IHME
Measuring what matters

Applied Simulation Modeling for Interrupting Malaria Transmission on Bioko Island

Daniel T. Citron

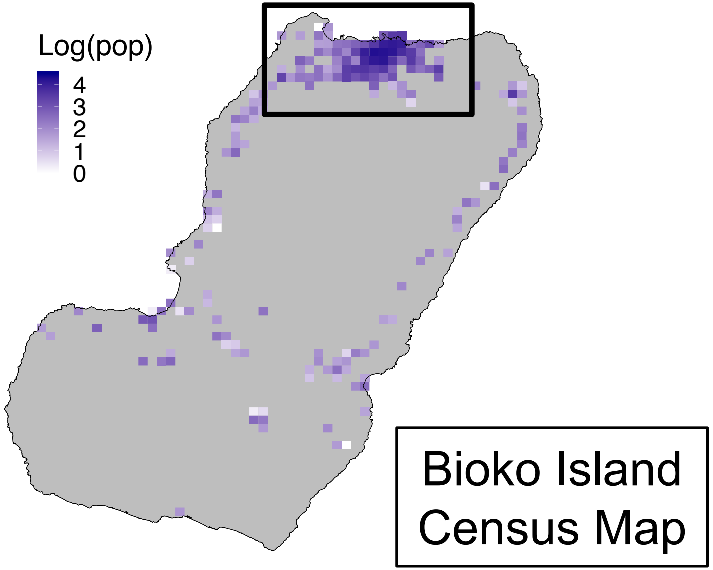
April 15, 2019

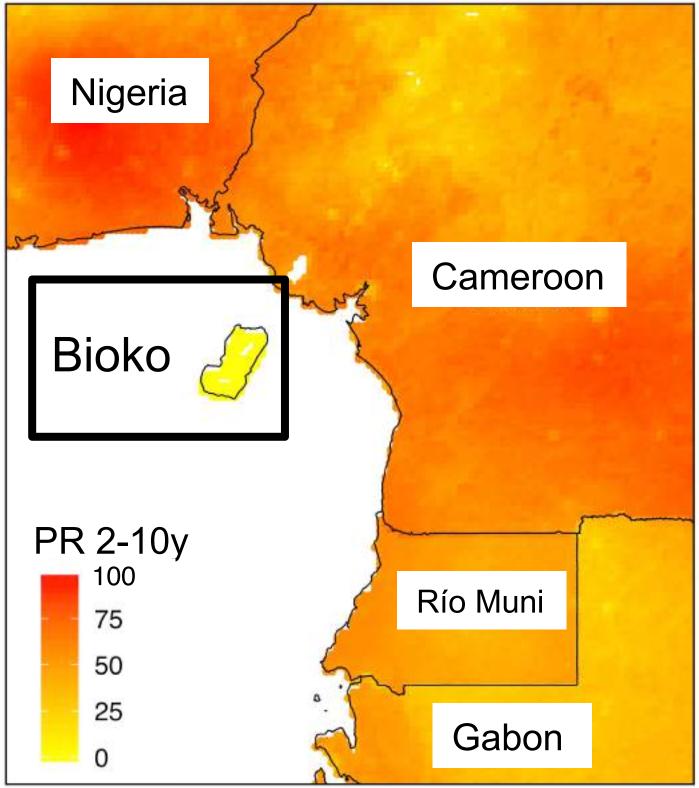
UNIVERSITY of WASHINGTON

Institute for Health Metrics and Evaluation

Bioko Island

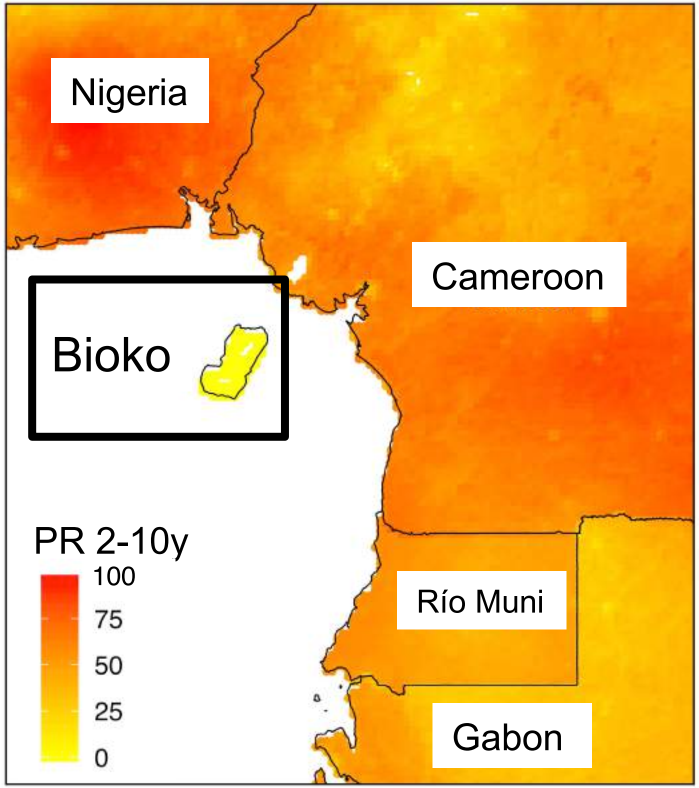
- Island Population: ~250,000
- Malabo Population: ~190,000





Malaria on Bioko Island

- PR = Parasite Rate, a measure of prevalence
- High risk region
- 2004 – Bioko PR ~ 40%
- 15-year control program, including:
  - Extensive surveillance
  - Extensive vector control
  - Freely available treatment
  - Capacity building
