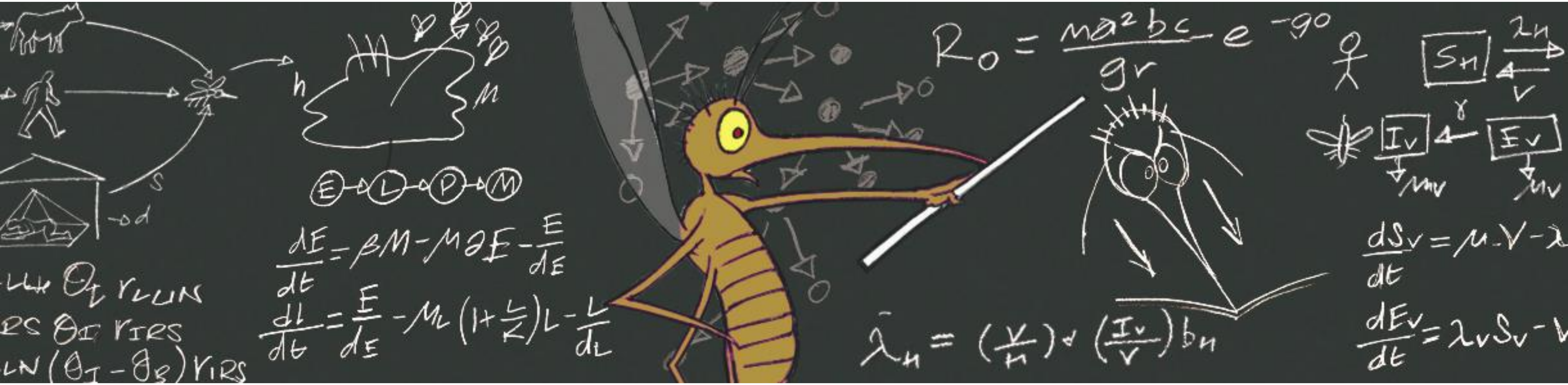
Close-kin mark-recapture methods to estimate dispersal parameters & barrier strength for mosquitoes



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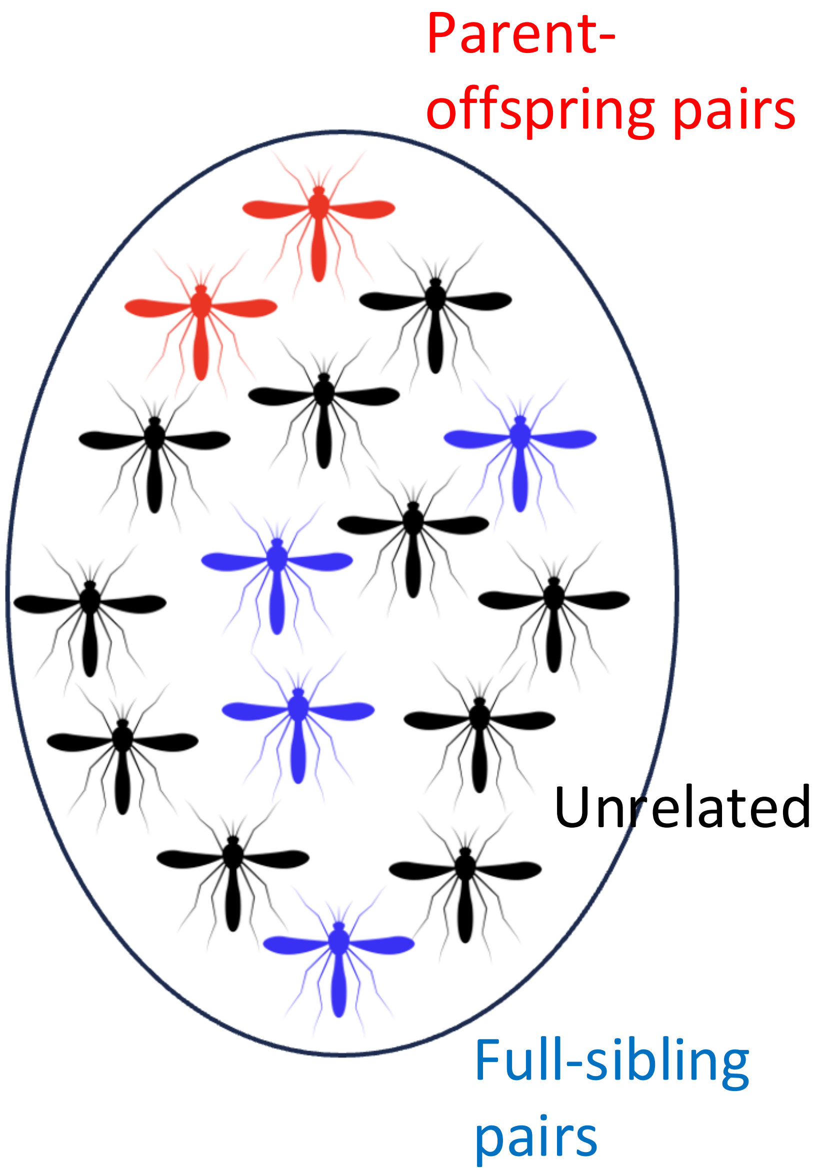
Talk outline

1. Background
   - Mark-release-recapture vs. close-kin mark-recapture (CKMR)

2. CKMR for mosquito populations
   - Theory:
     i. Kinship probabilities
     ii. Sum of log likelihoods
   - Inference of:
     i. Demographic parameters
     ii. Dispersal parameters
     iii. Barrier strength



Credits

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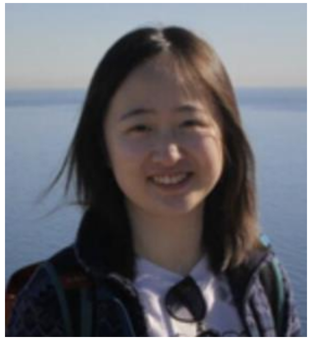
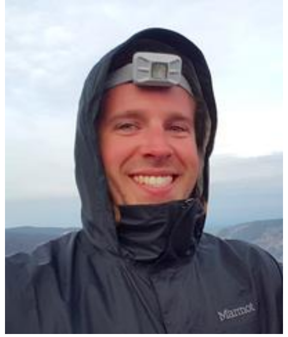

