Is there an “optimal” network of primary healthcare centres to select for passive surveillance?

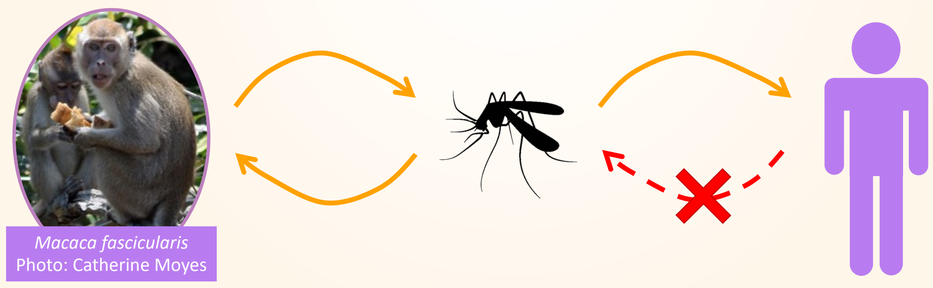
Lucinda Harrison[1], Freya Shearer[2], Jennifer Flegg[1] & David Price[2,3]

[1]School of Mathematics and Statistics, the University of Melbourne,
[2]School of Population and Global Health, the University of Melbourne,
[3]Doherty Institute for Infection and Immunity, the University of Melbourne

Introduction

Disease surveillance activities are resource-limited so should be optimised to achieve **specific objectives**. In a spatial context, the allocation of surveillance resources should therefore be based on our knowledge of the spatial distribution of the disease. But how can we account for **uncertainty** in our understanding of the disease's distribution?

Plasmodium knowlesi malaria is increasingly identified throughout Southeast Asia, maintained through a wildlife transmission cycle involving macaque hosts and mosquito vectors. While the disease is likely linked to the habitats of non-human host and vector species, spatial information on the disease’s distribution is **sparse** and **biased**.



Macaca fascicularis
Photo: Catherine Moyes

Human disease surveillance at **primary healthcare centres** is planned.

Workflow

1. Characterise healthcare centre catchment: area within which detected *P. knowlesi* malaria transmission is expected to have occurred
   - Defined as area within 100 minutes travel time[2]
2. Consider a quantitative **objective**:

   We aim to select a network of sites …
   1. maximising the inclusion of areas where disease risk is predicted to be high under an existing geospatial model[1]
      = maximising **anticipated disease burden**
   2. minimising the distance between selected sites
      = maximising **travel efficiency** within a network

3. Apply **simulation-based optimal design** algorithm:
   - Explore design space and evaluate designs for *P. knowlesi* malaria surveillance.
   - Avoid evaluating all possible surveillance designs

