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Modelling the Impact of TB Transmission in Households and Communities

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Protecting Health, Saving Lives—*Millions at a Time*

Background: Heterogeneity in TB Transmission

- TB transmission is heterogeneous across space and time.
  - Seattle (5.9 per 100,000/yr) vs. Khayelitsha (1600)
  - USA: 1955 (52.6) vs. 2011 (3.6)
- In many other infectious diseases, “core groups” or spatial “hotspots” have become the focus of control efforts.
  - “80/20 rule” Woolhouse ME et al, Proc Natl Acad Sci 1997; 94:338
  - “Core groups” in STIs Thomas JC, JID 1996; 174:S134
  - “Hitting hotspots” in malaria Bousema T, PLoS Med 2012; e1001165
- The degree to which spatial “hotspots” contribute to community-wide TB transmission remains uncertain.
  - Is there an “80/20 rule” for TB?

Research Objectives

- To investigate the degree of ongoing community-wide TB transmission in Rio de Janeiro, Brazil, that originates from spatial hotspots

- To project 5- and 50-year reductions in community-wide TB incidence if those hotspots could be “normalized”
  - Bringing TB incidence in the hotspots to current levels in the community

TB in Rio de Janeiro

- Slums *(favelas)* integrated into to low-incidence areas
- Surveillance data available at the sub-district level
- Active attempts to “pacify” the *favelas* in advance of World Cup/Olympics

TB Incidence City-Wide: 95 per 100,000 (pop. 6.3 mil)
3 Hotspots: 6.0% of Population, 16.5% of TB Incidence

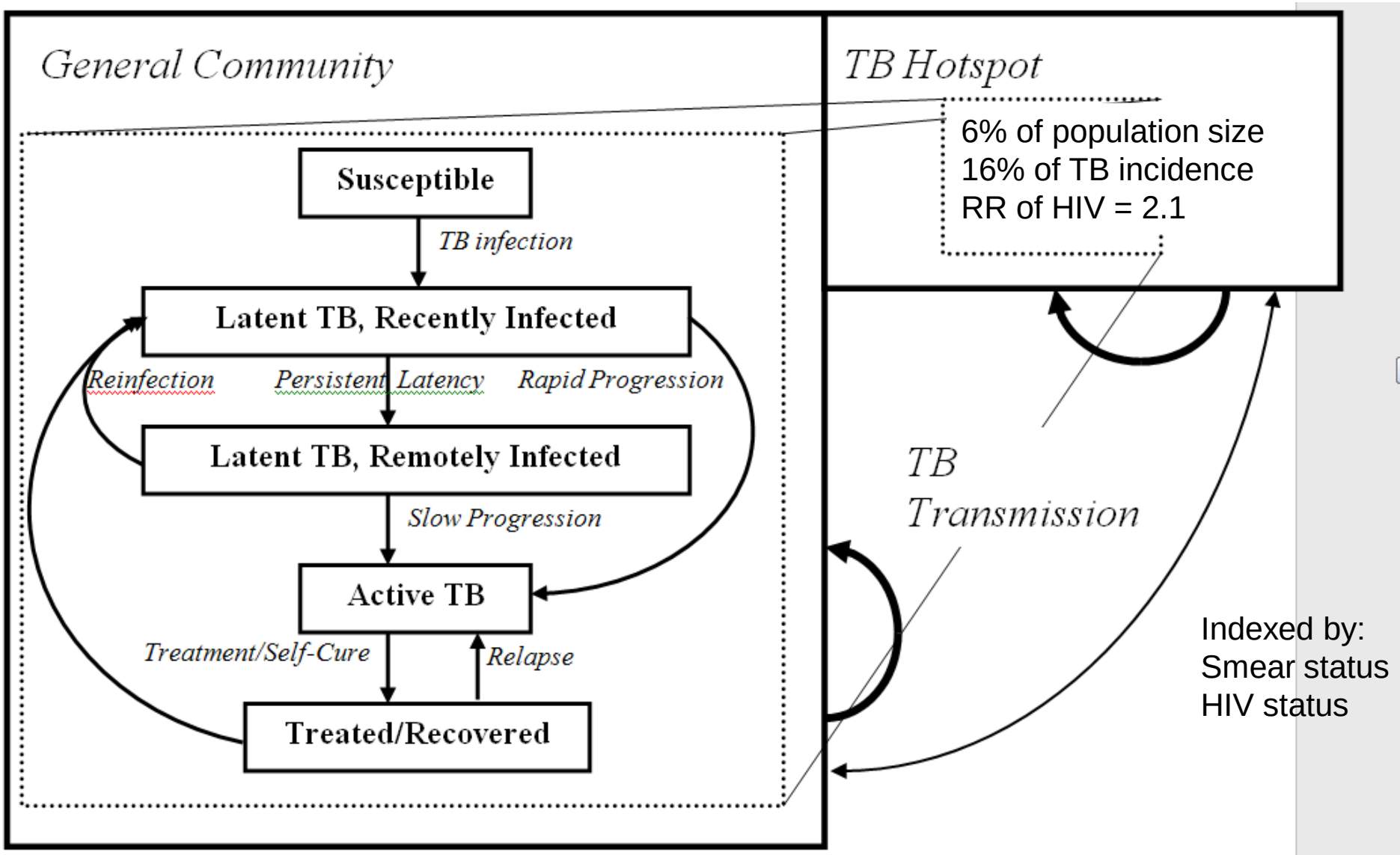
Manguinhos: 313/100k (55,600)