- Since 2015 – Bioko PR ~ 10%

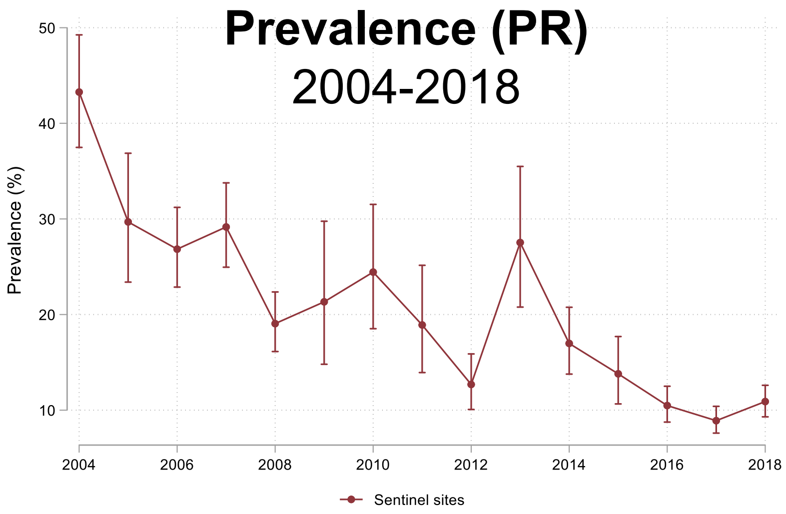


Bioko Island Malaria Elimination Program

- Program managed by MCDI
- Collect data in Malaria Indicator Survey:
  - Annual survey of ~15,000 residents
  - Parasite Rate
  - Travel history
- Close collaboration was crucial for understanding transmission environment

Key Questions

- The conundrum:
  - No reduction in PR since 2015
  - Why has progress stalled?
- What to do next?
  - Will adding vaccination to the current intervention package halt transmission on Bioko Island?
- What is the role of off-island transmission?
  - High risk among travelers from mainland EG
  - Few vectors in Malabo, yet malaria persists

