Mathematical modelling of HIV and injection drug use:

Introduction to models & discussion of challenges

J. Lindquist, J. Ma, P. van den Driessche
Department of Mathematics & Statistics
University of Victoria

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OUTLINE

1. Background: IDU & HIV modelling
2. Survey data (Victoria, BC)
3. A new model

Background

- 2004/2006 ITrack identified high HIV rates among Victoria IDU (2x national avg)
- Team goal: identify personal risk networks that could be behind high prevalence
- Modeling goal: describe syringe-sharing and HIV spread among injection drug users in Victoria, BC; identify control options

Existing Models

- Needles as vectors
  Kaplan, 1989; Greenhalgh et al. 1997; Massad, 1997
- Susceptible-Infectious ODE models
  Blower et al. 1991; Kretschmar & Weissing 2004
- Sharing group models
  Murray et al. 2003; Vickerman et al. 2006; Kwon et al. 2009
- Simulation models
  Hutchinson et al. 2006; Kretschmar & Weissing 1998, 2004; Peterson et al. 2007

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Target Population

- Important characteristics
  - demographics
  - sharing behaviors
  - other risk factors
- 105 clients of Victoria needle exchange program interviewed

Survey Results

- 70 % male
- 73 % shared drug paraphenalia
- 21 % shared syringes in past 6 months
- No. of Syringe sharing parter (SSP) ≡ <u>one</u>
- SSP is sex partner or trusted friend
  - sharing and helping inject highly correlated
  - women also likely to share with sex partners

Need for a New Model

- Spread of HIV occurs due to partnership formation & dissolution
  - Pair-formation models
    Dietz & Hadeler, 1988; Kretschmar & Dietz, 1998;
- Pairing model
  - female-male partnerships
  - male-male partnerships
- SI dynamics (no recovery)

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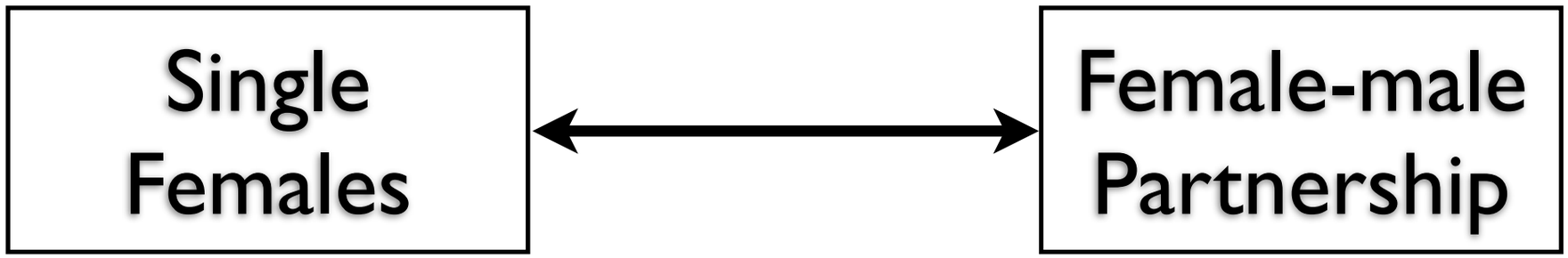
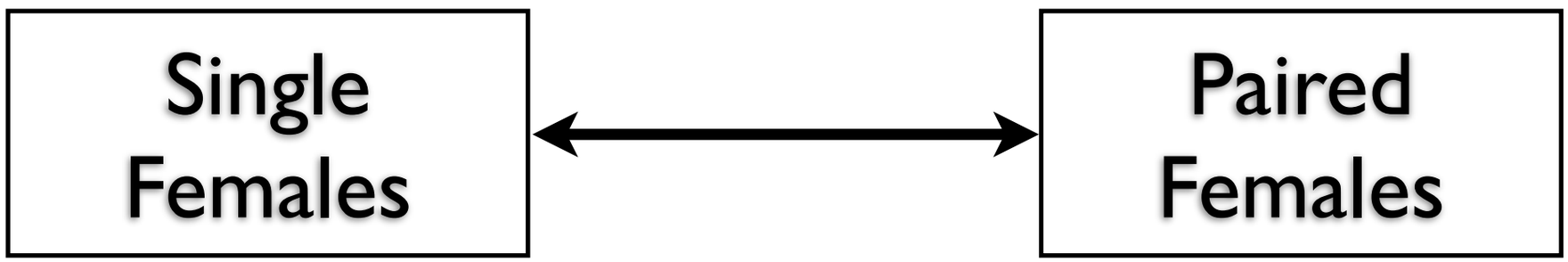
Pairing Dynamics



