Incorporating environmental variables into mosquito gene drive modelling: fine-scale dispersal, temperature, and landscape-dependent connectivity

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Introduction

Mosquito gene drives use two approaches:

- **Population suppression**: impact fertility and reproduction, induce population crash (no more mosquitoes)
- **Population replacement**: insert disease-refractory gene, change local population genetics (mosquitoes cannot transmit malaria, dengue, etc.)

Gene drives cause super-Mendelian inheritance, so the gene of interest spreads in a population quickly.

But how quickly, and how does the local environment affect mosquito population dynamics and the rate of spread/collapse?

Context is MGDrivE modelling framework (Sánchez *et al*. 2019), which connects:

- **Mosquito life cycle module**
- **Landscape module**
- **Inheritance module**
- **Disease epidemiology module**

We are considering how to simulate **population replacement** strategies in the **Comoros** as part of the **UC-Irvine Malaria Initiative**.

Dispersal

The landscape module governs how mosquitoes move between nodes, which can be defined as houses, blocks, neighborhoods, or villages, depending on available data and known behavior of the mosquito.

For ***Anopheles gambiae*** in the Comoros, we are using villages as the nodes. Satellite imagery and local maps are used to extract these locations.

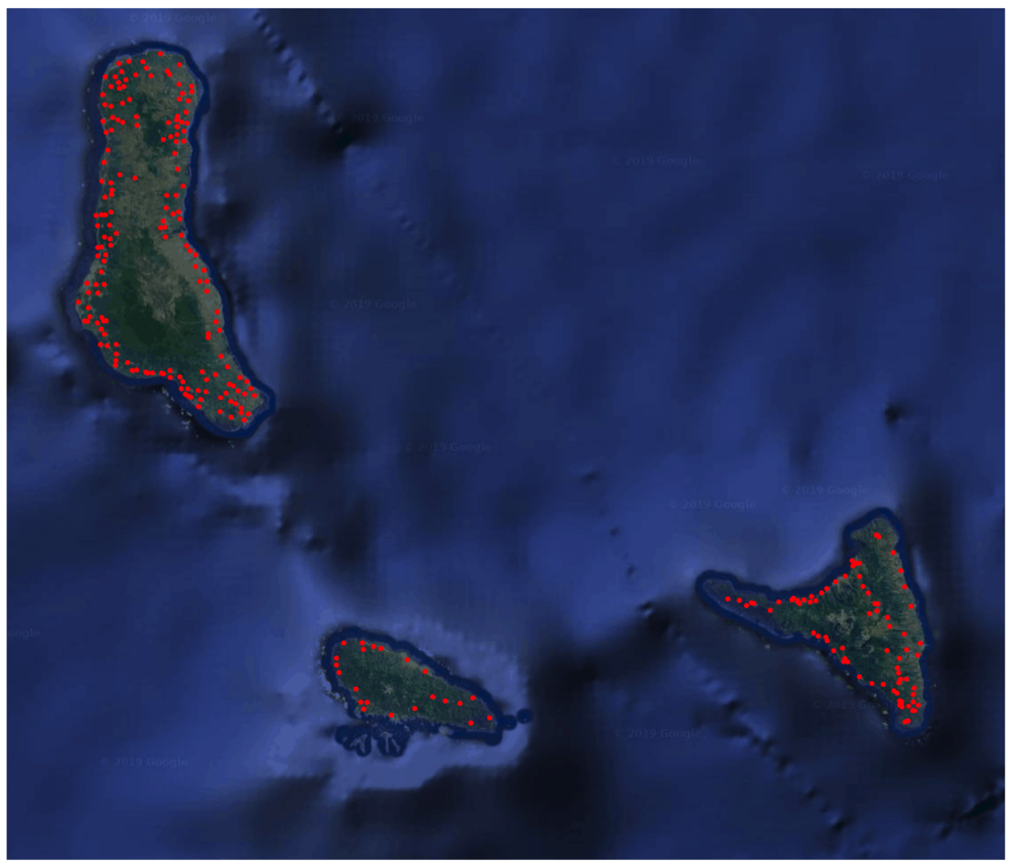

Figure 1: Known locations of villages/cities in the Comoros

Likelihood of dispersal between villages is estimated mechanistically via simulations of mosquito flight paths. These can be influenced by factors such as **elevation** and **land use**.