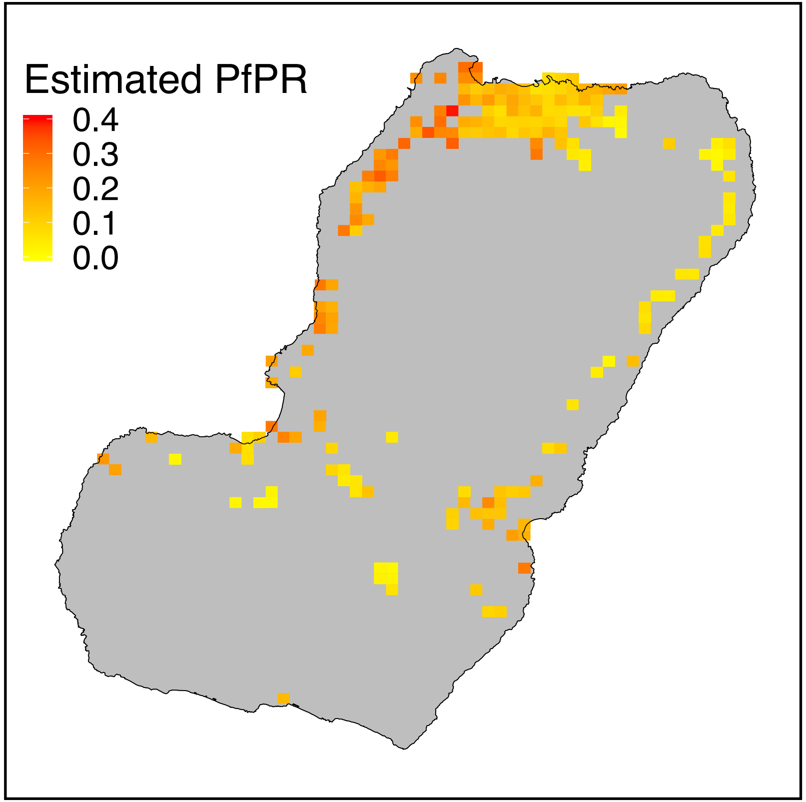


Modeling Methodology

- Begin with aggregated MIS data, 2015-2017
- Create geostatistical maps:
  - PR estimates
  - Travel behavior
- Use mechanistic models, calibrated to MIS and geostatistical maps
  - Geospatially explicit model of transmission
  - Include human travel between Bioko Island and Mainland EG
- Analysis:
  - Assess influence of cases acquired off-island with simple dynamical model
  - Simulate vaccination deployment scenarios