Research questions

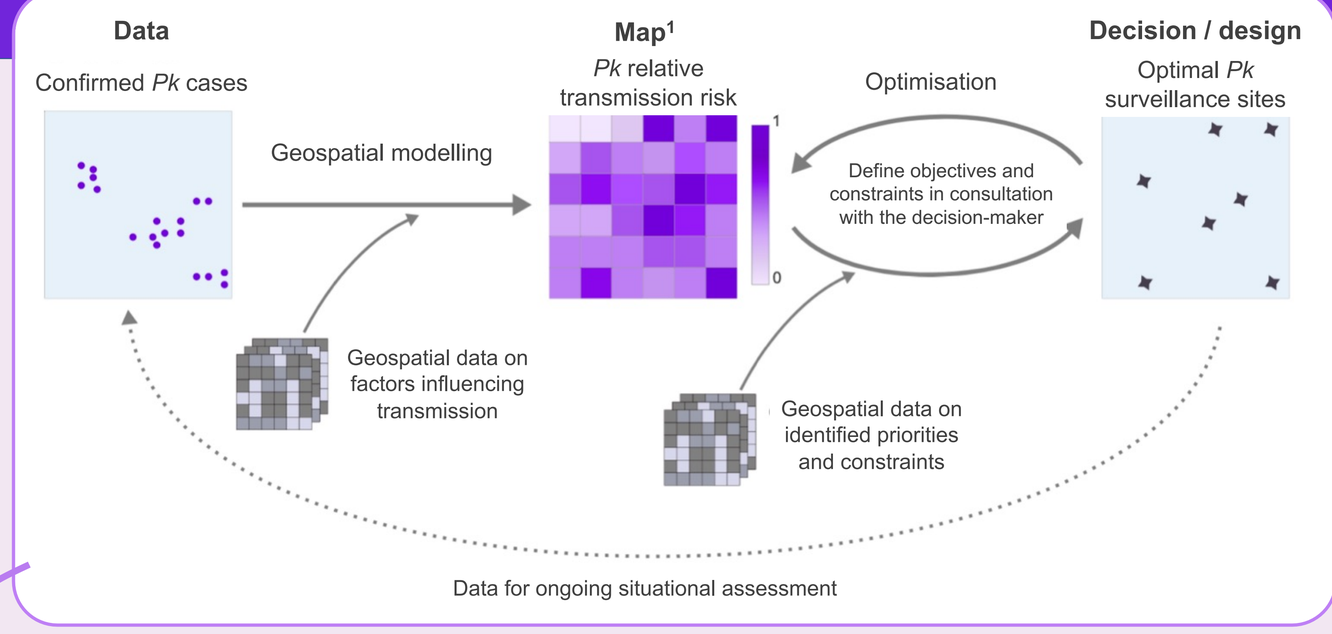
- Is there an “optimal” network of primary healthcare centres to select for surveillance?
- Is there an optimal number of primary healthcare centres to select?
- Does the approximate approach find optimal networks of primary healthcare centres?

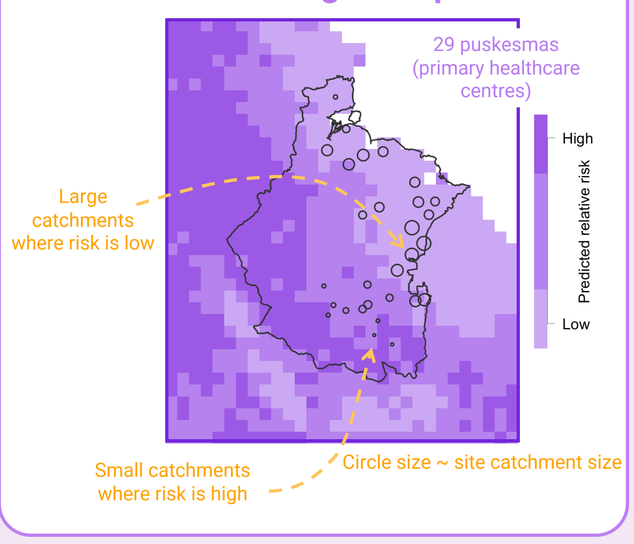
Key outcomes

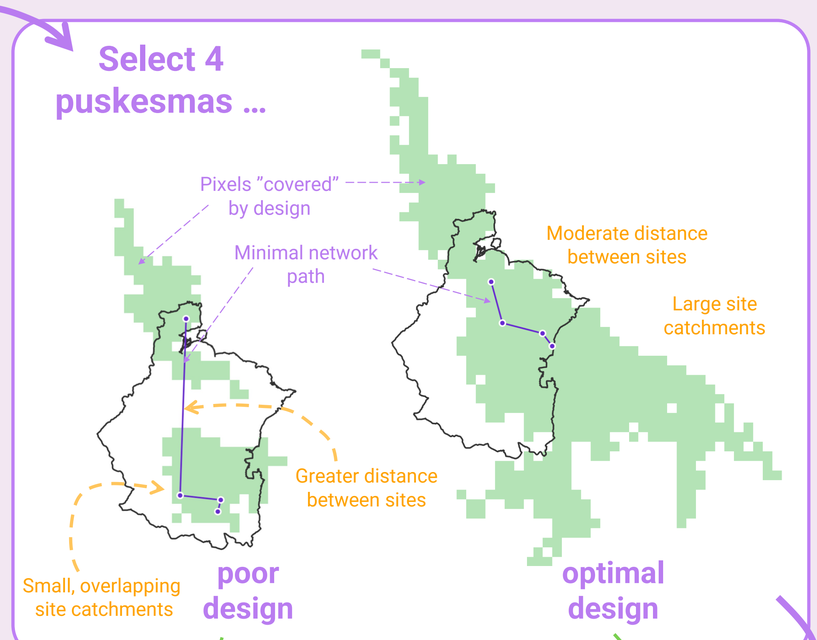
- A **statistical prediction of relative disease risk** based on disease occurrence and environmental data is incorporated into public health decisions, together with logistical factors
- Clinical stakeholders inform objective and constraint selection and maintain **ownership** of decision-making process
- Surveillance sites’ utility to public health can be **quantitatively compared**

