Dengue dynamics and projected effectiveness of vaccination and vector control in Yucatan, Mexico

Thomas Hladish et al
Model described/used in:


Dengue at a glance

*Flavivirus*

*Aedes aegypti, A. albopictus*

390 million infections

96 million cases

> 100 countries

Typical symptoms:

- Often none
- Fever (DF), up to 106 F (41 C)
- Rash
- Muscle, bone, joint pain

DHF / DSS

4 Serotypes

Temporary cross-protection, followed by enhancement
Research questions

- What benefit should be expected from the Sanofi-Pasteur vaccine?
- Why does killing mosquitoes seem ineffective?
- Given realistic options, how should vector control be done?
- Do combination strategies have synergistic benefits?
Dengue in Yucatan, 1979-2013

Reported cases

- Mild disease
- Severe disease

Serotype

1
2
3
4

Hladish et al. PLOS NTDs (2016)
Agent based model

People
- Home
- Day location
- Age
- Infection state
- Immune state
- May stay home if sick

Mosquitoes
- Location
- Age
- Infection state
- May move once per day
Dengue model overview

1.82 million people
- 38% employed
- 28% in school
- 34% stay at home

376k Households (5% sample, municipality)
96k Workplaces (size, postal code)
3.4k Schools (postal code)

Hladish et al. PLOS NTDs (2016)
Households are placed within municipalities according to nighttime light output (VIIRS/NASA).

Hladish et al. PLOS NTDs (2016)
Mosquitoes movement: Delaunay triangulation of locations

- Nodes are houses, workplaces and schools with (lat, long) coordinates
- Include all triangles whose circumscribed triangles contain no other nodes
- Remove edges longer than 1 km
Mosquito movement network

Delaunay triangulation

Hladish et al., PLOS NTDs (2016)
Reconstruct the past, forecast the future

Hladish et al. PLOS NTDs (2016)
Observed seasonality (1995-2011)
Indoor residual spraying*

Coverage: Treat 25/50/75% of houses per year
Efficacy: 80% reduction in equilibrium pop size in treated houses
  • Corresponds to 13% daily mortality due to IRS
Treatment lasts 90 days
Campaigns last 1/90/365 days
52 different start dates (1 and 90 day campaigns)

What happened in ~1980 and ~2012?

- Missing data from 1970’s?
- Spatial distribution of *Aedes*
Proposed mosquito spread model

- Locations each have a distinct, seasonally varying carrying capacity
- Mosquitoes could spread along Delaunay network, seeding new locations
- Long distance mosquito movement enabled by humans
ToDo:

- Implement mosquito spread model
- Re-fit using AbcSmc to historical data
- Project effectiveness of combined strategies
- Simulate IRS trial design for Yucatan