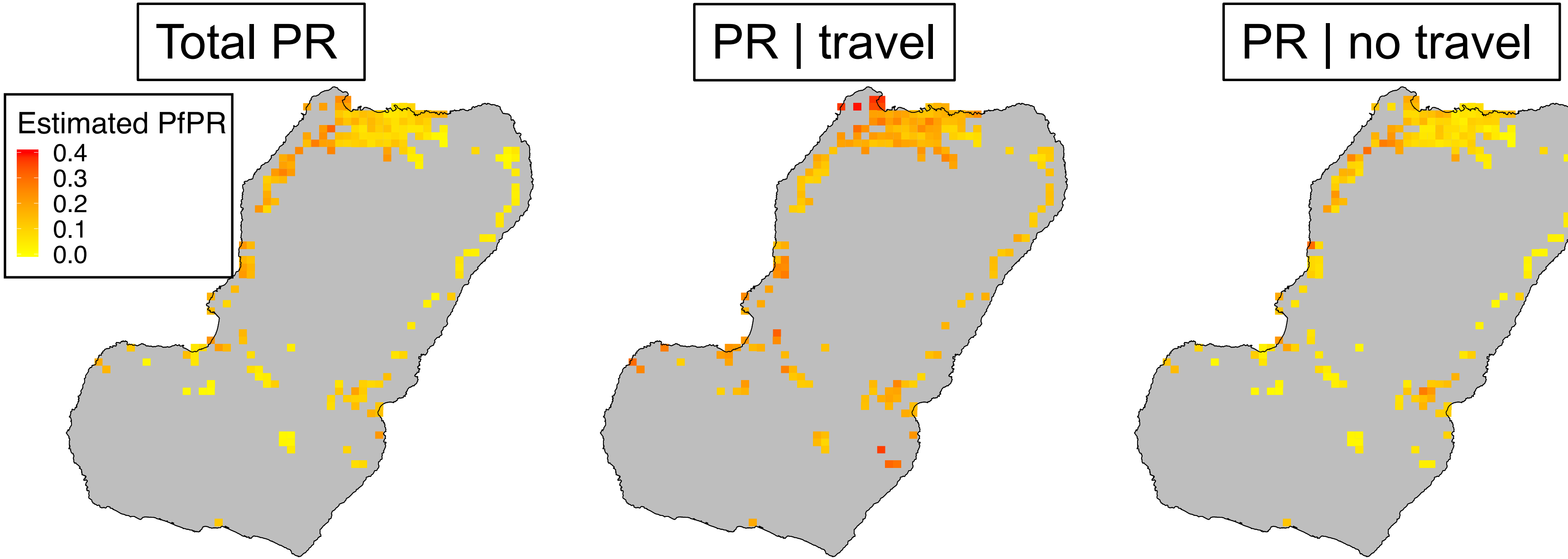
Mapping Malaria Prevalence

- Geostatistical prevalence mapping
  - Census
  - Survey data
  - Environmental covariates
- Estimate prevalence in each map-area
  - Captures km^2-scale variability in PR
  - Highest PR along northwest coast
  - ~10-14% in Malabo



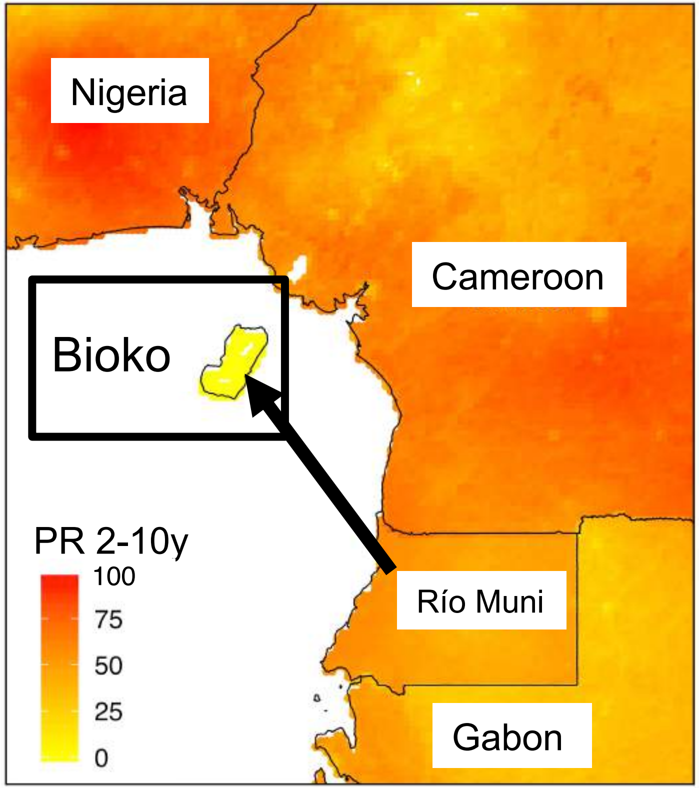
Prevalence Conditioned on Travel History

- Map PR, this time conditioning on recent travel
- Higher risk of malaria among those who traveled off-island



