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Simulating the Interruption of Transmission on Bioko Island

Daniel T. Citron

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TAG Meeting

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UNIVERSITY of WASHINGTON

Institute for Health Metrics and Evaluation

Overview

- Premise
  - Will the PfSPZ Vaccine be sufficient to interrupt local transmission?
  - Build a simulation model of malaria transmission on Bioko Island, calibrated to geospatial maps generated using MIS data

Simulation Model Rationale

- Scenario planning
- A guide to understanding efficacy of adding new interventions
  - Can compare outcomes from many different potential plans
  - Can quantify uncertainty in different outcomes
- Carefully calibrated to data
  - Malaria Indicator Survey
  - Geospatial Maps

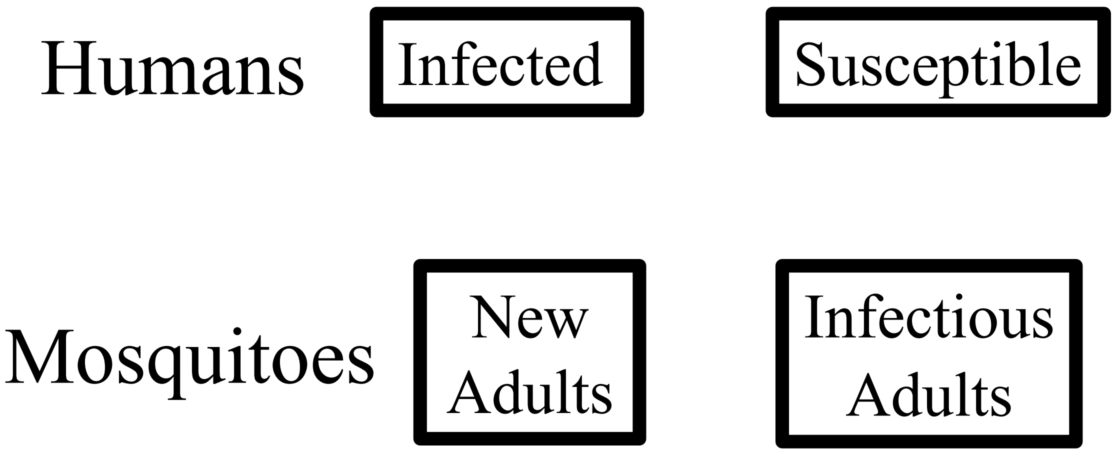
Our Model

