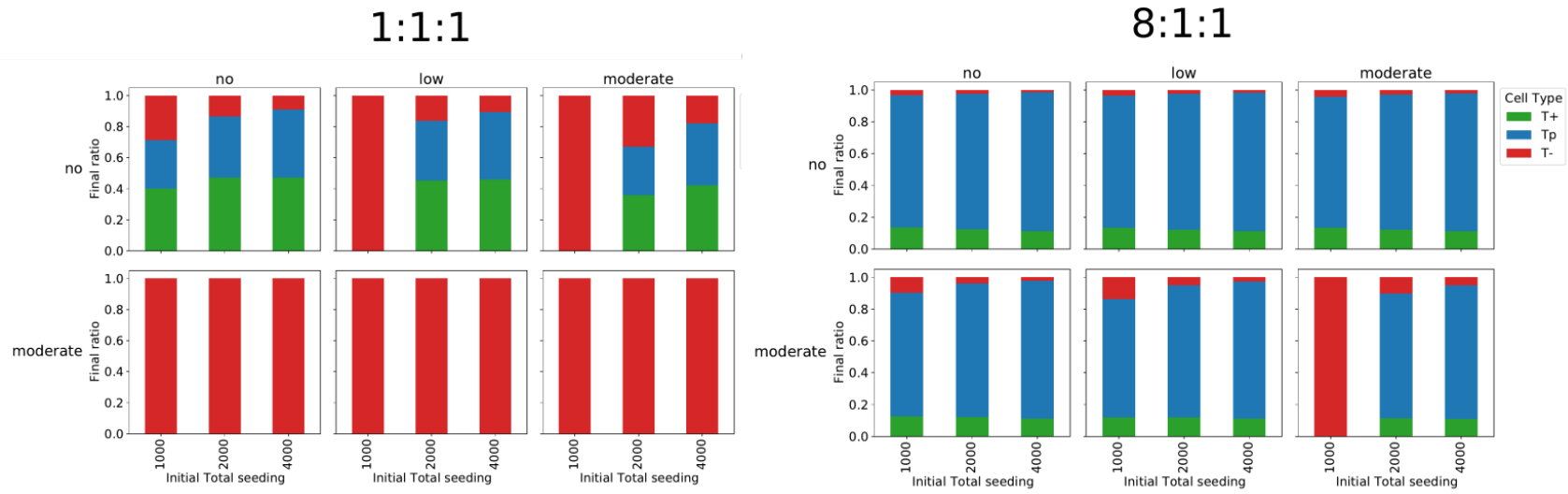

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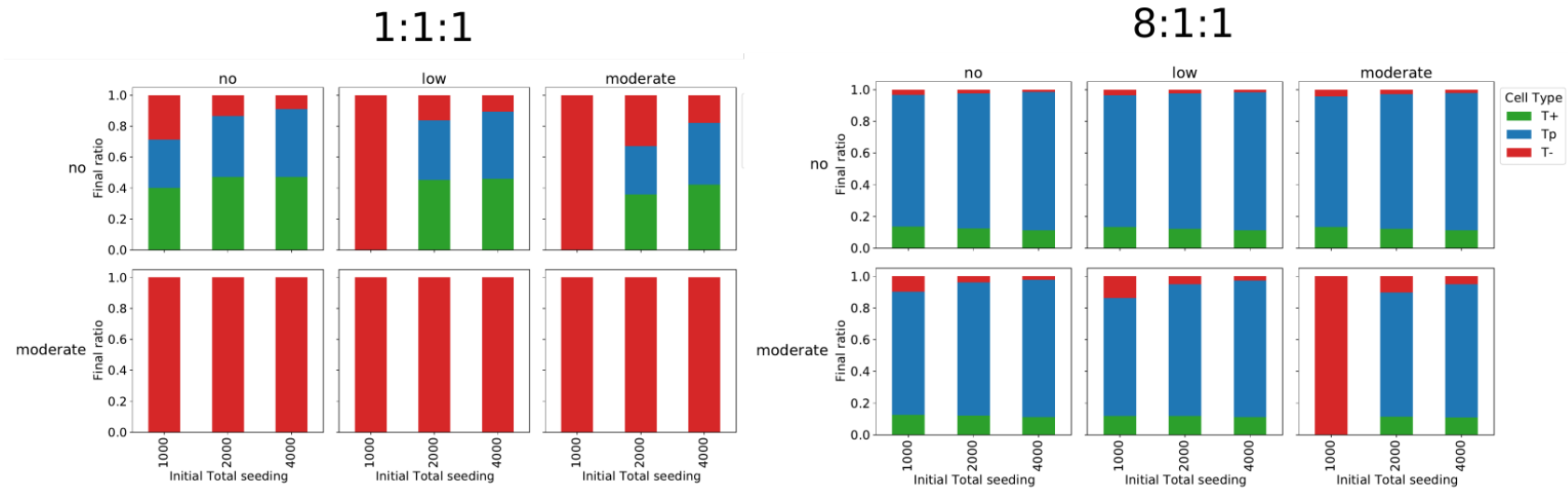

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- Resource limitations can be used to tune co-existence.
- Testosterone is the stronger limiting resource in this system.
- Higher T^- proportion makes tumours harder to treat and more unresponsive.

Further development

- A resource-consumer model without explicit carrying capacity terms-parameterisation is ongoing
- Further exploration of therapy parameters in the same model-rules of on and off, frequency, multi-drug combinations
- Spatial dynamics-a discrete reaction-diffusion system is being considered at the moment

All three lines are being developed with undergraduate students from IISER Pune.

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Patterns in cancer incidence

Trends across species

- Body size as well as lifespan varies widely across species and taxa.
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- Cancer risk is not correlated to this variation (Peto, 2015).
- Lack of data and multiple disparate lines of theoretical inquiry
- How does greater number of cells or cell division cycles not increase risk of mutation and cancer?
- Selection on somatic mutations and clonal expansion are uncommon in current theory (Nowell, 1976).
- Neutral vs non-neutral somatic mutation accumulation

Patterns in cancer incidence

Within species-late-life decline

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Work on developing an agent-based model based on Erten and Kokko (2020) for both these questions is ongoing with a Master's student.

Timeline

- Lab change in 2019
- Pandemic and lockdown in 2020
- Multiple lines of active work that would take at least a year to complete

Erten, E. Y. and Kokko, H. (2020). From zygote to a multicellular soma: Body size affects optimal growth strategies under cancer risk. Evolutionary Applications *13*, 1593–1604.

Harding, C., Pompei, F. and Wilson, R. (2012). Peak and decline in cancer incidence, mortality, and prevalence at old ages. Cancer *118*, 1371–1386.

Nowell, P. (1976). The clonal evolution of tumor cell populations. Science *194*, 23–28.

Peto, R. (2015). Quantitative implications of the approximate irrelevance of mammalian body size and lifespan to lifelong cancer risk. Philosophical Transactions of the Royal Society B: Biological Sciences *370*, 20150198.

Rozhok, A. and DeGregori, J. (2019). A generalized theory of age-dependent carcinogenesis. eLife *8*, e39950.

Thank you for your attention.