Groundtruthing the locations of villages and possible environmental refugia will improve the movement simulations and therefore gene drive modelling results.

Dispersal/Connectivity

Figure 2: Example simulated mosquito flight paths

Using movement modelling, we can simulate and predict dispersal of wild and released modified mosquitoes from different sites

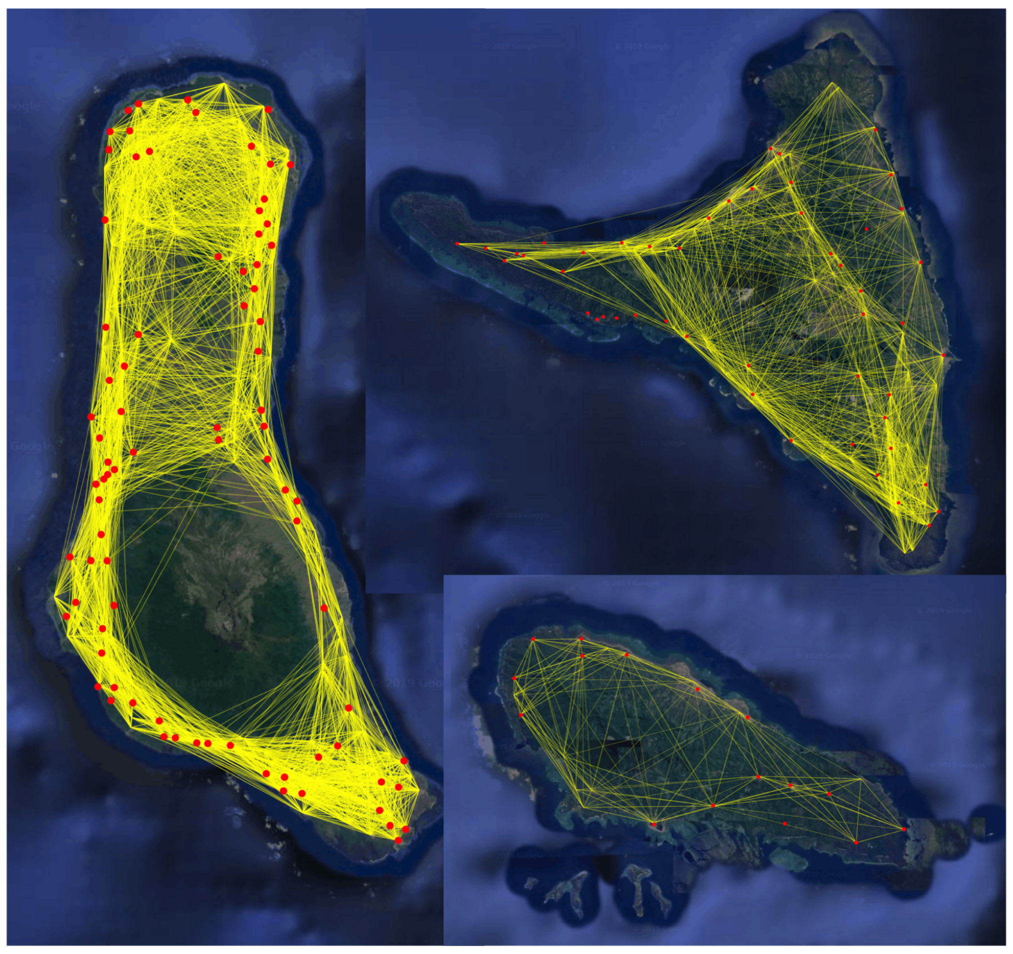

Figure 3: Predicted connectivity between sites on Grande Comore, Anjouan, and Moheli.