- Based on Ross-Macdonald model
- Begin with human population

Humans | Infected | Susceptible

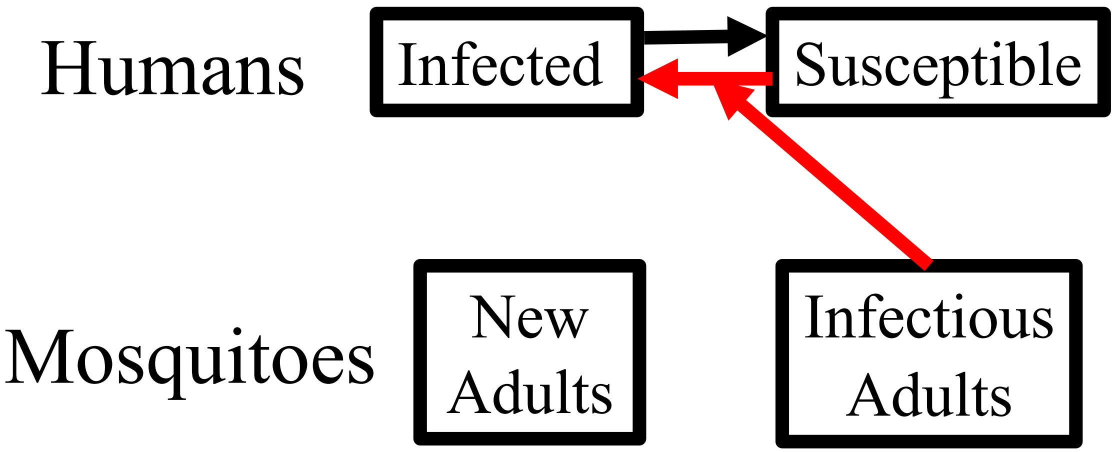
Our Model

- Add interactions with mosquito population



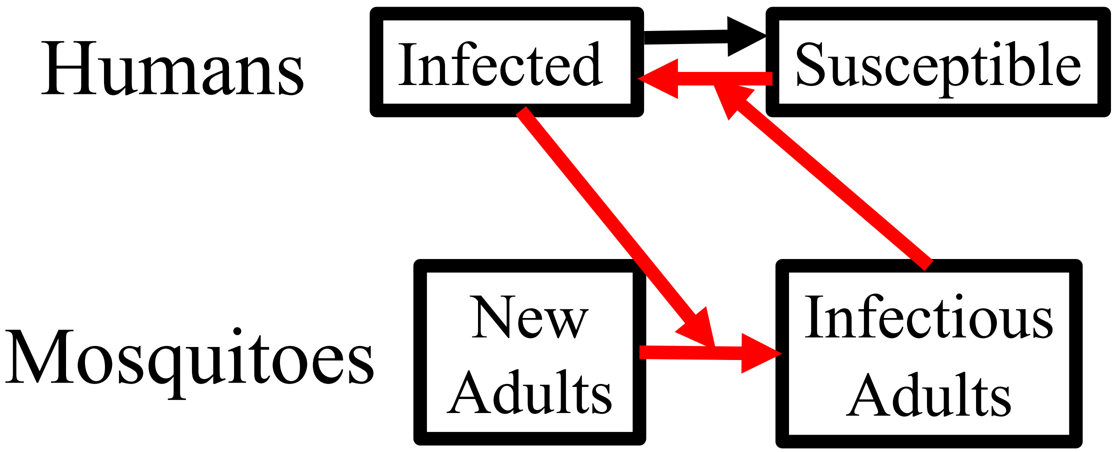
Our Model

- Infectious mosquitoes infect humans, who recover over time



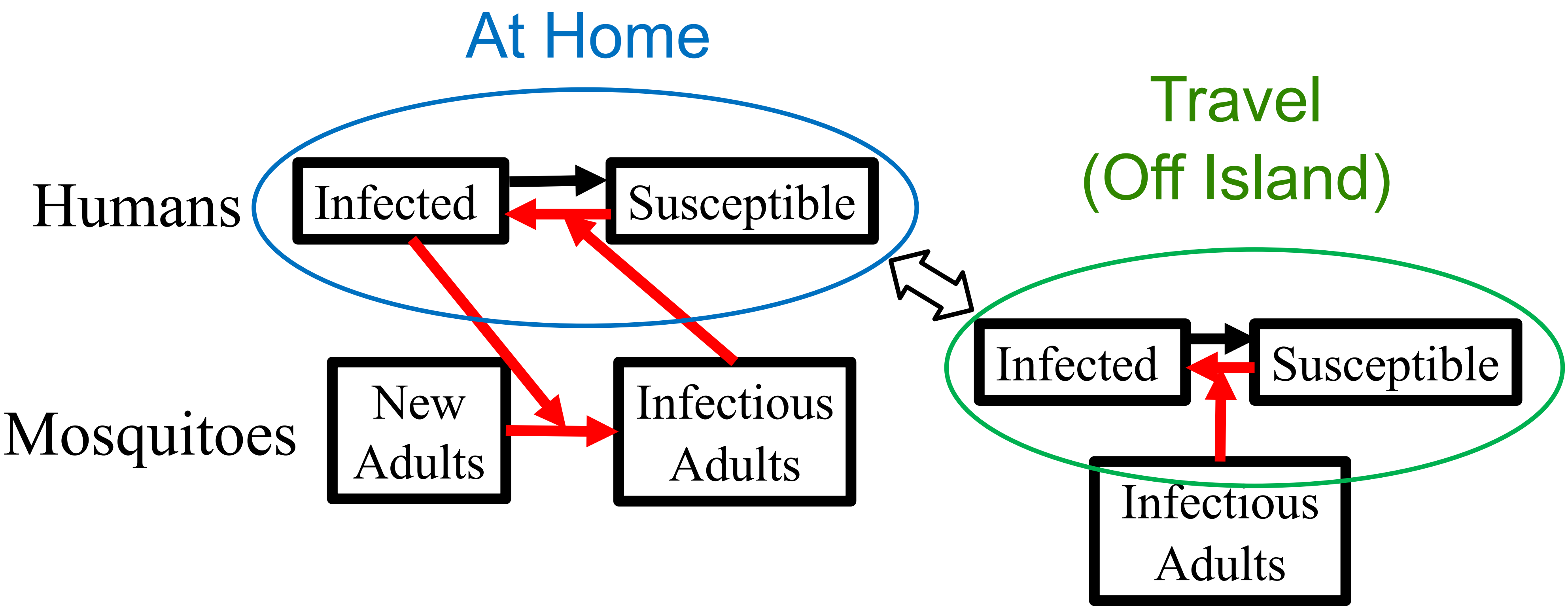
Our Model

- Humans also infect mosquitoes when they are bitten



Our Model

- Include human travel to other locations, imported infections



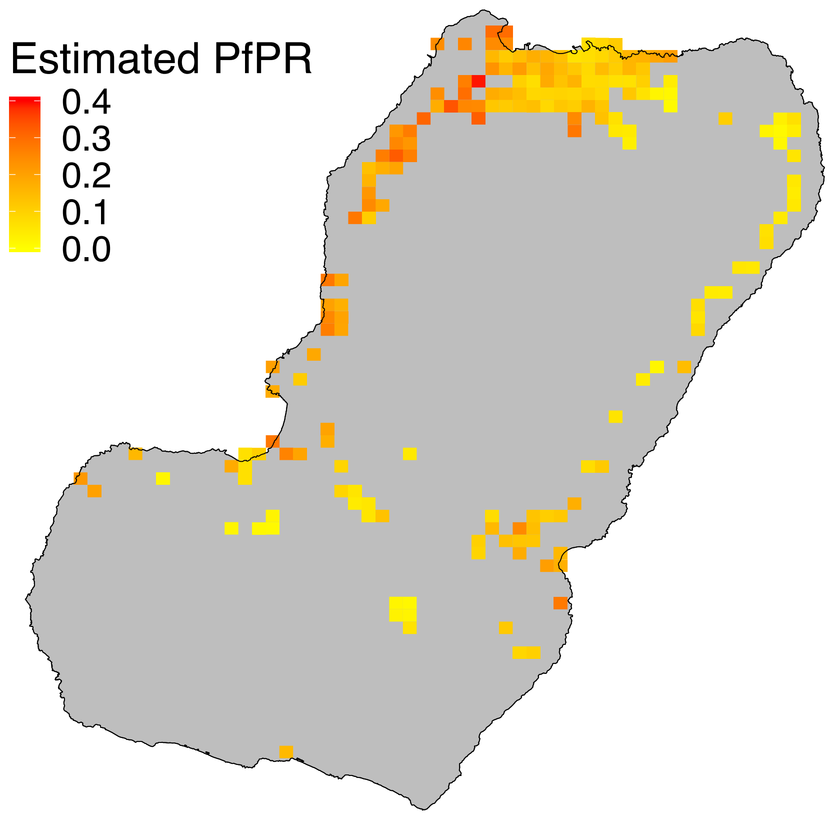
Model Calibration – area by area

Calibrate model for each 1km^2 area on Bioko Island

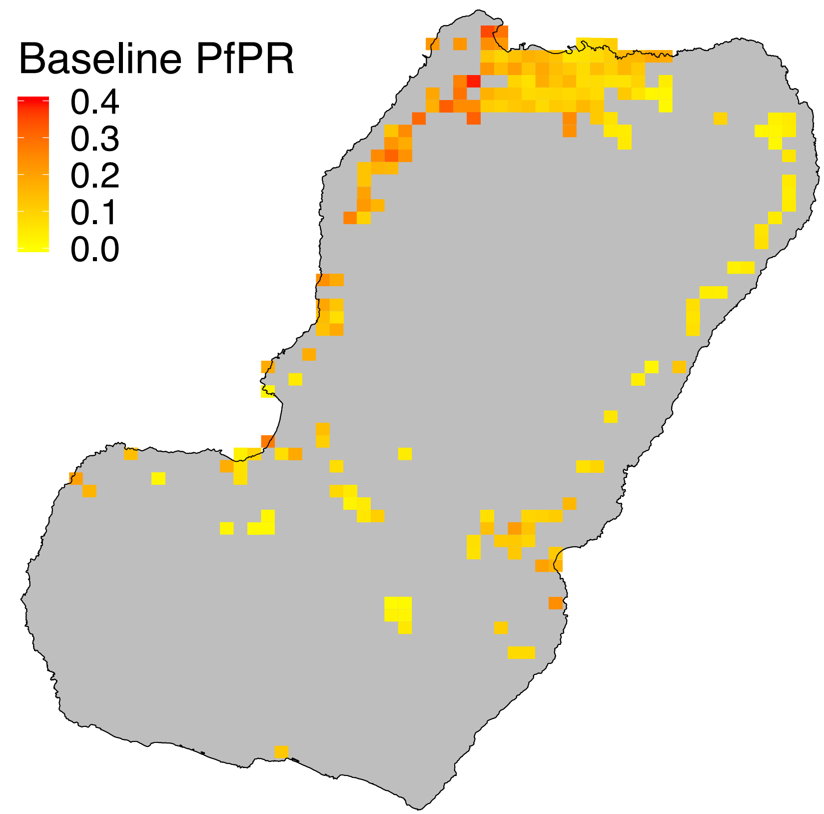
Features		Data Inputs
• Population	←	Population Census
• Prevalence	←	Geospatial estimates, PR
• Travel frequency	←	Geospatial estimates, travel
• Local Transmission	←	Geospatial estimates, PR & Travel
• Risk while traveling	←	Bata PR estimate (Ncogo et al. 2015)

