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Quantifying Malaria Acquired During Travel and Its Role in Malaria Elimination on Bioko Island

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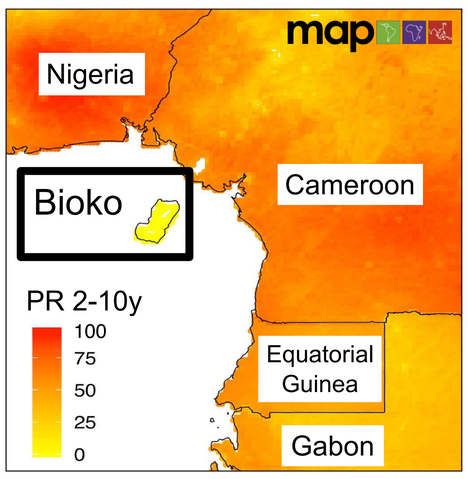
SUMMARY

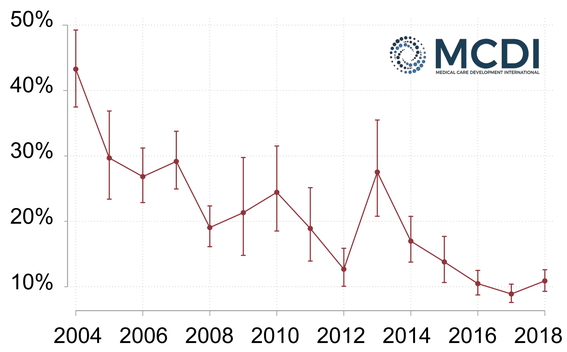
- **We have created a simulation model of malaria transmission across Bioko Island, Equatorial Guinea which accounted for spatially heterogeneous transmission and human travel patterns.**
- **The simulation was calibrated based on geostatistical estimates of malaria prevalence, which in turn were based on RDT samples from annual malaria indicator surveys (MIS) collected 2015-2018.**
- **The simulation model revealed that elevated risk among travelers was sufficient to explain a large fraction of cases on Bioko Island.**
- **We also used the simulation model to predict the impact of future interventions, and found that reducing risk of infection among travelers may be effective in further reducing malaria prevalence on Bioko Island.**

EPIDEMIOLOGICAL CONTEXT

Bioko Island, Equatorial Guinea



Prevalence (PR, 2-14y)
Sentinel Site Surveillance
2004-2018

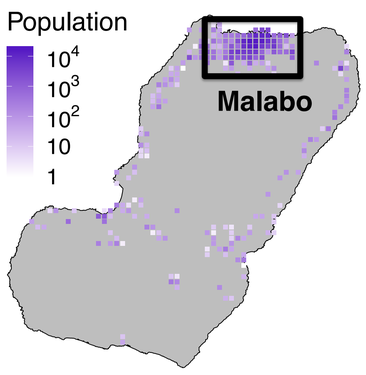


Bioko Island is now a relatively low-prevalence region in a high-prevalence area. Beginning in 2004, the Bioko Island Malaria Control & Elimination Program has dramatically expanded surveillance and interventions, including IRS; LLIN distribution; and access to treatment. There has been a significant reduction in *Plasmodium falciparum* malaria prevalence since 2004, but progress has slowed since 2015.

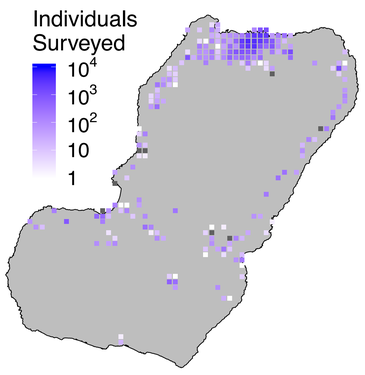
MALARIA INDICATOR SURVEY DATA

We have assembled data from Bioko Island's population census and MIS data collected annually 2015-2018 by the Bioko Island Malaria Elimination Program. The MIS data included RDT results, which suggest heterogeneous prevalence across Bioko Island