Shuyi Yang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Igor Filipović

National Environment Agency
Safeguard · Nurture · Cherish


Chanditha Hapuarachchi

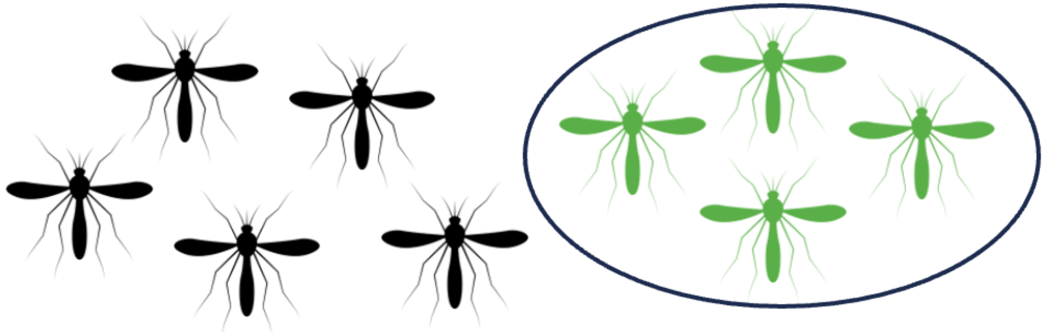

Chee Seng Chong


Lee Ching Ng


Tan Cheong Huat

MRR vs. Close-kin mark-recapture (CKMR)

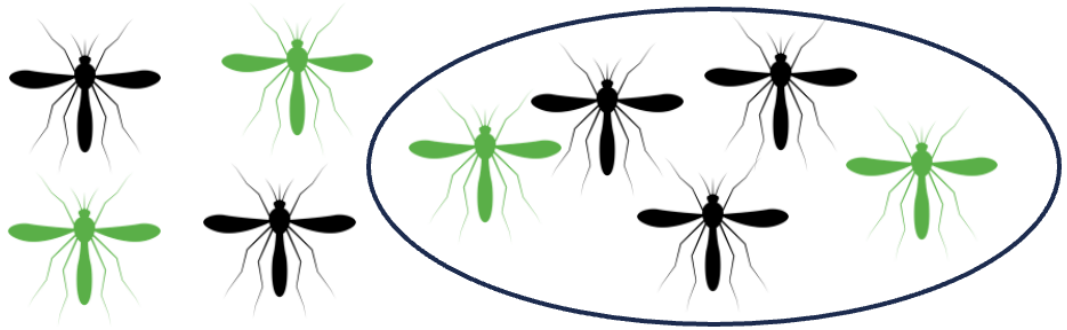
MRR sample 1:



Unmarked

Marked

MRR sample 2:

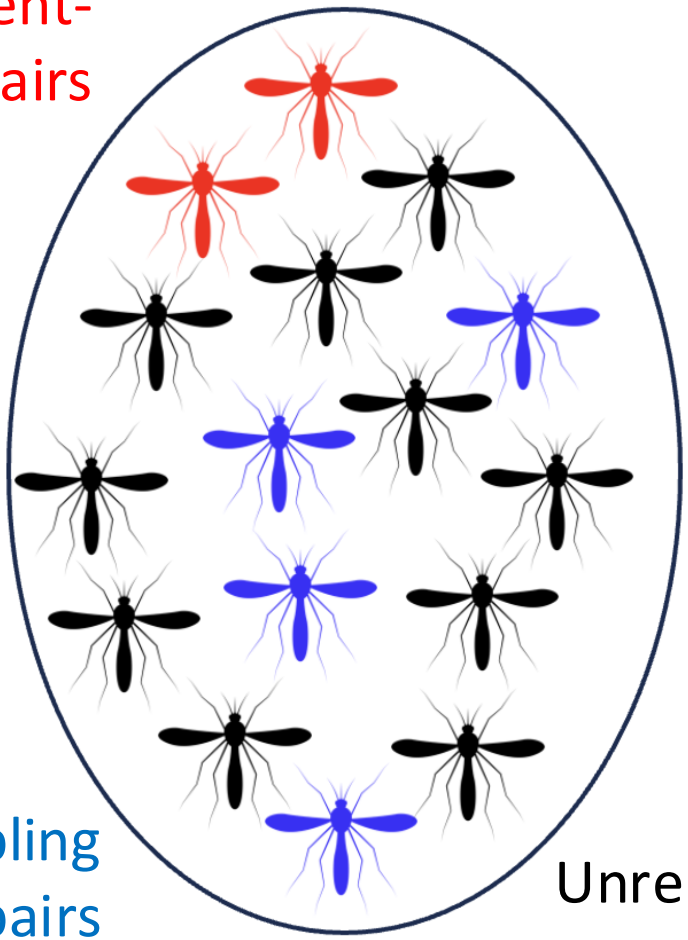


Population size:
(Lincoln-Petersen index)

$$\frac{4}{N} = \frac{2}{5}$$

CKMR sample:

Parent-offspring pairs



Full-sibling pairs

Unrelated

CKMR framework

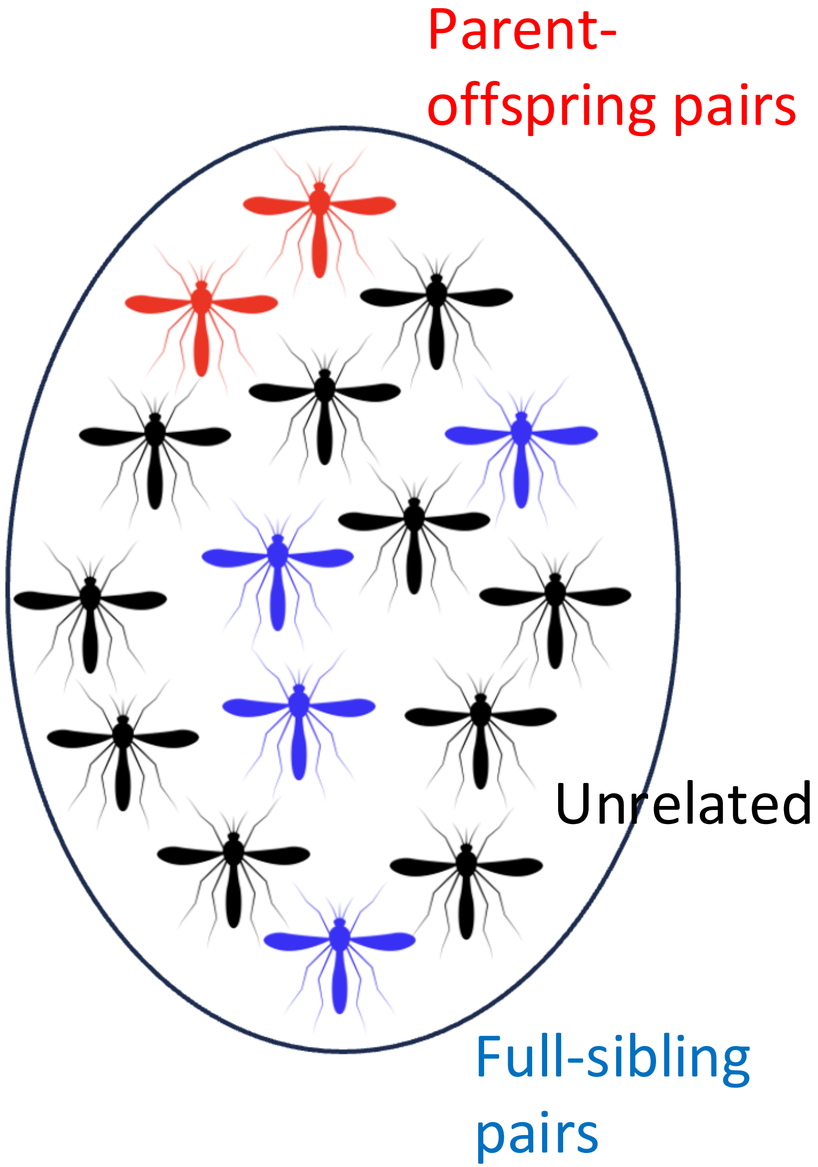
Parent-offspring kinship probability:

- Given an individual sampled at time t_1, what is the probability an individual sampled at time t_2 is their offspring?

$$P_{PO}(t_2|t_1) = \frac{\text{Expected num offspring at time } t_2 \text{ of an individual sampled at } t_1}{\text{Expected population size at time } t_2}$$

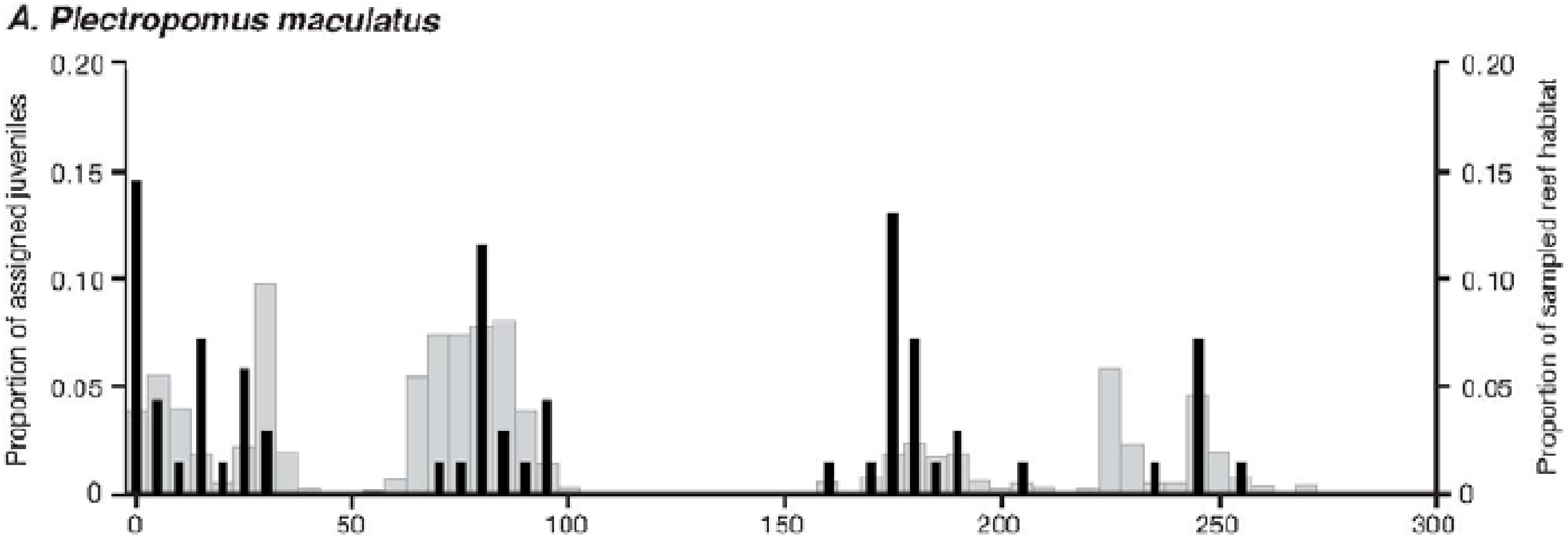
Sum of log likelihoods:

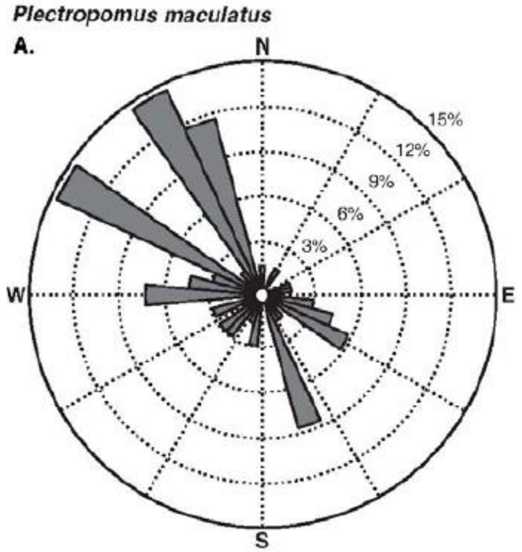
- Sum log likelihood of kinship category for each pair (assuming independence of each pair)
- This is a function of demographic model parameters, which we infer by optimizing the pseudolikelihood

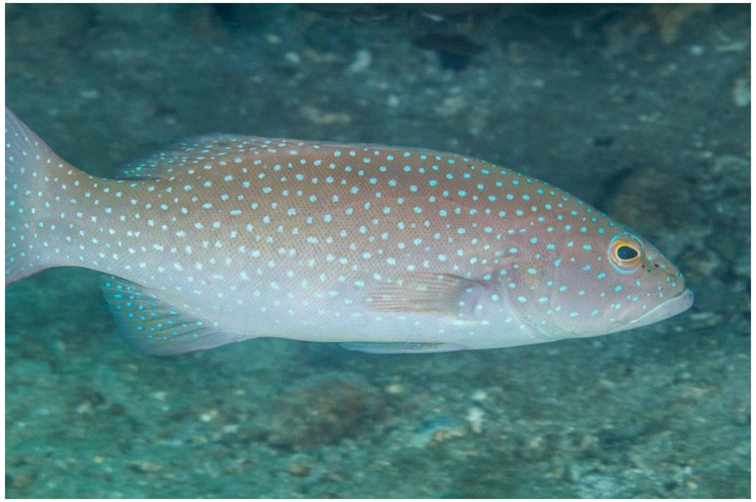


- Bravington MV, Skaug HJ, Anderson EC (2016) Statistical Science

CKMR applied to coral trout in Great Barrier Reef

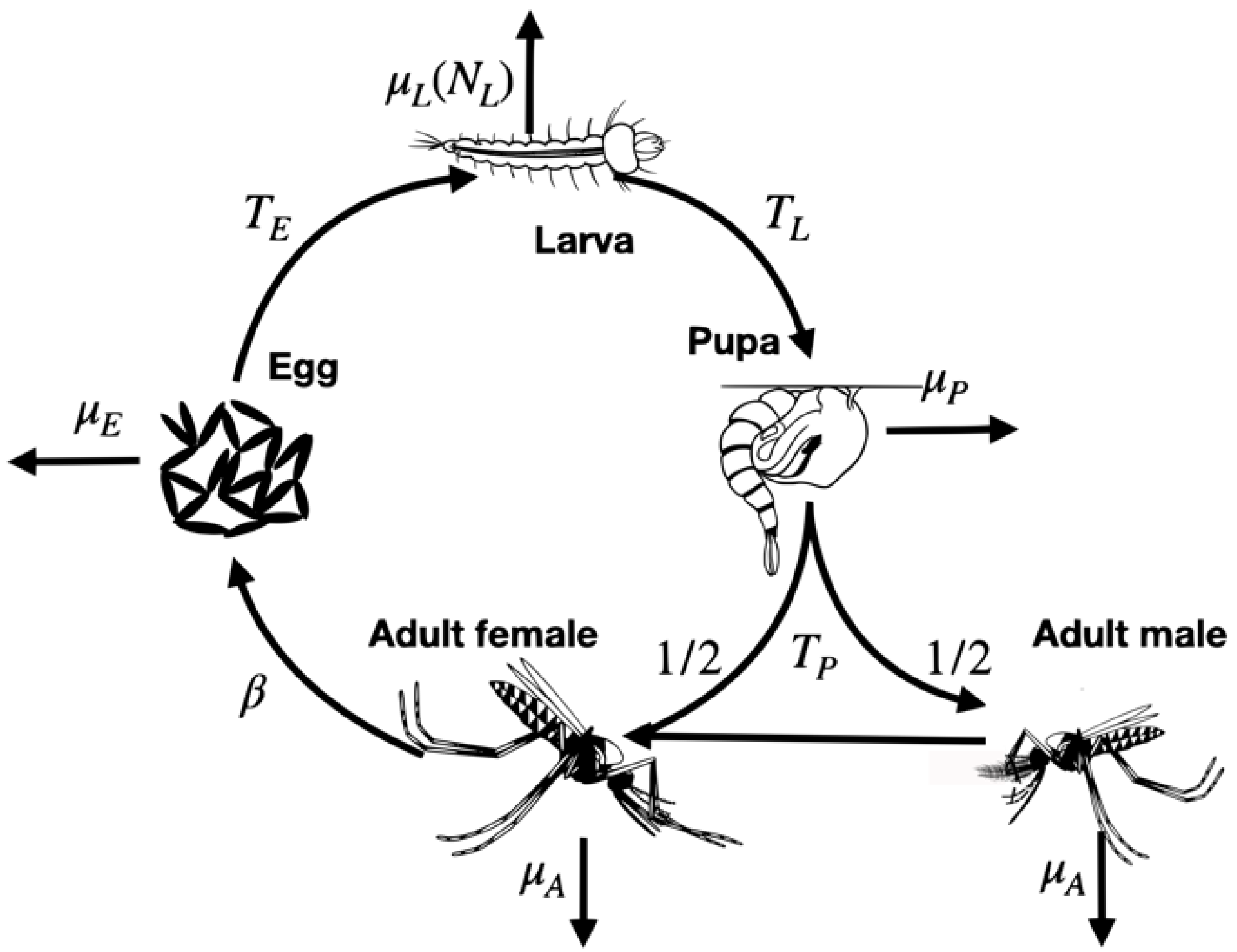






- Williamson DH, Harrison HB, Almany GR *et al.* (2016) Mol Ecol

Mosquito life history model



- Sharma Y, Bennett JB, Rašić G, Marshall JM (2022) PLoS Comput Biol

Inference of adult demographic parameters

Adult census population size:

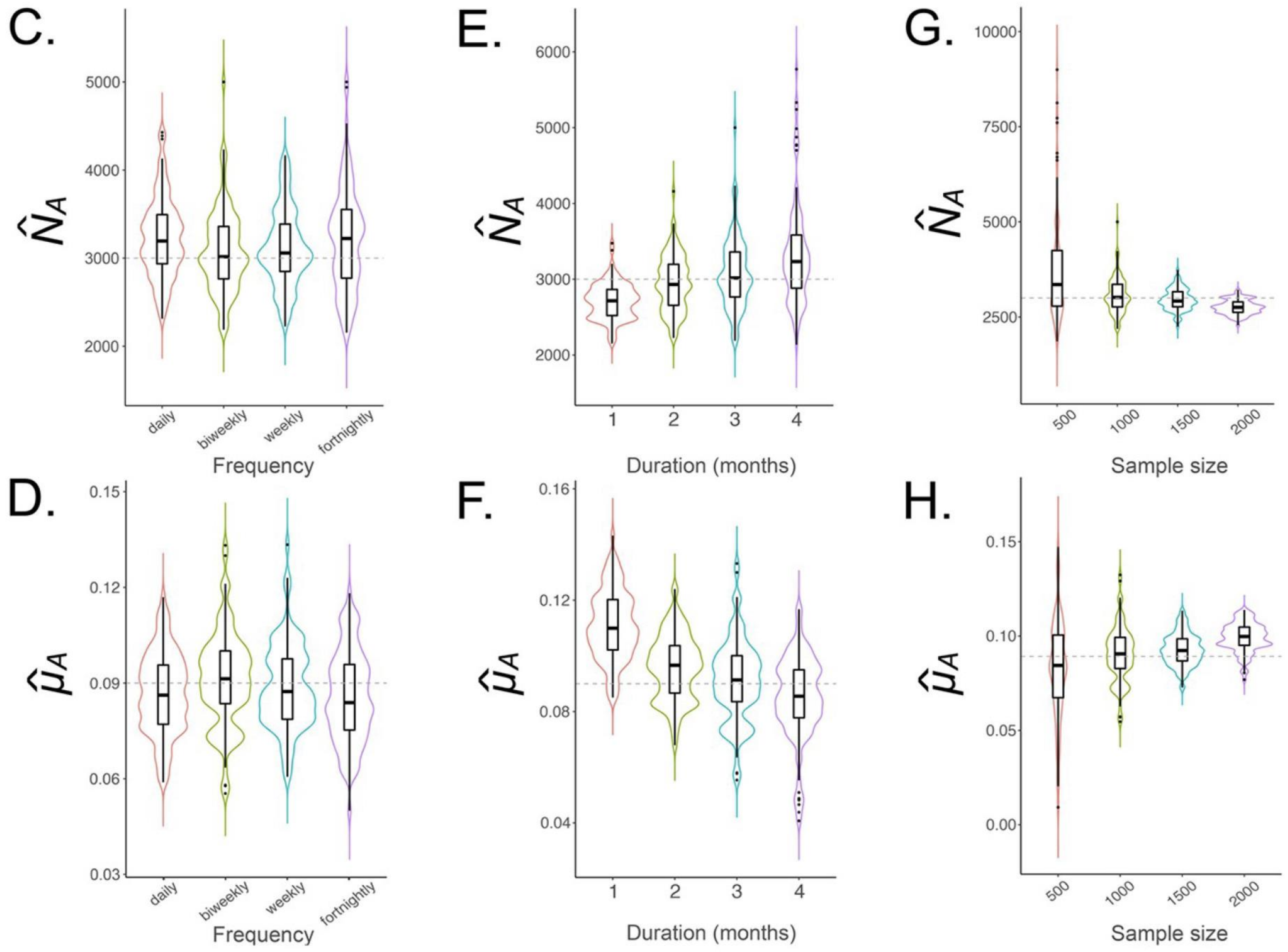
- The smaller the population, the larger the chance of finding a close-kin pair

Adult mortality rate:

- When mortality rate is low, close-kin pairs can be found further apart in time

Optimal sampling scheme:

- Adult females are sufficient
- Bi-weekly, weekly, fortnightly
- 2-3 months
- 1000 individuals (assuming population of 3000)