Model Calibration – Matching PR

Geospatial Estimate Mean PR

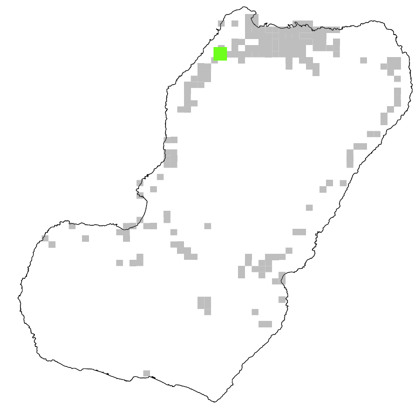


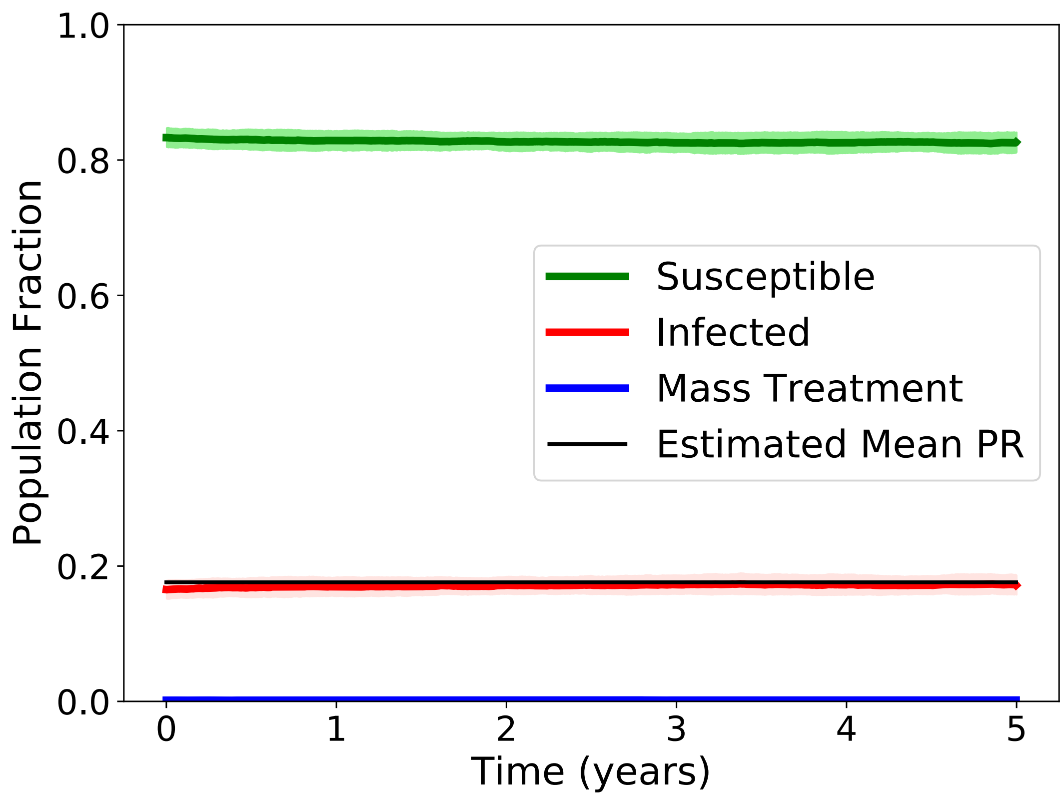
Calibrated Model Mean PR



Simulation results

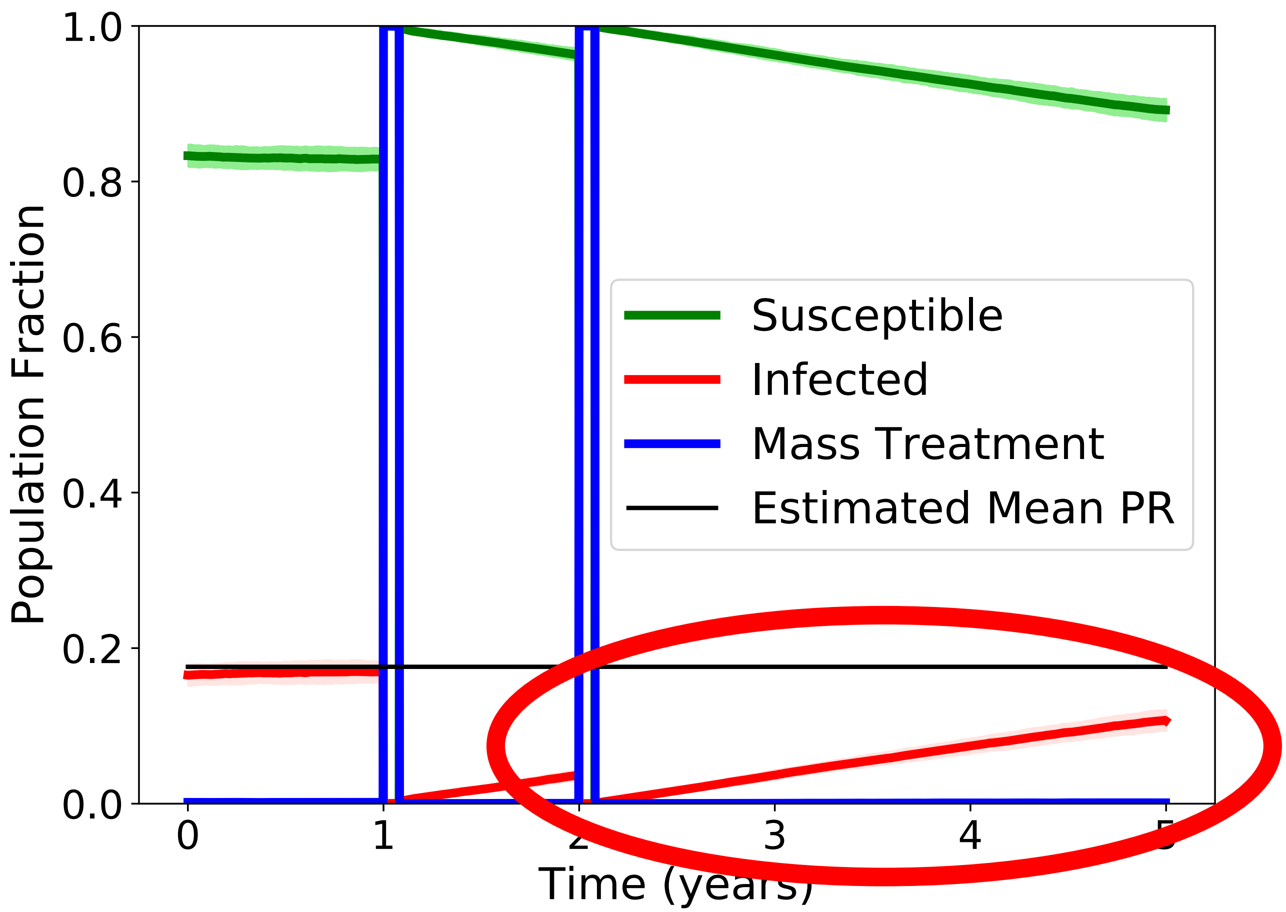
- Example: Basupu – 2028 people, PR = .18
- Baseline case with no interventions
- Ensemble of 100, plotting mean behavior





Adding Mass Treatment

- Mass treatment scheduled at start of years 2 and 3
- Clears infections, prevents new infections, lasts 30 days