Future work

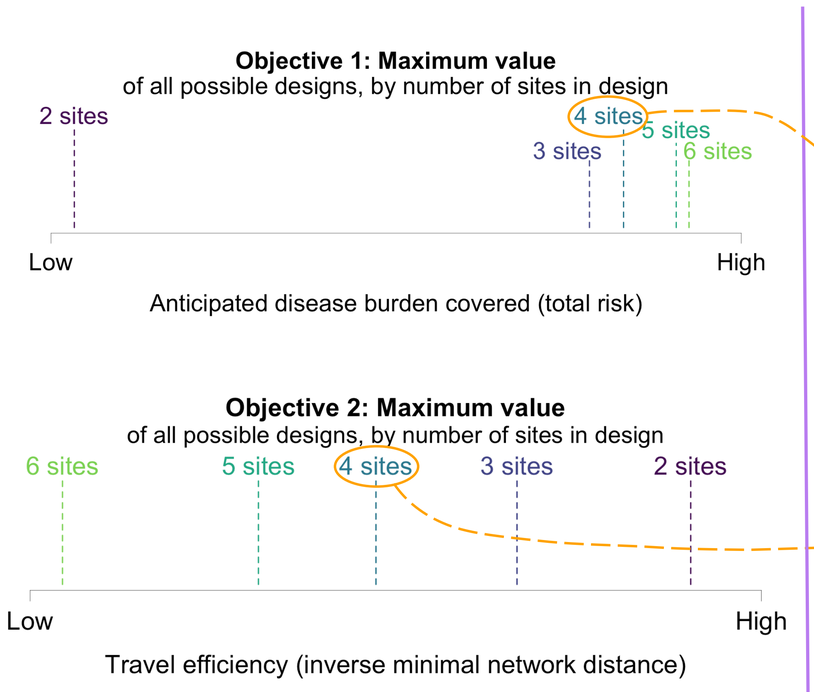
- Scale up to select sites across multiple regions
- Incorporate environmental diversity (e.g. prioritise sites near oil palm plantation)
- Incorporate other health infrastructure (e.g. aim to select sites not ‘over-shadowed’ by regional hospital)
- Select mosquito and macaque surveillance sites within healthcare centre catchments