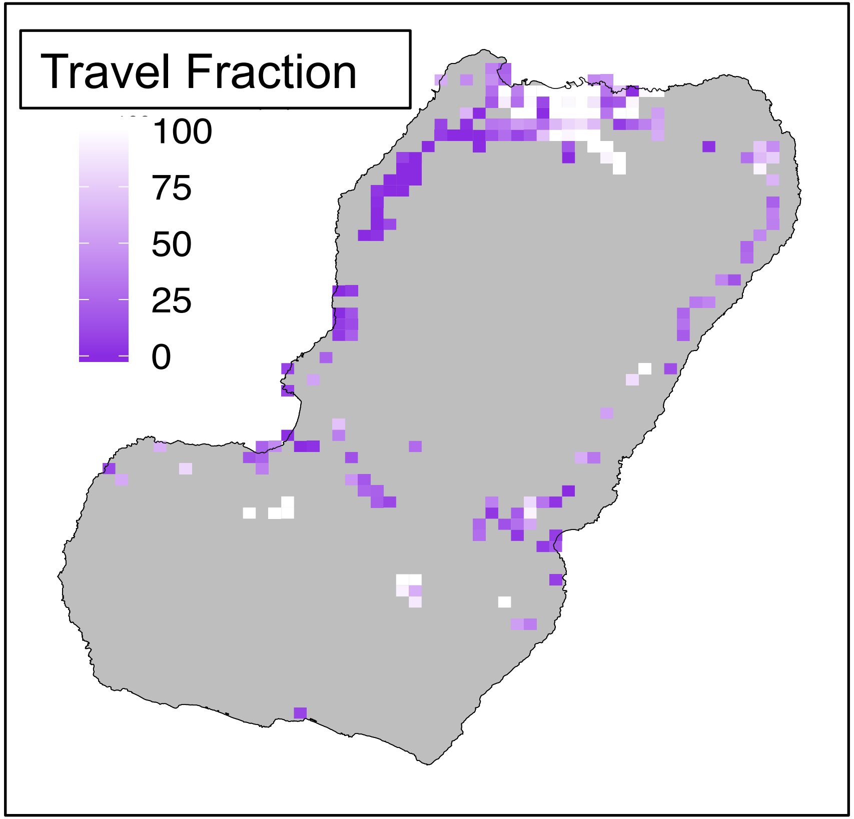
Influence of Off-Island Transmission

- Mainland EG has very high transmission risk
- Frequent off-island travel from Malabo
- How much of the prevalence seen on the island is attributable to travel?
- Use simple dynamical model
  - Ross-Macdonald
  - Include off-island infections
  - Calibrate based on PR + travel survey



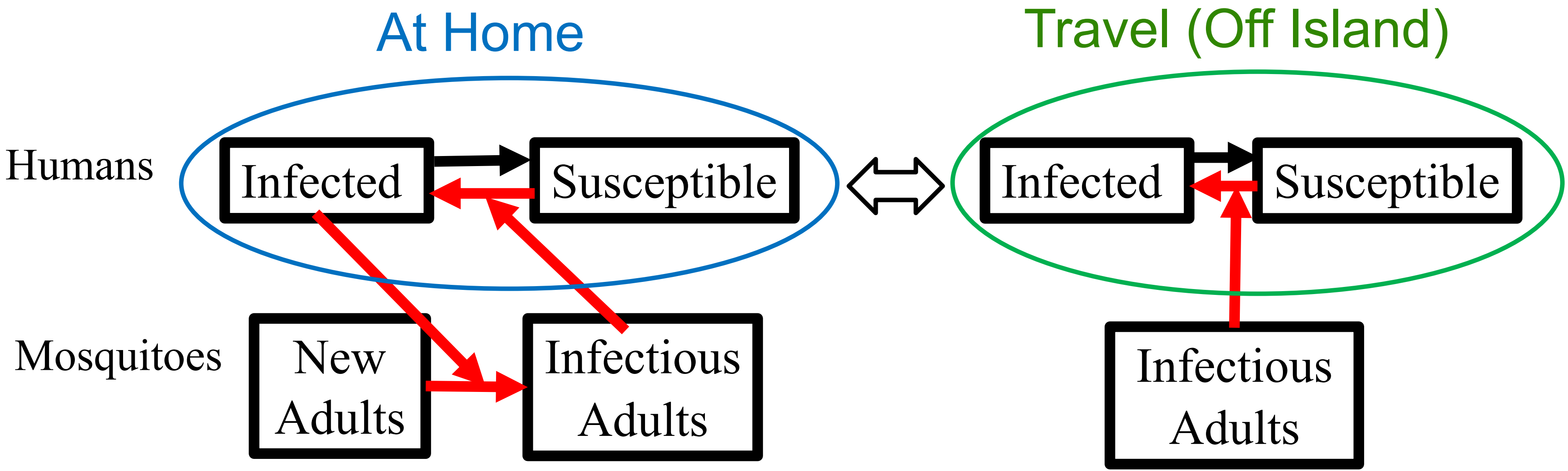
Influence of Off-Island Transmission

- Travel Fraction: % cases attributable to off-island transmission
- Malabo
  - High travel fraction (white)
  - Infections not occurring locally
  - Explains high prevalence and few viable vectors in urban area
- Malaria cases acquired off-island maintain PR in parts of Bioko