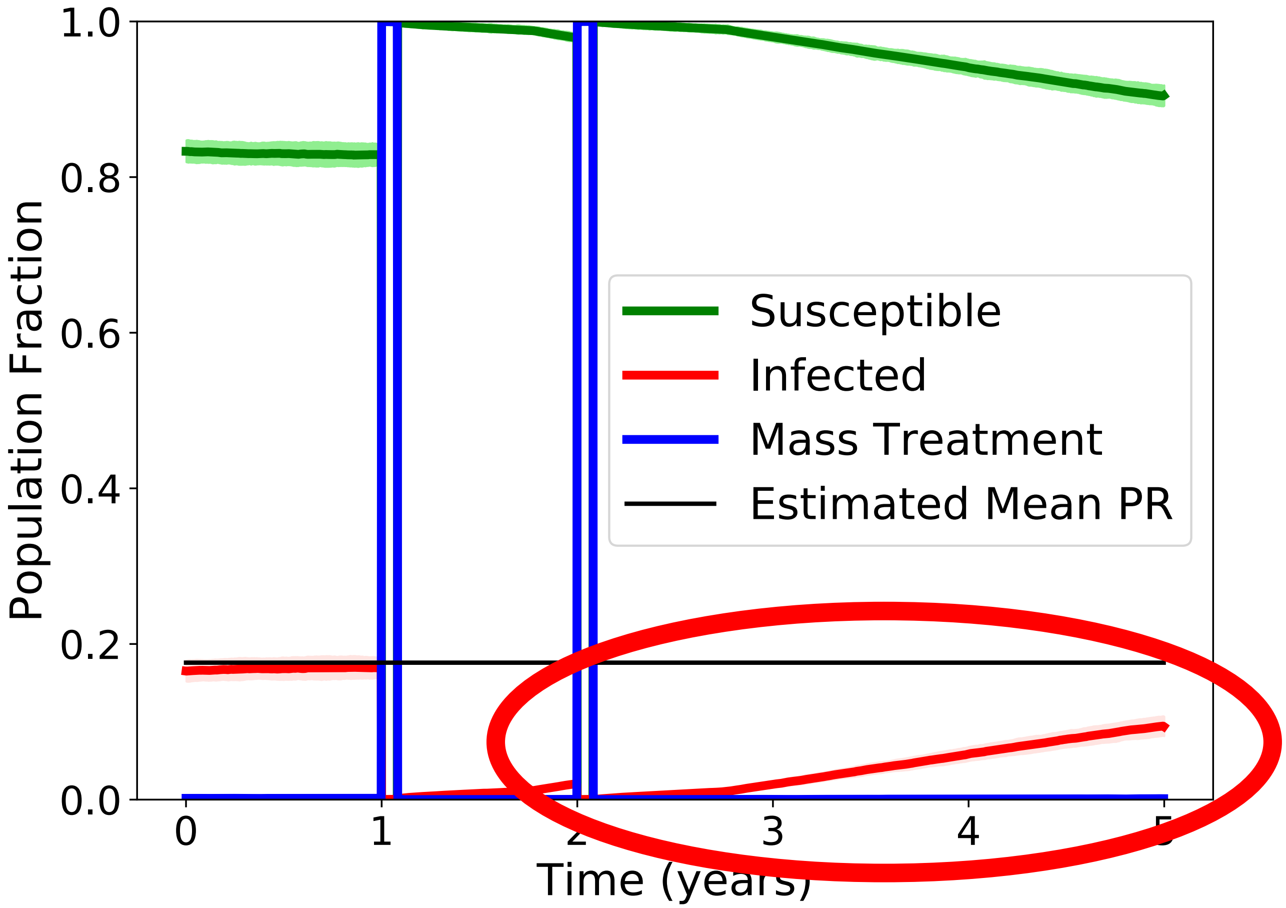
Effect of Imported Cases

Simulated PfSPZ Vaccine

- Schedule
  - Vaccinate at years 2 and 3
  - Accompany with mass treatment
- Assumptions
  - Vaccine remains effective for 9 months
  - 100% coverage – all people vaccinated
  - 50% of recipients granted 100% personal protective efficacy

Adding Vaccination

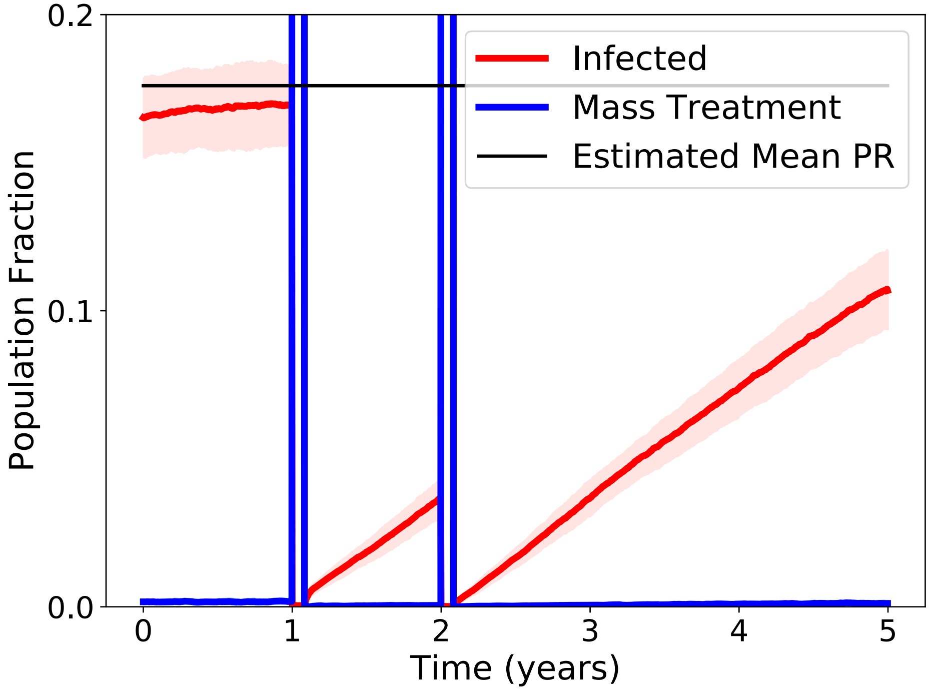
- 50% of recipients granted 100% personal protective efficacy