Rocinha: 382/100k (70,600)

Botafogo: 62/100k (234,700)

AP 1.0: 219/100k (250,000)

Model Diagram



Model Fitting

Epidemiological Data	Value, Rio de Janeiro	Value, Model
TB incidence, per 100,000/yr	95.3	95.3
Proportion of TB incidence in the hotspot	16.5%	16.5%
HIV/TB incidence, per 100,000/yr	10.7	10.7
TB mortality, per 100,000/yr	5.0	5.0
HIV/TB mortality, per 100,000/yr	0.7	0.7
TB prevalence, per 100,000	103.1	103.1
HIV prevalence, per 100,000	390	390
HIV mortality, per 100,000/yr	16.0	16.0
Proportion of retreatment cases	27.4%	27.4%

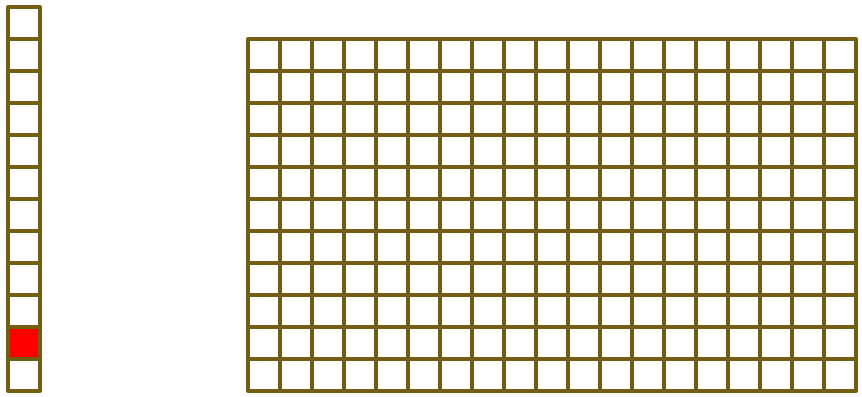
From a Modeling Perspective:

Key parameter is the relative transmission rate:

$$\beta_{HC}/\beta_{HH}$$

FROM: **TO:**	Community	Hotspot
Community	β_{CC}	β_{CH}
Hotspot	β_{HC}	β_{HH}

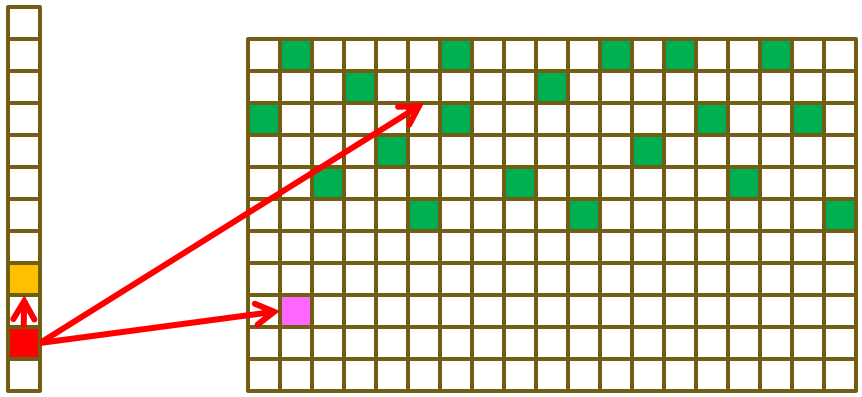
Quantifying Transmission Heterogeneity



"Hotspot"
11 people:
1 TB case
10 susceptible

Community
190 people

Quantifying Transmission Heterogeneity



β_{HC}/β_{HH} =

(Probability of infecting someone in the hotspot)/

(Probability of infecting someone in the general population)