Assume homogeneous mixing of single persons

Infection Dynamics



Infection Dynamics

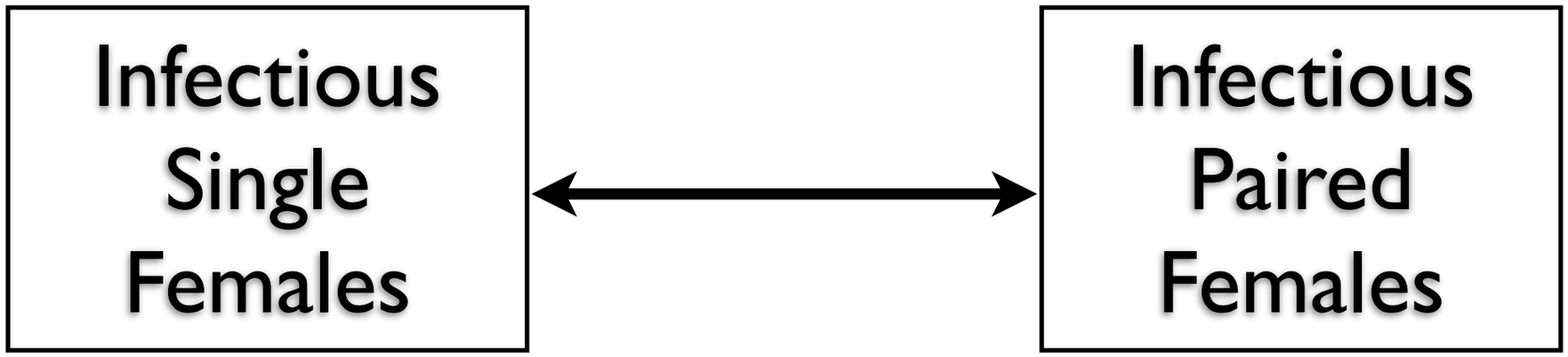
Infectious
Single
Females