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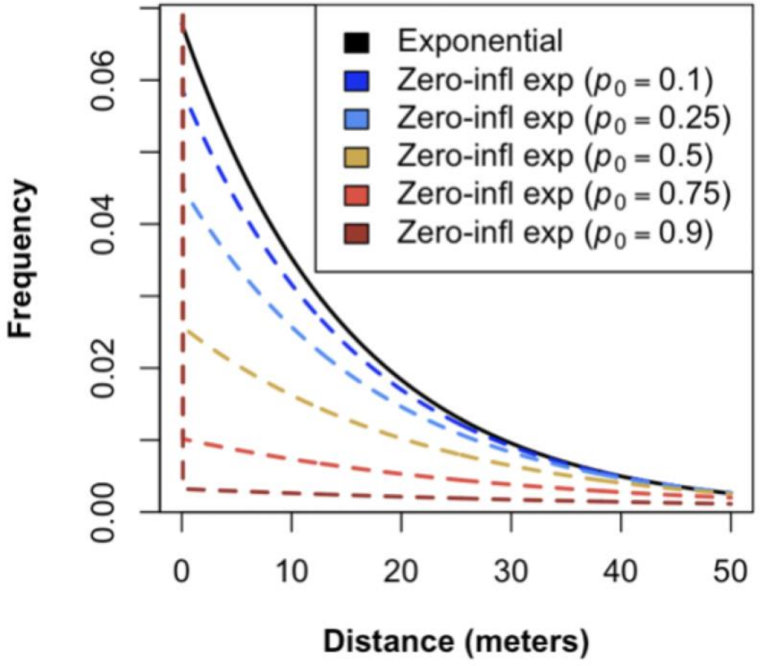
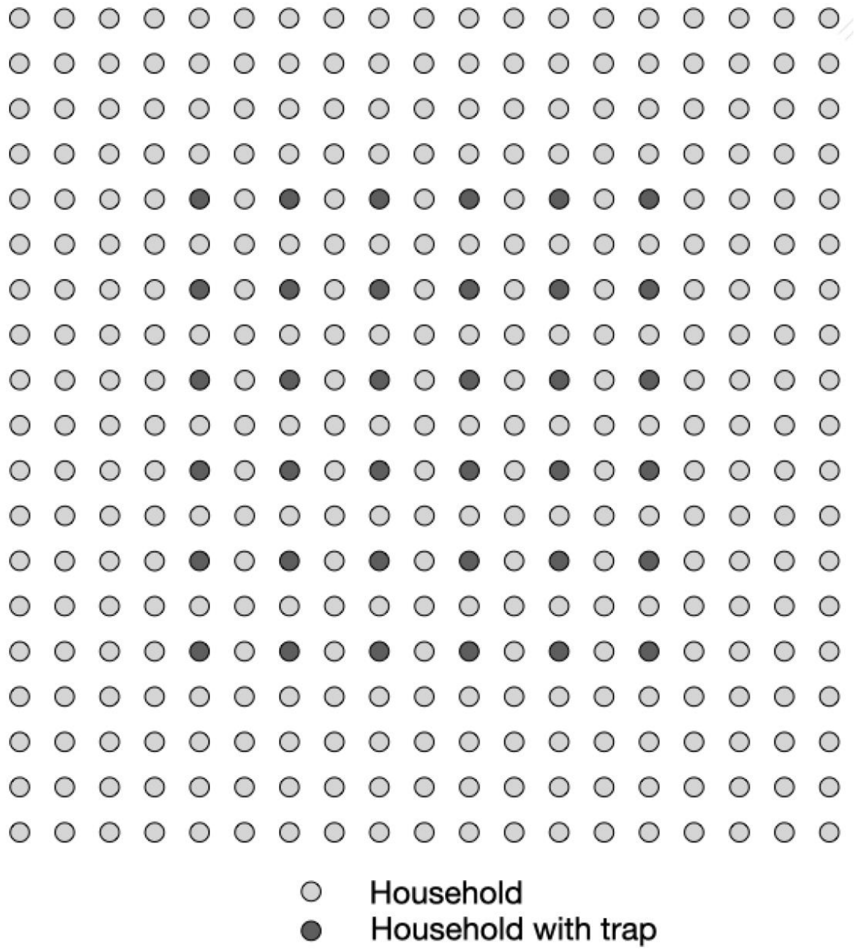
Inference of dispersal parameters

- Model mosquito movement according to a (zero-inflated) exponential kernel on a grid landscape (resembling suburban houses)





- Marshall JM, Yang S, Bennett JB, Filipović I, Rašić G (2025) PLoS Comput Biol

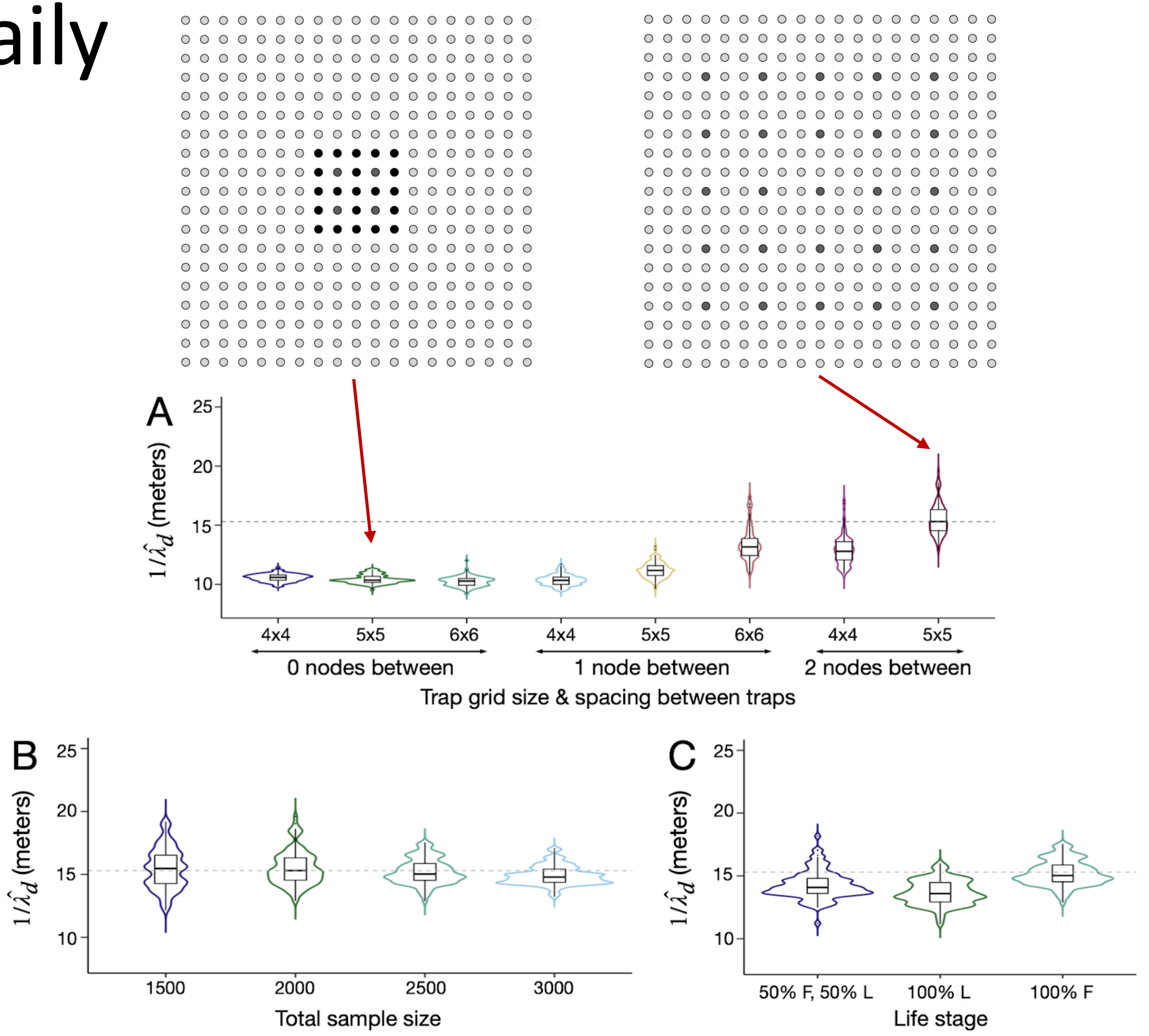
Inference of mean daily dispersal distance