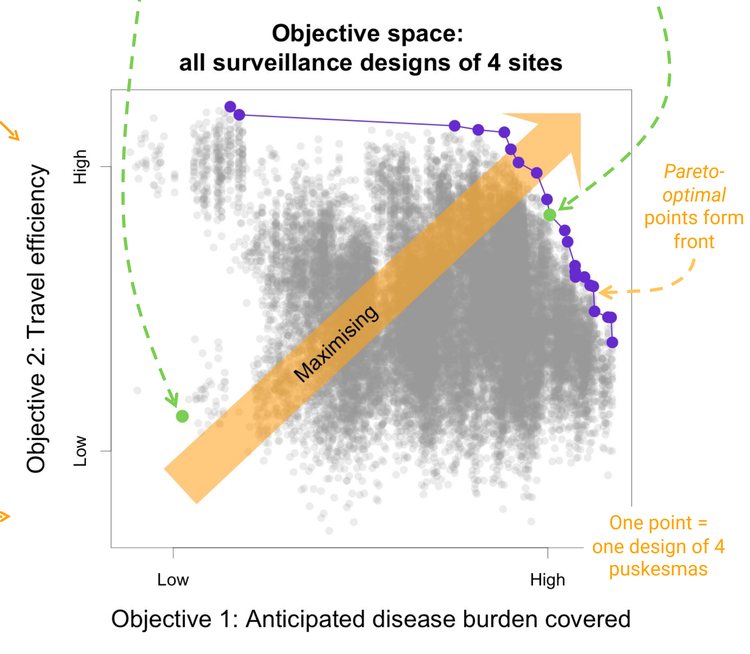




Exact solution



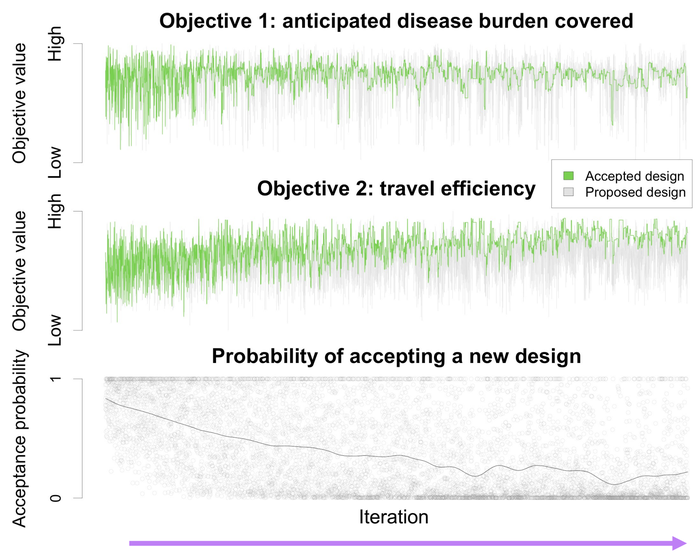
- Amount of anticipated disease burden gained decreases for each additional site added
- Travel efficiency decreases as sites are added

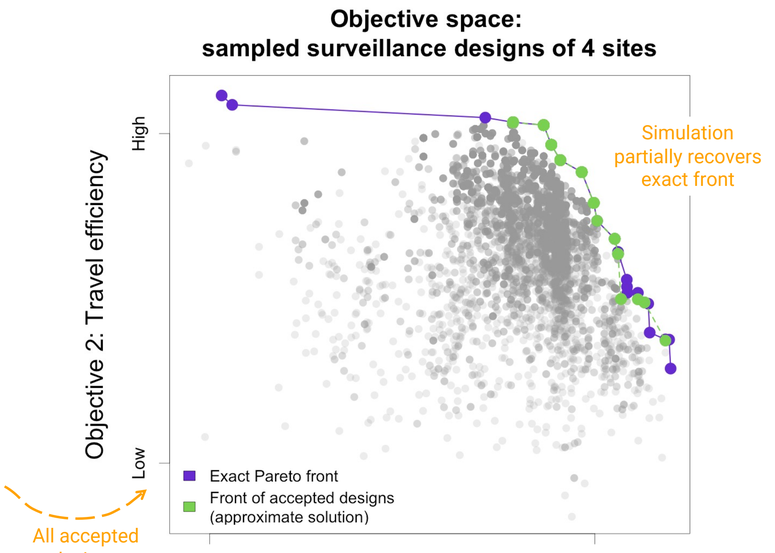


- Many designs *balance* both objectives
- Many designs are better than others under one/both objectives (Pareto-optimal)

Approximate solution

via rejection sampling





All accepted designs

E: harrisonl2@student.unimelb.edu.au

This project is being completed with the support of the ZooMal consortium
I work on the lands of the Wurundjeri Woi Wurrung people of the Kulin nation

1. Shearer, F. M. et al., (2016). Estimating geographical variation in the risk of zoonotic Plasmodium knowlesi infection in countries eliminating malaria. *PLoS neglected tropical diseases*, *10*(8), e0004915.
2. Weiss, D. J., et al., (2018). A global map of travel time to cities to assess inequalities in accessibility in 2015. *Nature*, *553*(7688), 333-336.