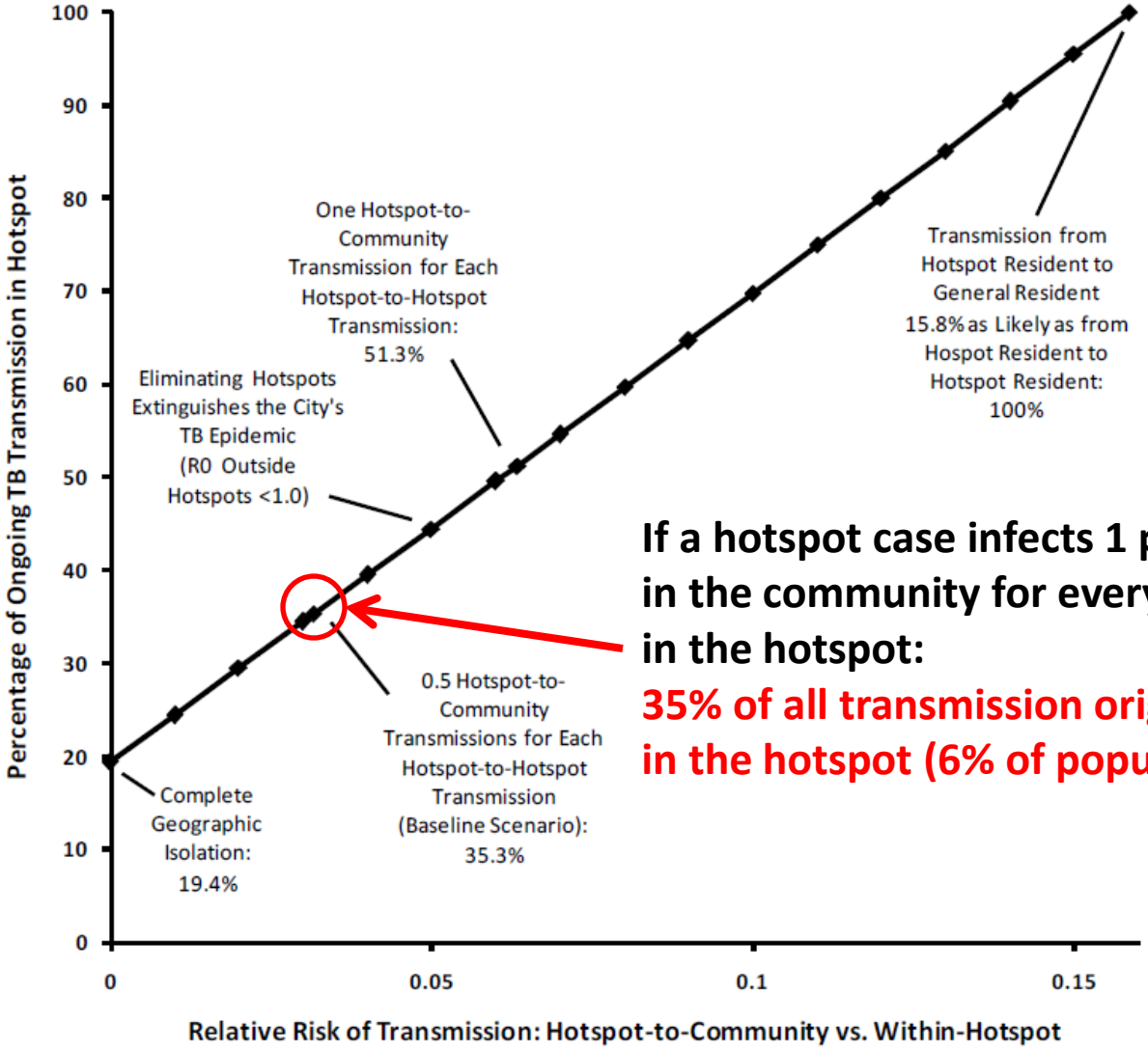
1.0 = homogeneous transmission = unreasonable

1/19 = heterogeneous transmission = more reasonable

The baseline assumption in our model will be that one hotspot case causes 2 transmission events in the hotspot for every event in the general population.