Mean dispersal distance:

- When dispersal distance is larger, close-kin pairs will be found further apart in space

Optimal sampling scheme:

- Most important factor is trap placement – distance apart should be 1-2.5 times mean lifetime dispersal distance
- Sample size of 2000+ (assuming total population of 9000)
- Life stage is less important, adult females are fine



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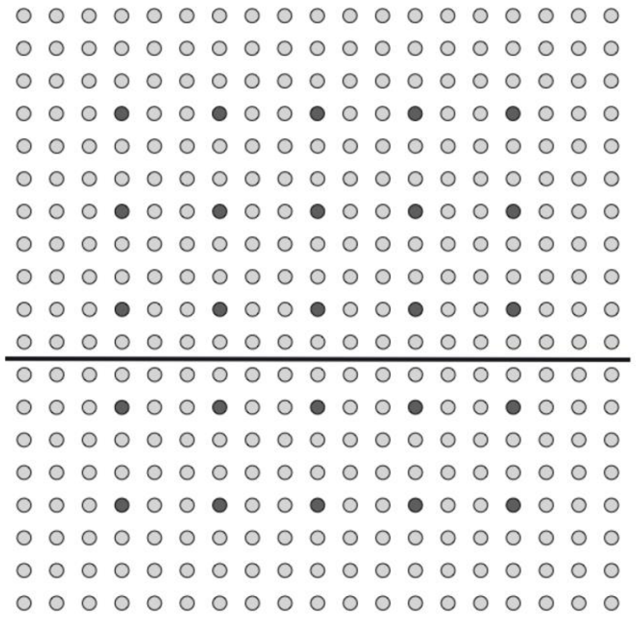
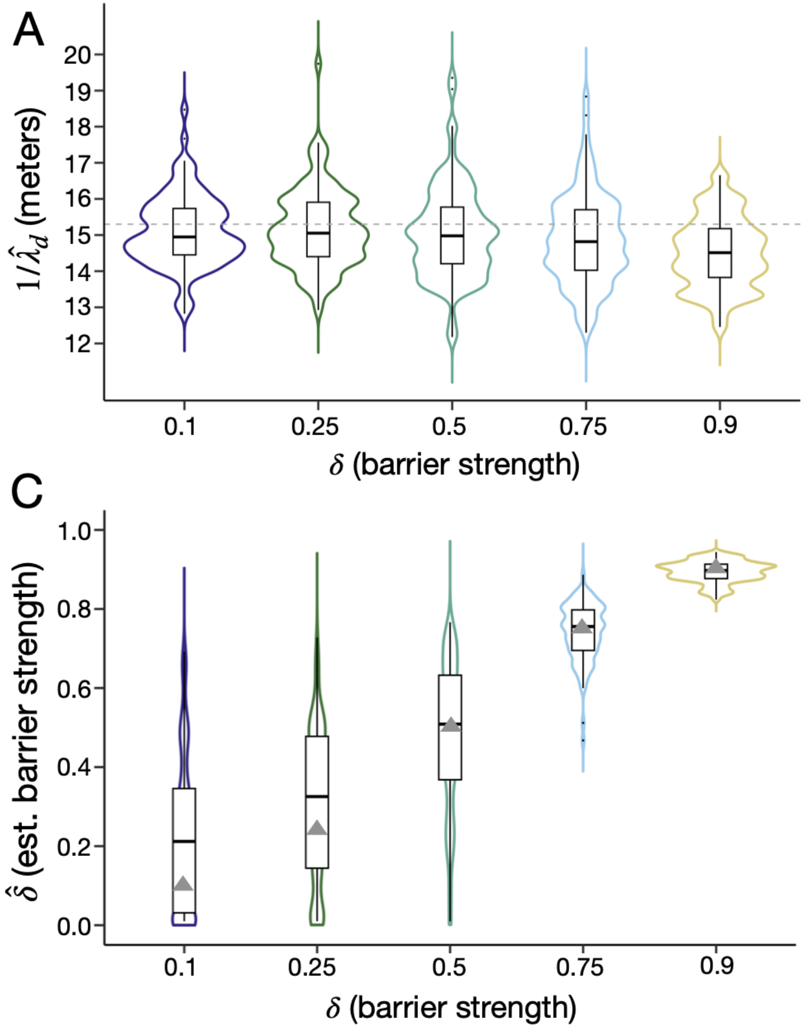
Inference of barrier strength





Barrier strength:

- Influences distribution of pairs across a barrier
- Can be estimated accurately for barrier strengths ≥ 50%