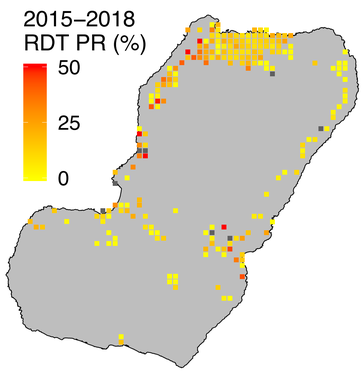
Population Census 2018



MIS Sample Size 2015-2018

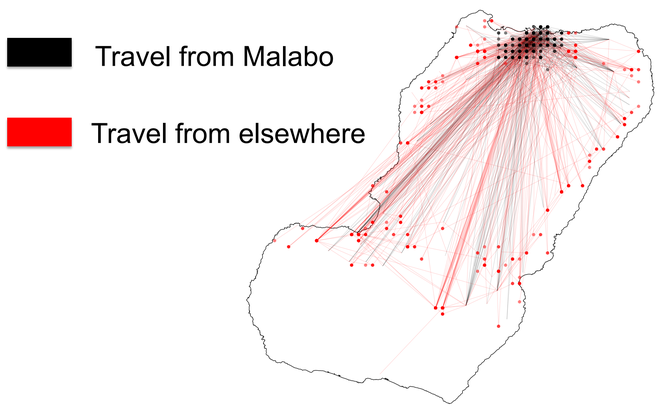


RDT PR 2015-2018

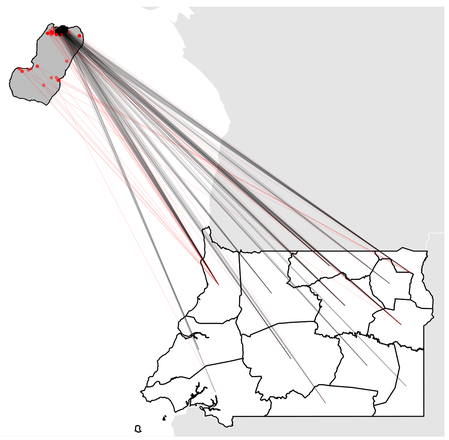


The MIS data included travel histories, revealing patterns in how humans moved both on- and off-island. Given the heterogeneity in prevalence across the region, knowing how frequently people traveled; where they went; and for how long was crucial for assessing infection risk, particularly among travelers to mainland Equatorial Guinea.

2018 Reported Travel On-Island



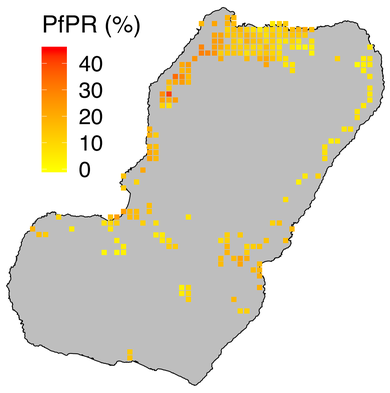
2018 Reported Travel Off-Island



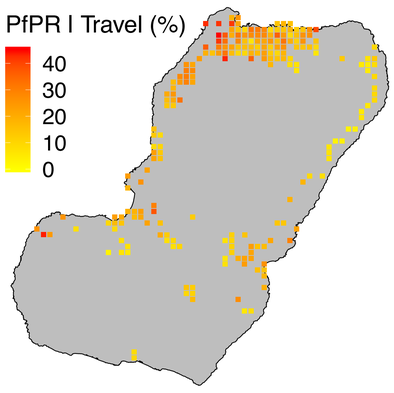
GEOSTATISTICAL MODELING

We used geostatistical inference methods, which smooth out sample variance in the MIS RDT data and incorporate environmental covariates, to obtain prevalence estimates across Bioko Island. The maps clarified the heterogeneous distribution of malaria prevalence, with the highest prevalence occurring along the northwest coast and ~12% prevalence in densely-populated Malabo in the north. We also mapped estimates of prevalence among people who had traveled recently and quantified the elevated risk of infection among travelers, suggesting that some infections could be attributable to off-island travel.