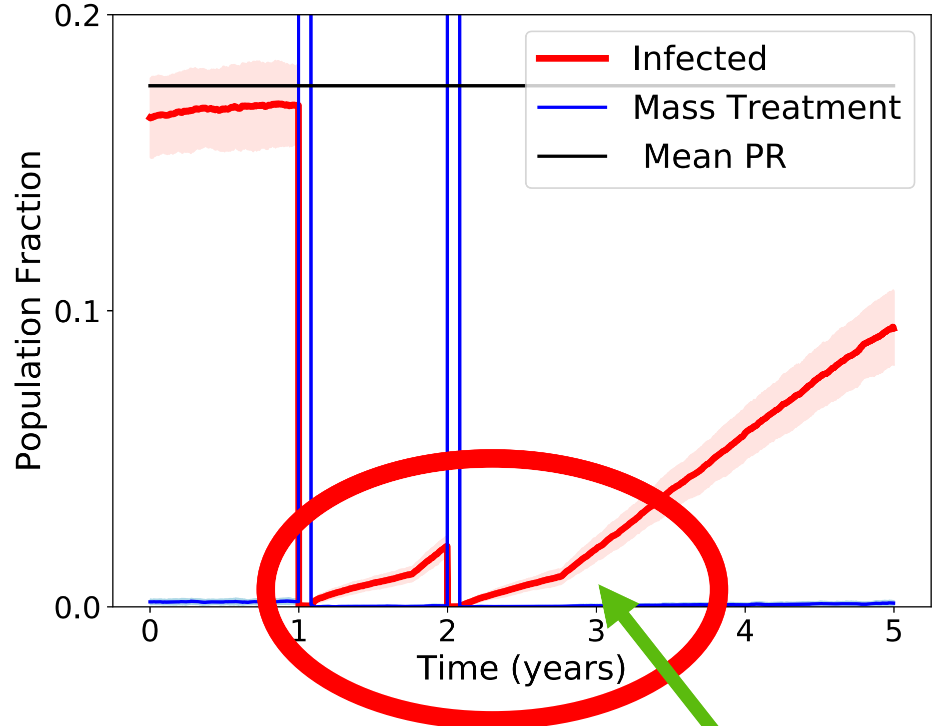
Effect of Imported Cases

Adding Vaccination

Mass Treatment Only



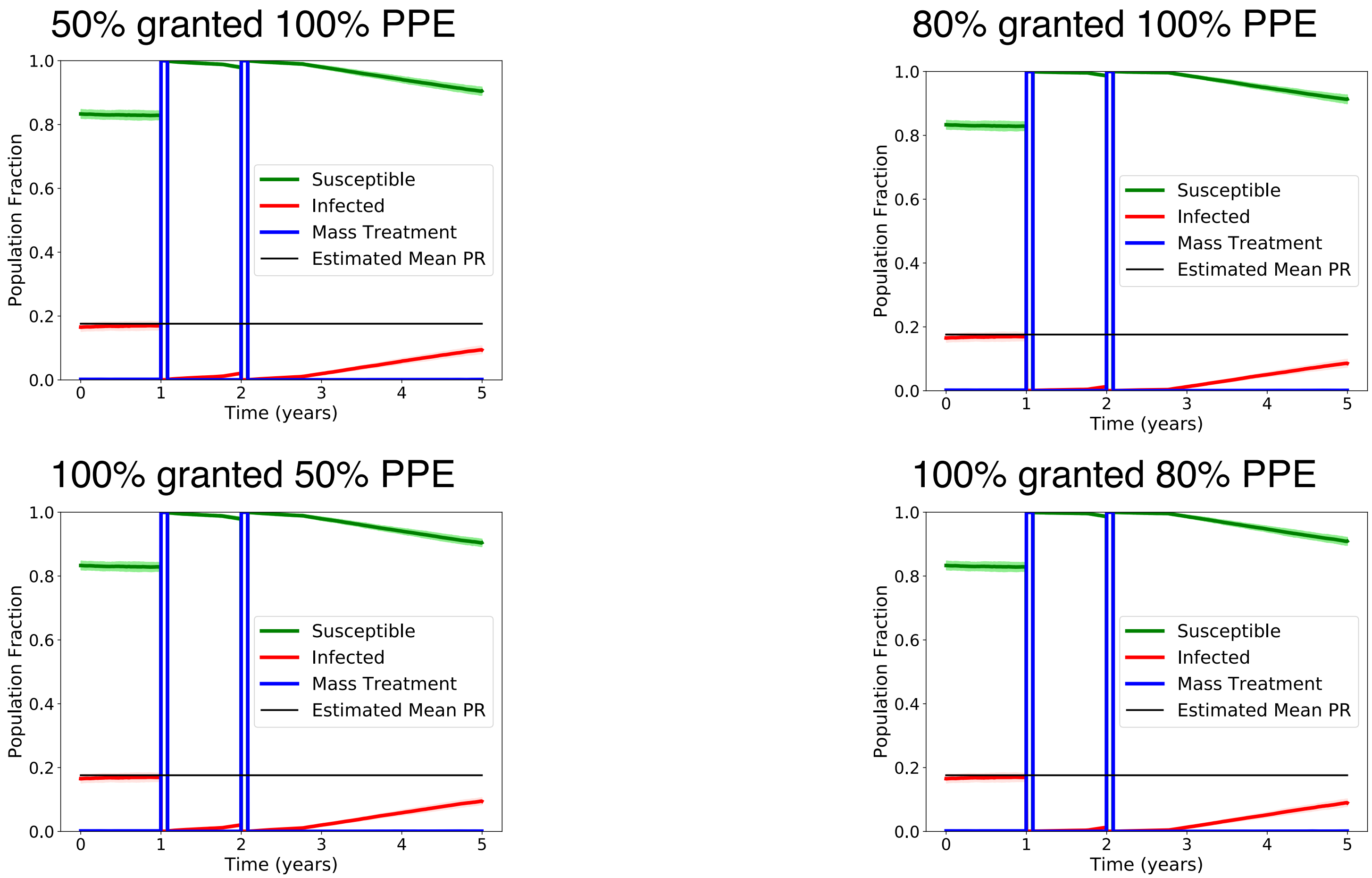
Adding Vaccination



- Improvement – slows down rate of new cases
- Not a permanent fix

Waning Vaccine

Results Robust to Varying Vaccine Efficacy

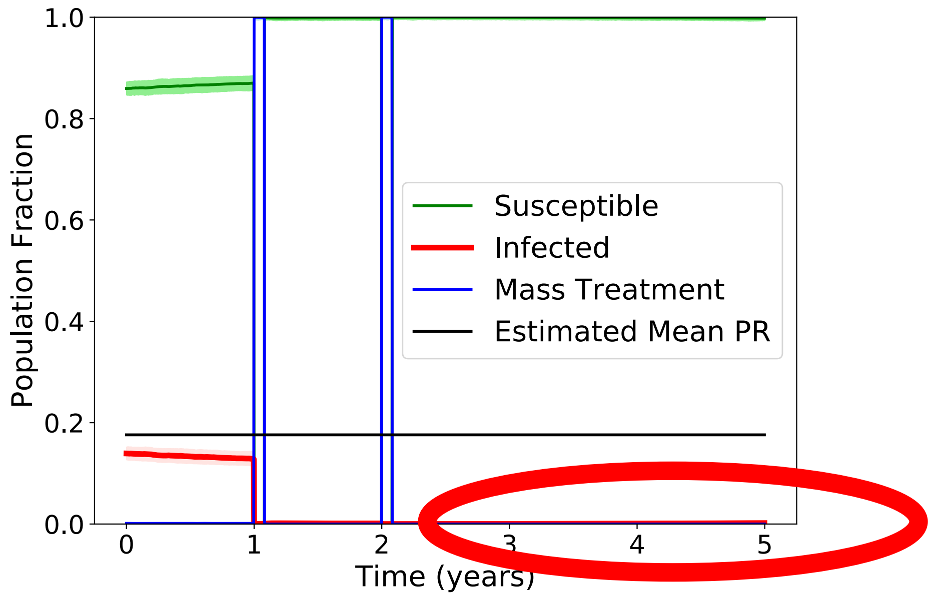


- Temporary protection limits long-term efficacy
- Reintroduction through importation occurs in all cases