Rainfall

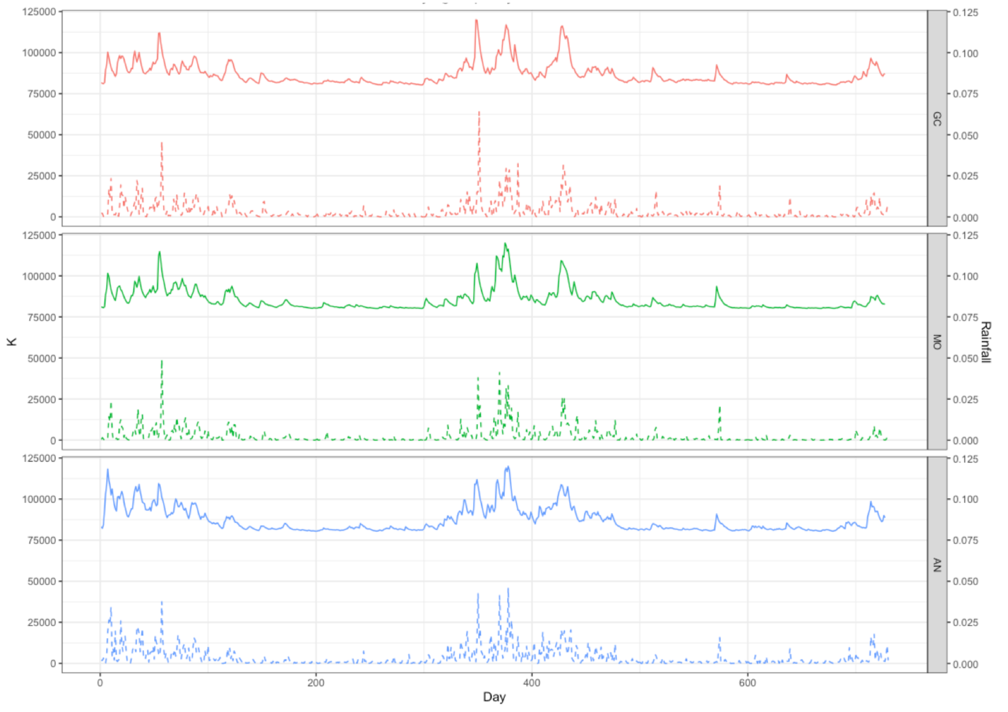

Figure 4: Larval carrying capacity for each island based on rainfall using the methods in White *et al.* 2011 for historical precipitation data.

Remotely-sensed rainfall data can inform larval carrying capacity in the gene drive model. Weather stations and mosquito surveillance data would help us better understand the true seasonality of this relationship in the Comoros.

Temperature

Incorporating temperature drastically changes gene drive modelling results because of its effects on population dynamics.