β_{HC}/β_{HH} ~0.03

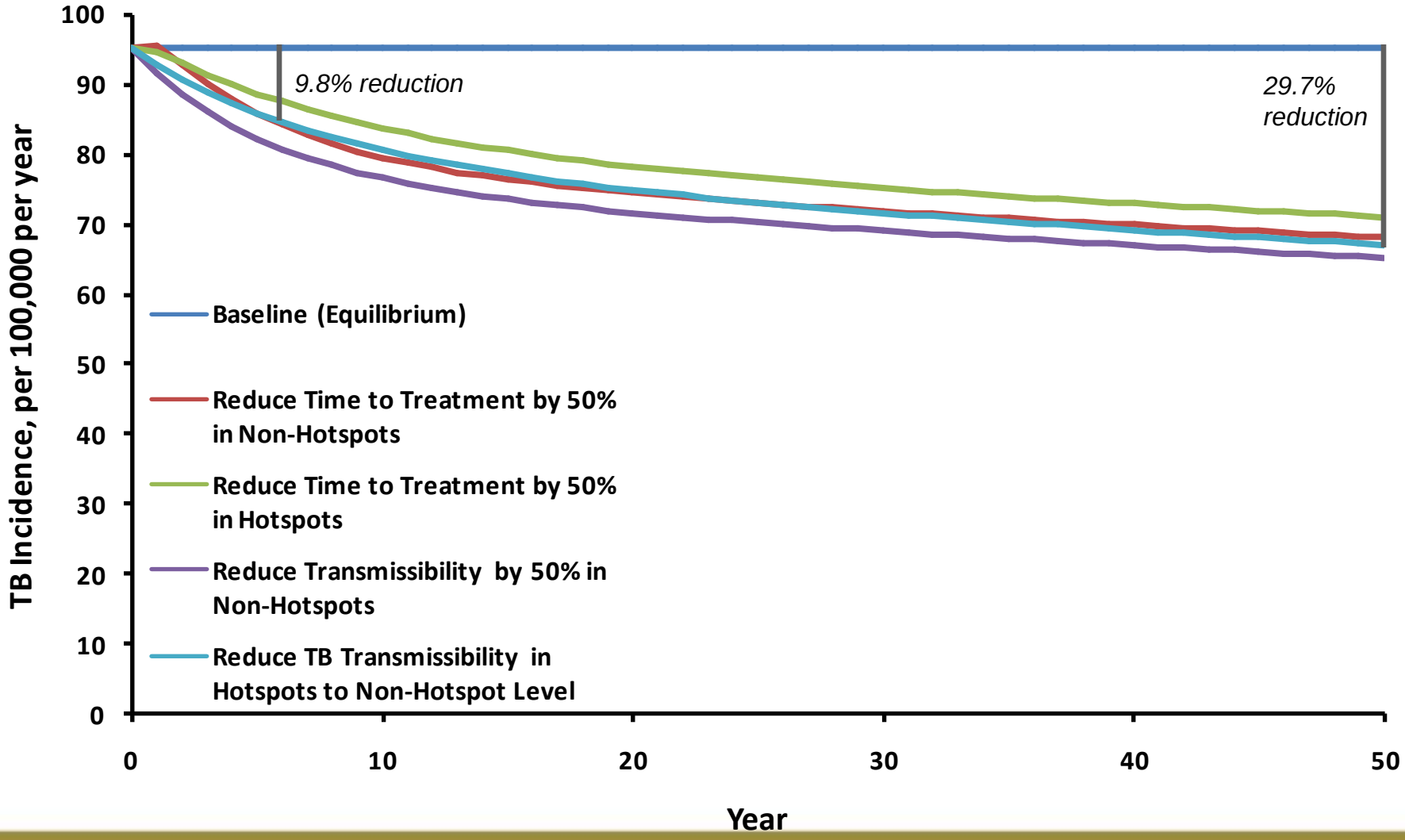
Results: Proportion of TB Transmission Arising from Hotspot Cases



If a hotspot case infects 1 person in the community for every 2 people in the hotspot:

35% of all transmission originates in the hotspot (6% of population)

Results: Impact of TB Control Interventions



Summary Points

- Small geographic hotspots are likely responsible for large proportions of TB transmission.
  - "35/6 rule"
  - 80/20 probably unreasonable
- Achieving TB control targets in a 6% hotspot vs. the 94% general population may have similar long-term impact.
  - Hotspot-targeted interventions may be appropriate, even if it costs 10x as much per person.
- Relative transmission rate (β_{HC}/β_{HH}) is critical to estimate.
  - Foci of cross-transmission: public transit, hospitals, occupational, prison
  - We need innovative methods to evaluate this parameter

Limitations/Additional Considerations

- Combining geographically-disparate groups into 1 hotspot
  - No change in results when split into 3 hotspots
- Rio de Janeiro: relatively unique epidemiological laboratory
  - Other hotspots may be more geographically and culturally isolated.
  - Most countries have no real intention of “normalizing” those areas.
- “Early saturation” of transmission in hotspots
  - Need more complex models (e.g., agent-based network) to study

Conclusions

- Under realistic conditions, 6% of a city's population could account for 35% of ongoing TB transmission.
  - Achieving TB control targets in a 6% hotspot vs. the 94% general population may have similar long-term impact.
- To better estimate the impact of TB transmission in households and communities, we need to better understand the relative transmission rate (β_{HC}/β_{HH}).
  - Hotspot-to-community vs. hotspot-to-hotspot

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