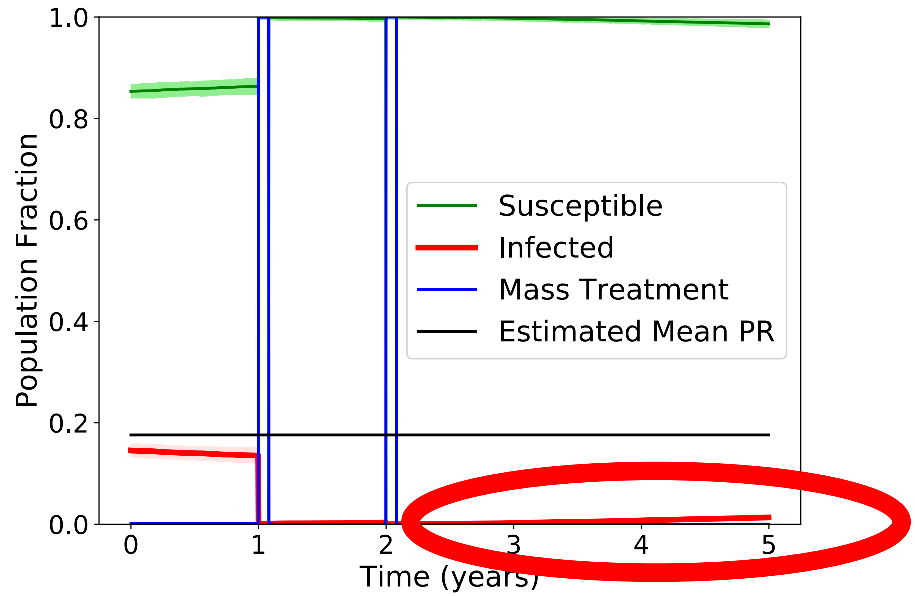
Reducing Imported Cases

- Reduce number of imported infections
- Following vaccination, importations drive return of PR

100% Reduction

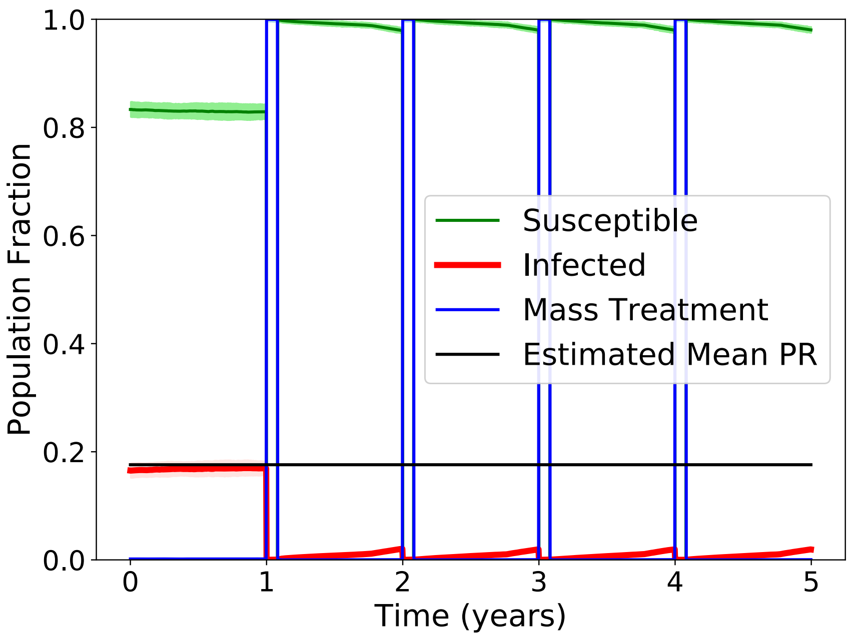


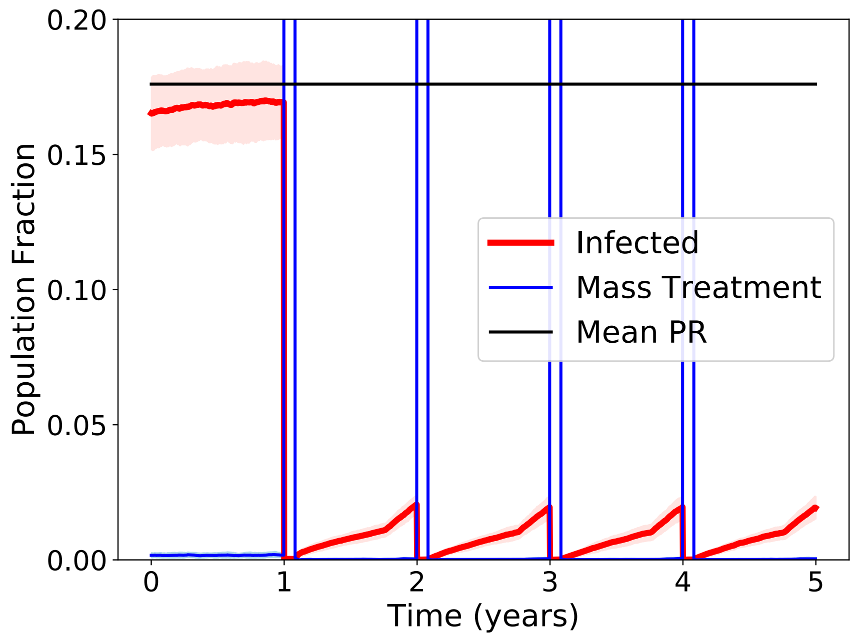
90% Reduction



Annual Distribution of Vaccine

- Vaccine slows rate of new cases in short term
- Possible that periodic re-distribution could contribute to sustaining reduced prevalence





Conclusion

- Is the PfSPZ Vaccine sufficient to interrupt local transmission?
- Our results:
  - Vaccine slows but does not stop transmission over long-term
  - Volume of imported cases appears to be too high
  - Reducing importations, or frequently re-distributing vaccine may hold transmission near zero

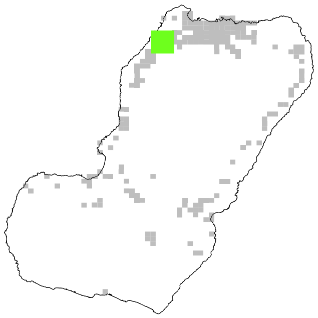
- Additional considerations and future work
  - Open to simulating additional proposed scenarios
  - Plan a full sensitivity analysis – assess robustness of conclusions
  - Tools for planning upcoming cluster randomized trials

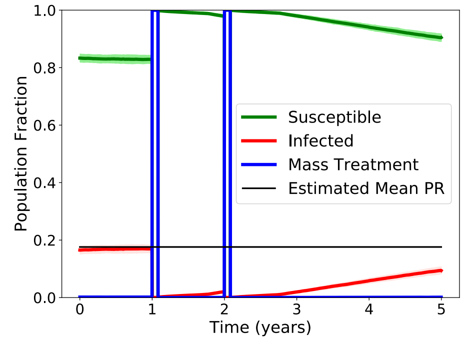
Acknowledgements

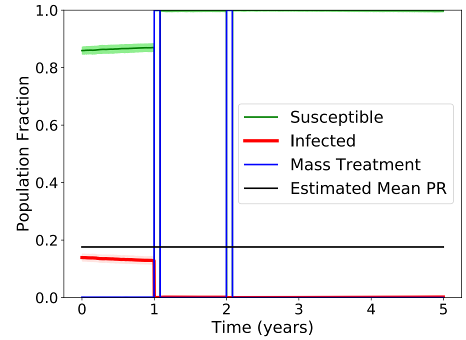
- Support provided by the BMGF
- Sean Wu (designed our software)
- David Smith
- Carlos Guerra
- Dianna Hergott & Guillermo Garcia
- Peter Billingsley & Stephen Hoffman