Wild-type, Drive, Resistance

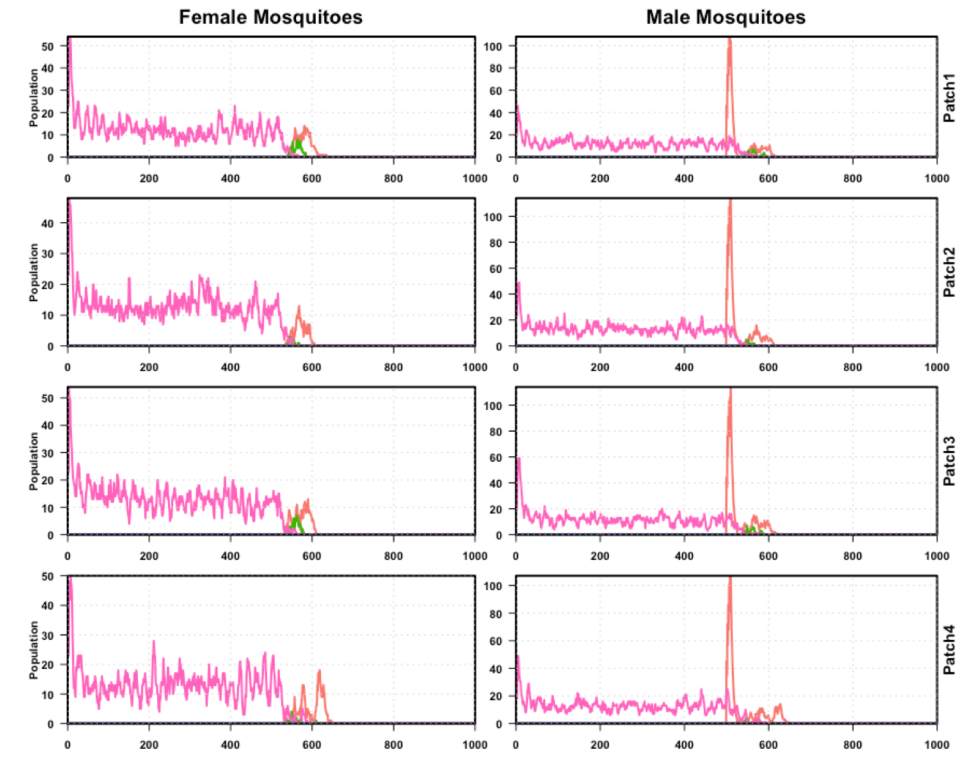

Figure 5: Gene drive simulation **without** temperature-dependent adult mortality.

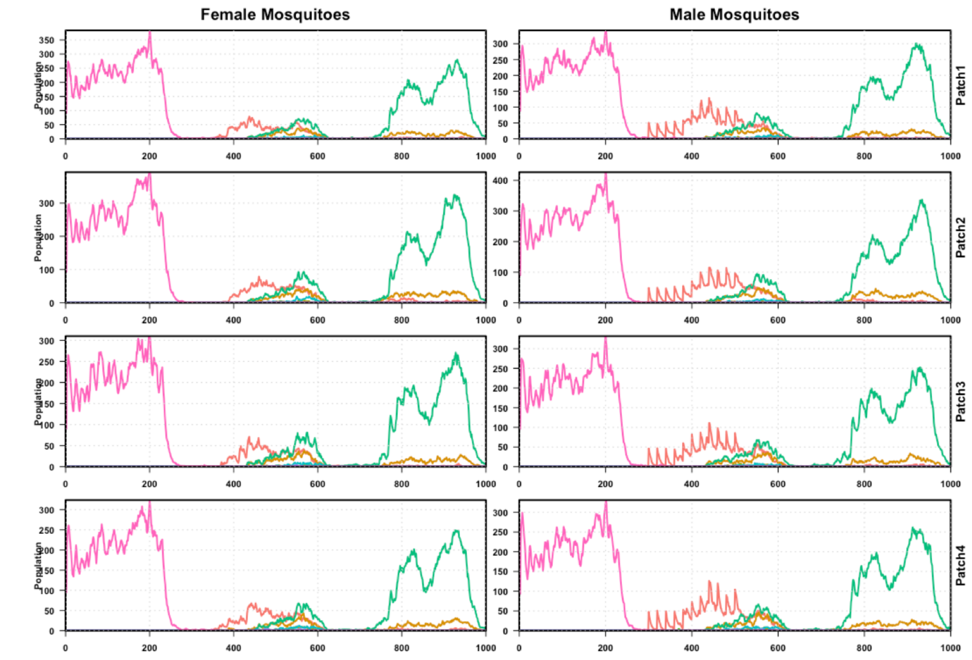

Figure 6: Gene drive simulation **with** temperature-dependent adult mortality.

Conclusion

- Incorporating environmental variables based on the locality has significant effects on the results of gene drive models for proposed release strategies
- Collecting longitudinal local environmental and entomological data will improve our ability to properly parameterize these relationships for better ecological realism
- Optimized design of release strategies will depend on seasonality and other insights from environmental effects on mosquito populations incorporated into gene drive models

Key References:

- Sánchez C HM, *et al.* (2019). MGDrivE: A modular simulation framework for the spread of gene drives through spatially-explicit mosquito populations. *Methods in Ecology and Evolution*.
- White MT, *et al.* (2011). Modelling the impact of vector control interventions on *Anopheles gambiae* population dynamics. *Parasites & Vectors*.

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