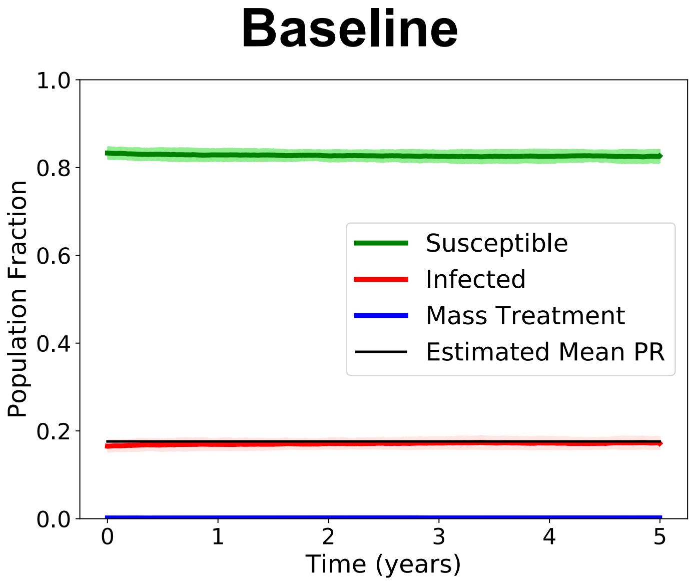
Effect of Additional Interventions

- Agent-based simulation model of malaria transmission
  - Allow individuals to travel, calibrated to travel survey data
  - Individuals come in contact with mosquitoes, transmit parasites



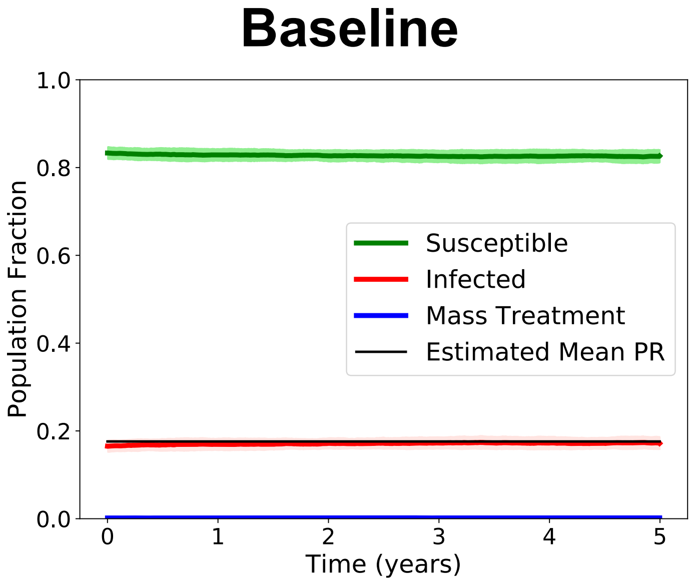
Simulation Modeling Results

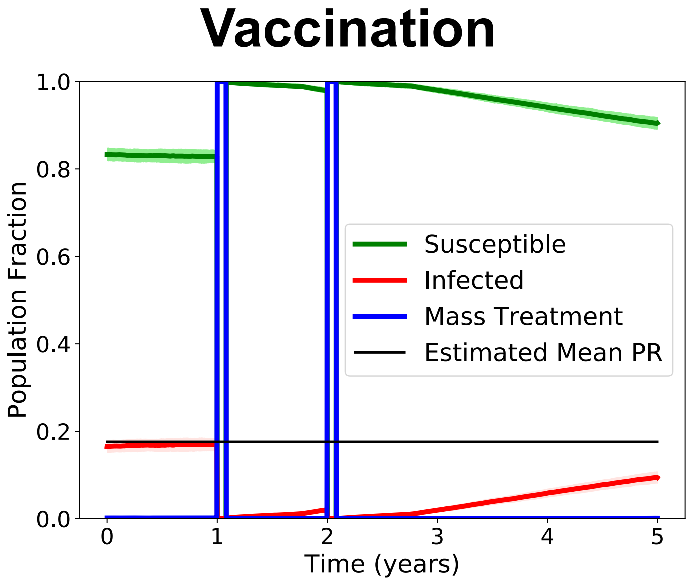
- Baseline: what would happen with no additional interventions
- Red: tracking mean prevalence over time