Results Robust Across Different Areas

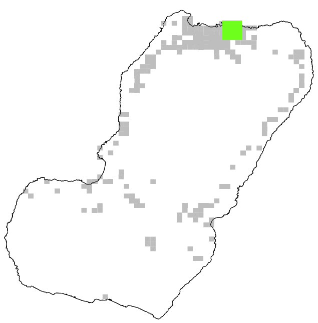
Basupu

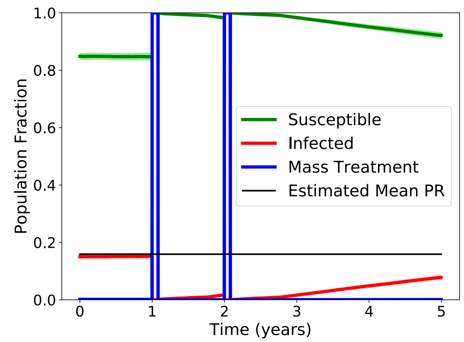


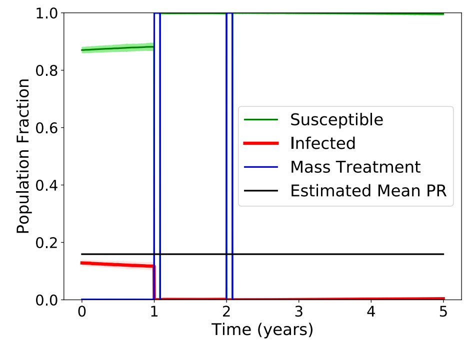




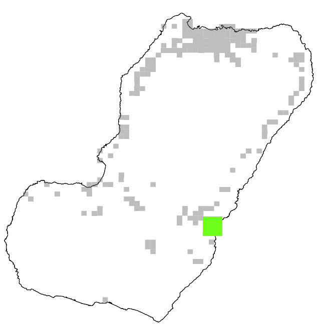
Malabo

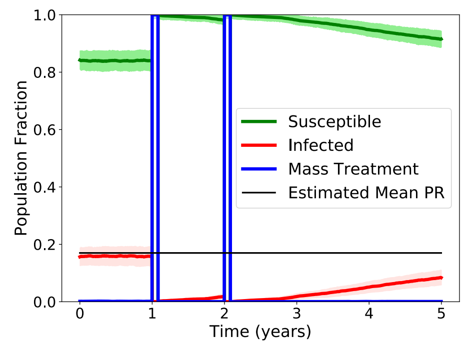


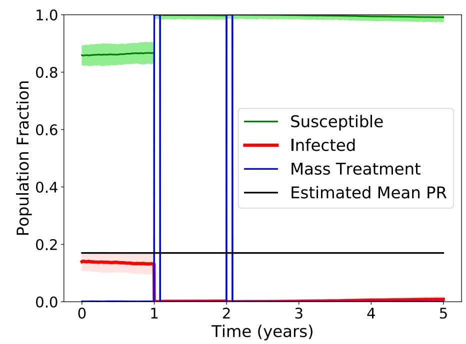




Riaba





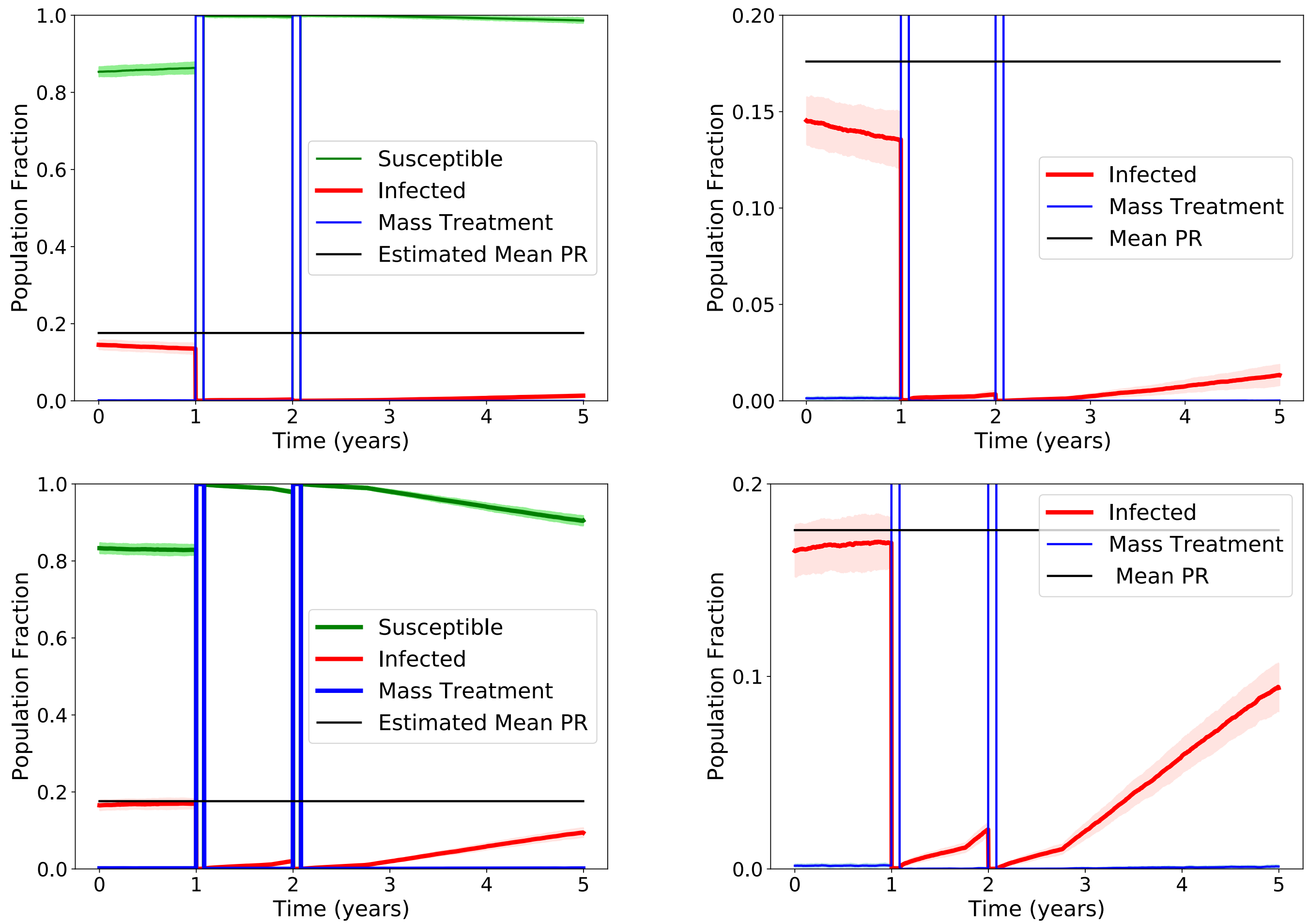


Reduced Importations

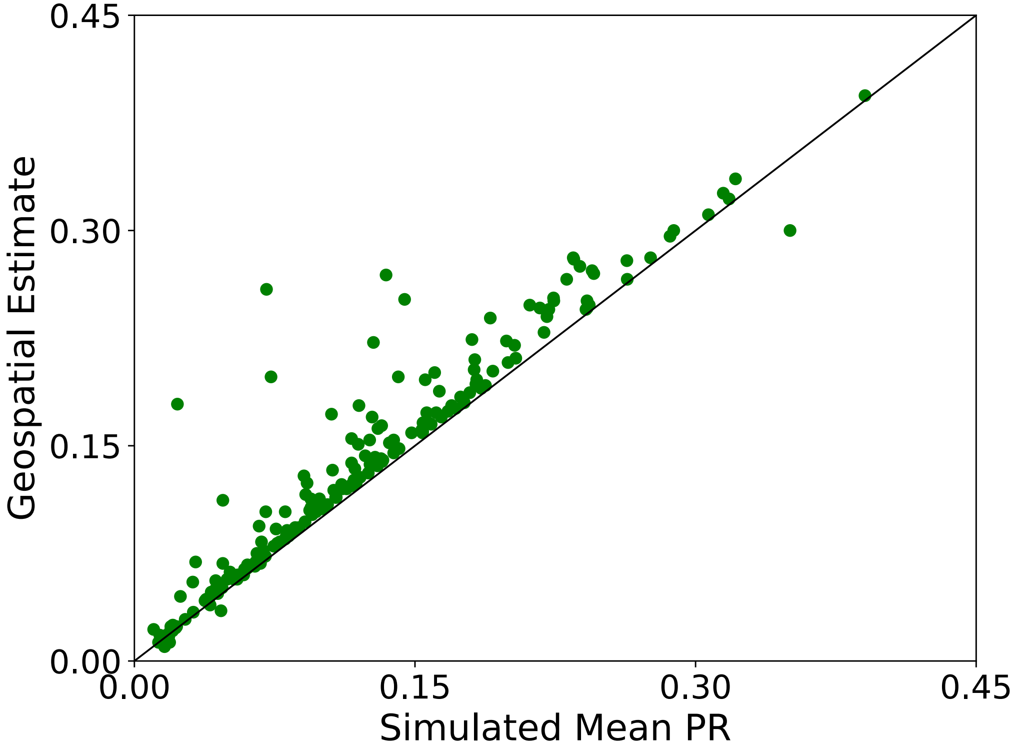
- Setting EIR on mainland to mean BI EIR – 90% reduction

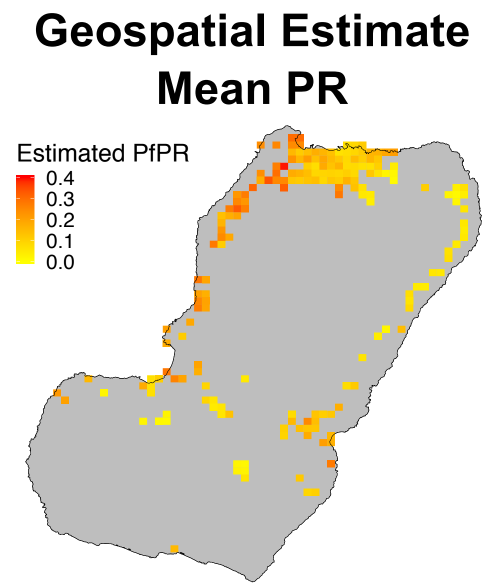