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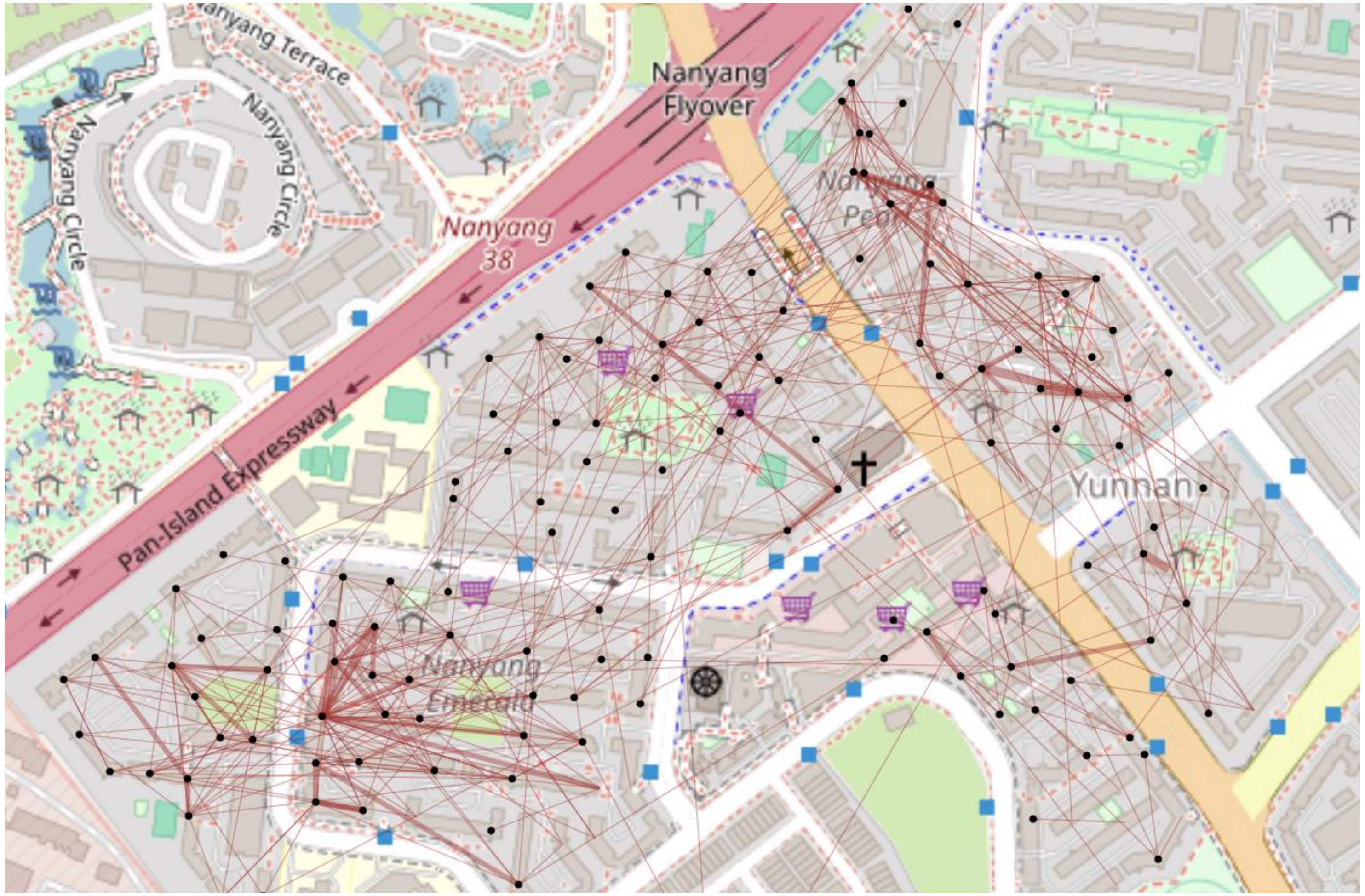
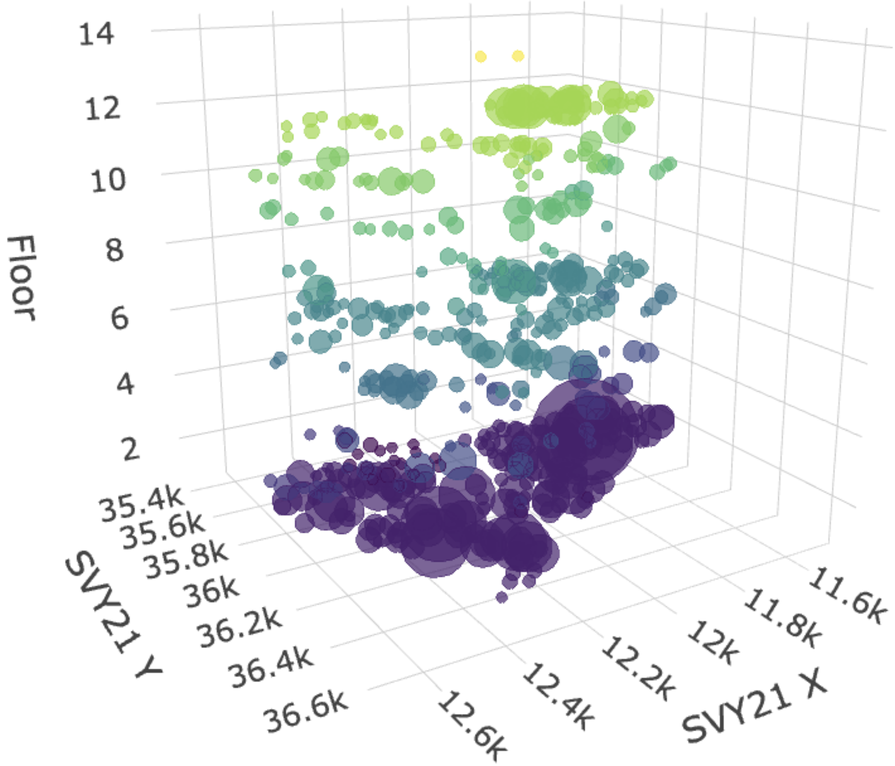
Field work studying *Ae. aegypti* in Singapore





Preliminary parameter estimates:

- Barrier strength of Pioneer Rd (6 lanes): ~80-90%
- Daily dispersal distance (horizontal): ~11-21 meters per day
- Daily dispersal distance (vertical): ~3-10 meters per day

Funding

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