Simulation Modeling Results

- Adding vaccine + treatment, as a best-case scenario
- Malaria returns after a few years – unlikely to eliminate

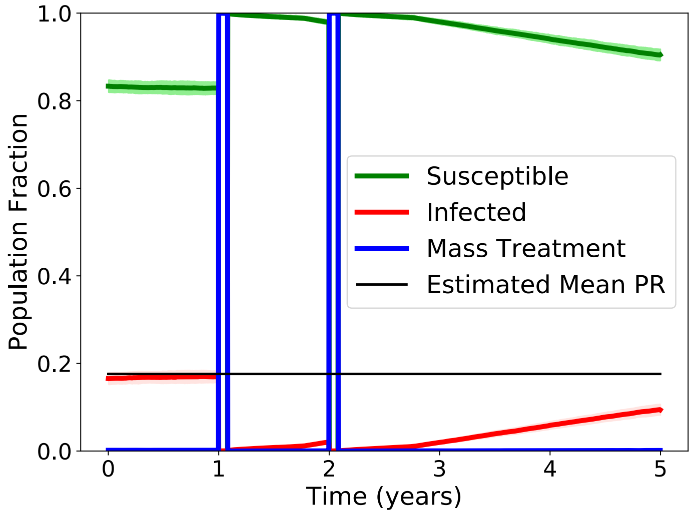




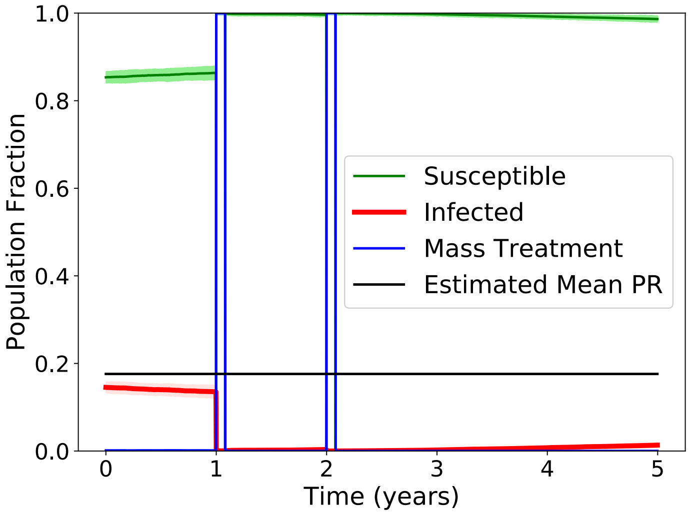
Simulation Modeling Results

- Simulated reducing risk of acquiring infections off-island
- Results robust to varying vaccine coverage and efficacy
- Addressing risk of returning with malaria may be more effective

Vaccination



Reduced Off-Island Risk



Conclusion

- Bioko Island malaria transmission reduced in many areas
- Continued elevated PR maintained by infections acquired off-island
- Vaccination + Mass Treatment campaign ineffective in long run
- Reducing off-island infections may be more effective

Next Steps

- Augmenting travel model with highly detailed 2018 MIS data
- Improving transmission model
- Extending sensitivity analysis to show robustness of results to data inputs

Acknowledgments

- Forthcoming: CA Guerra et al. *Nature Communications*

- Support from BMGF
- MCDI: Carlos A. Guerra, Guillermo Garcia, Julie Niemczura, Dianna Hergott,
  Jordan Smith, Megan Perry, Wonder Philip Phiri,
  Jose Osá Osá Nfumu, Jeremias Nzamio
- MAP: Su Yun Kang, Katherine E. Battle, Harry S. Gibson
- IHME: Sean Wu, David Smith