Reduced Importations

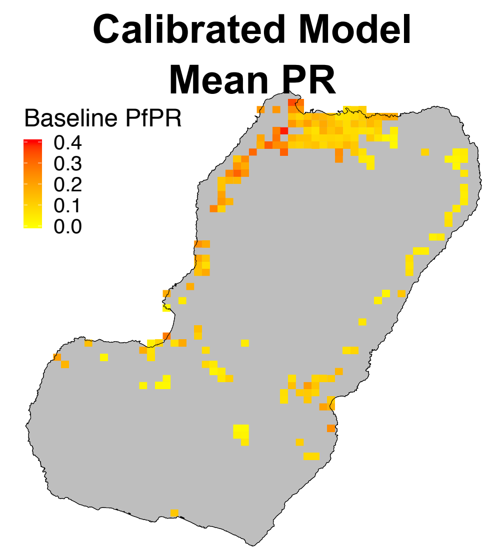
Current Importations



Model Calibration

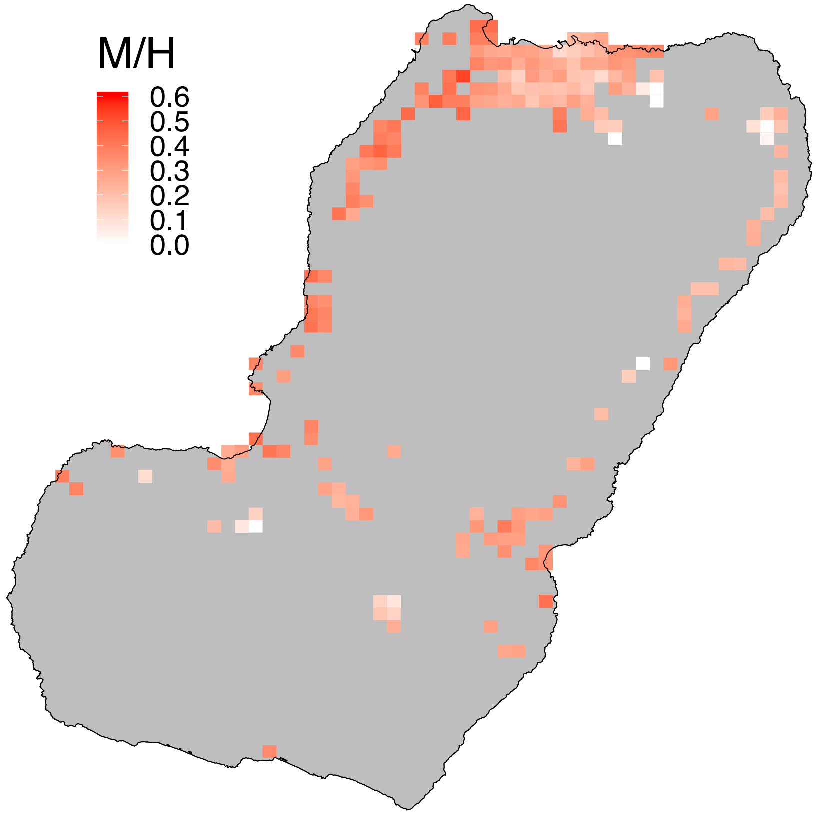






Mosquito Density

- Mosquitoes/Human, calibrated to PR using Ross-Macdonald
- Accounts for PR attributable to importations
  - Lower: East, Malabo, Moka
  - Higher: Northwest



Vaccines in the absence of importations

- Set number of infections imported from mainland travel to 0
- Rate of new infections extremely slow without importations