Estimated Prevalence



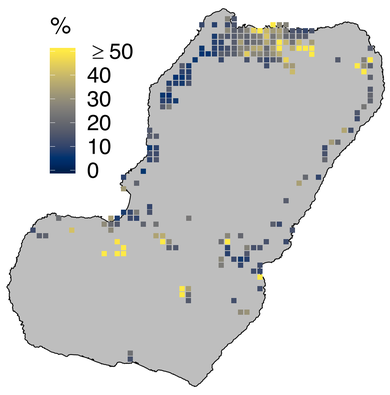
Estimated Prevalence, given recent off-island travel



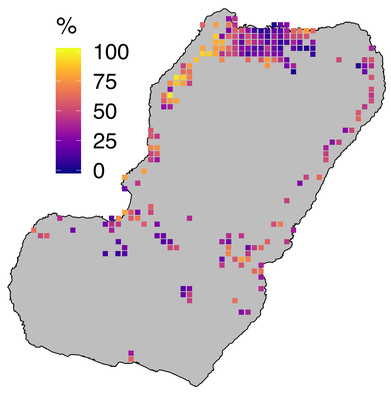
SIMULATION MODELING

We used the geospatial estimates of prevalence and the MIS travel data to parameterize a simulation model of malaria transmission across Bioko Island. The simulation included human movement on- and off-island, accounting for elevated risk among those who traveled to high-transmission areas. The simulation model allowed us to treat on-island and off-island transmission separately, and to quantify the fractions of cases attributable to traveling off-island only (*below, left*) or to local transmission only (*below, right*). In particular, it appears that elevated risk while traveling can explain many of the cases occurring in Malabo.

Fraction of Cases Attributable to Travel



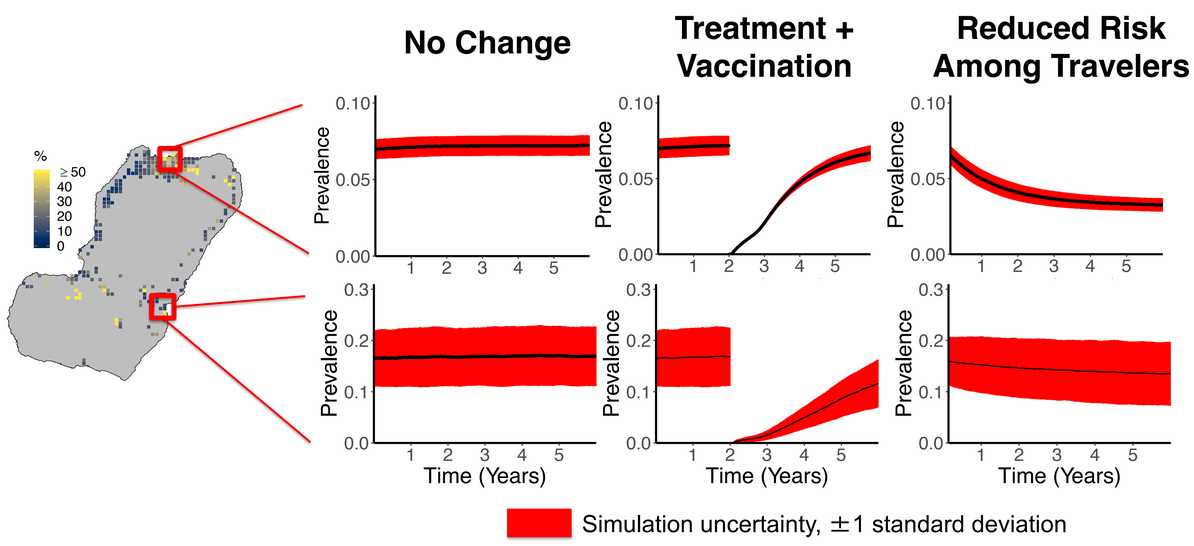
Fraction of Cases Attributable to Local Transmission



PREDICTING INTERVENTION IMPACT

We used the simulation model to predict the potential impact of additional interventions in different locations across Bioko Island, taking into account the spatial uncertainty in the data.

- Mass treatment and distribution of a pre-erythrocytic vaccine resulted in a temporary reduction of infections from the island, followed by steady increase back to current prevalence levels due to infections acquired by travelers off-island.
- Reducing risk among off-island travelers by 50% results in a long-term reduction in prevalence, particularly in locations with high travel rates such as in Malabo.



The simulation model may also be used to assess the uncertainty in our predictions, a powerful tool for assisting policy makers with planning future interventions.

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