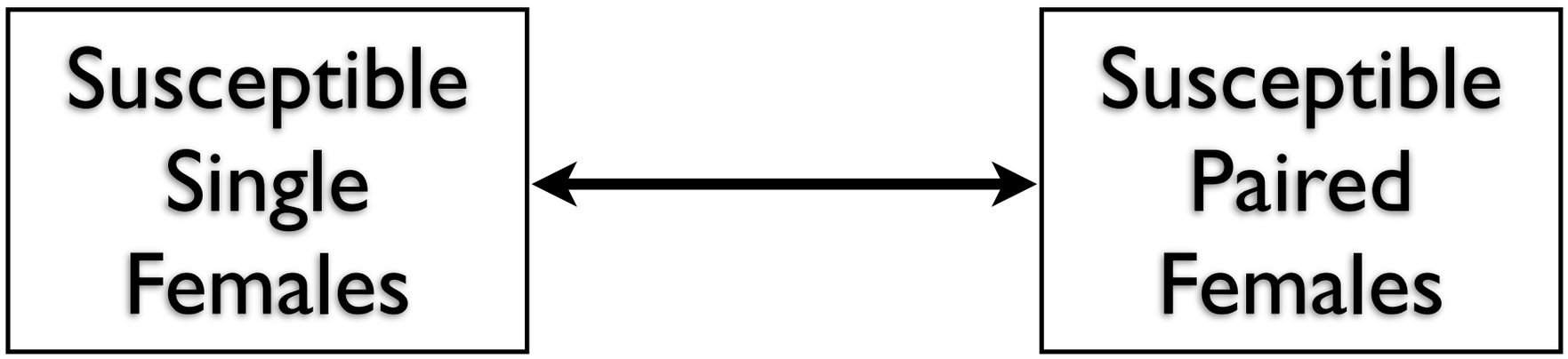
Infectious
Paired
Females

Susceptible
Single
Females

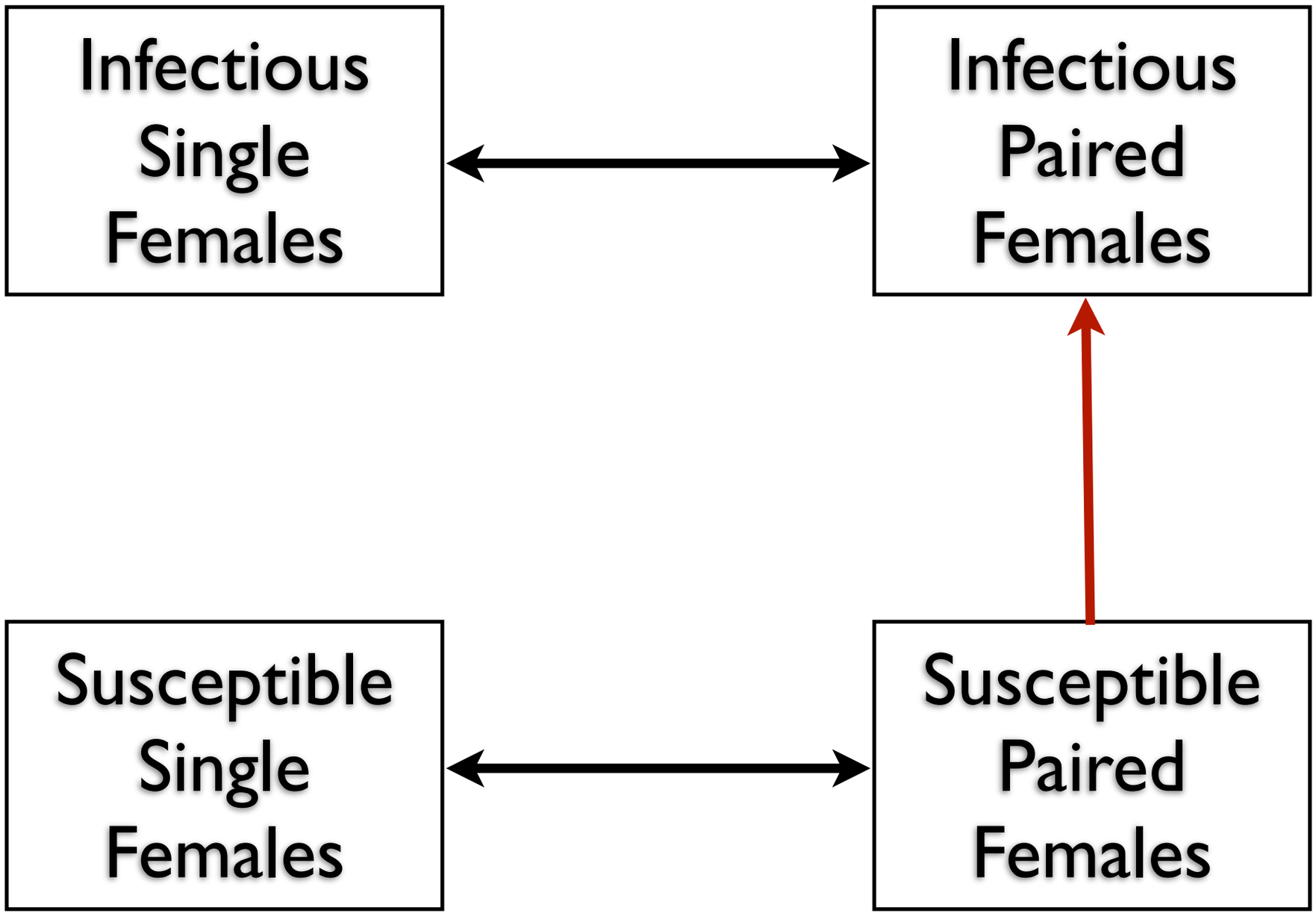
Susceptible
Paired
Females

Infection Dynamics



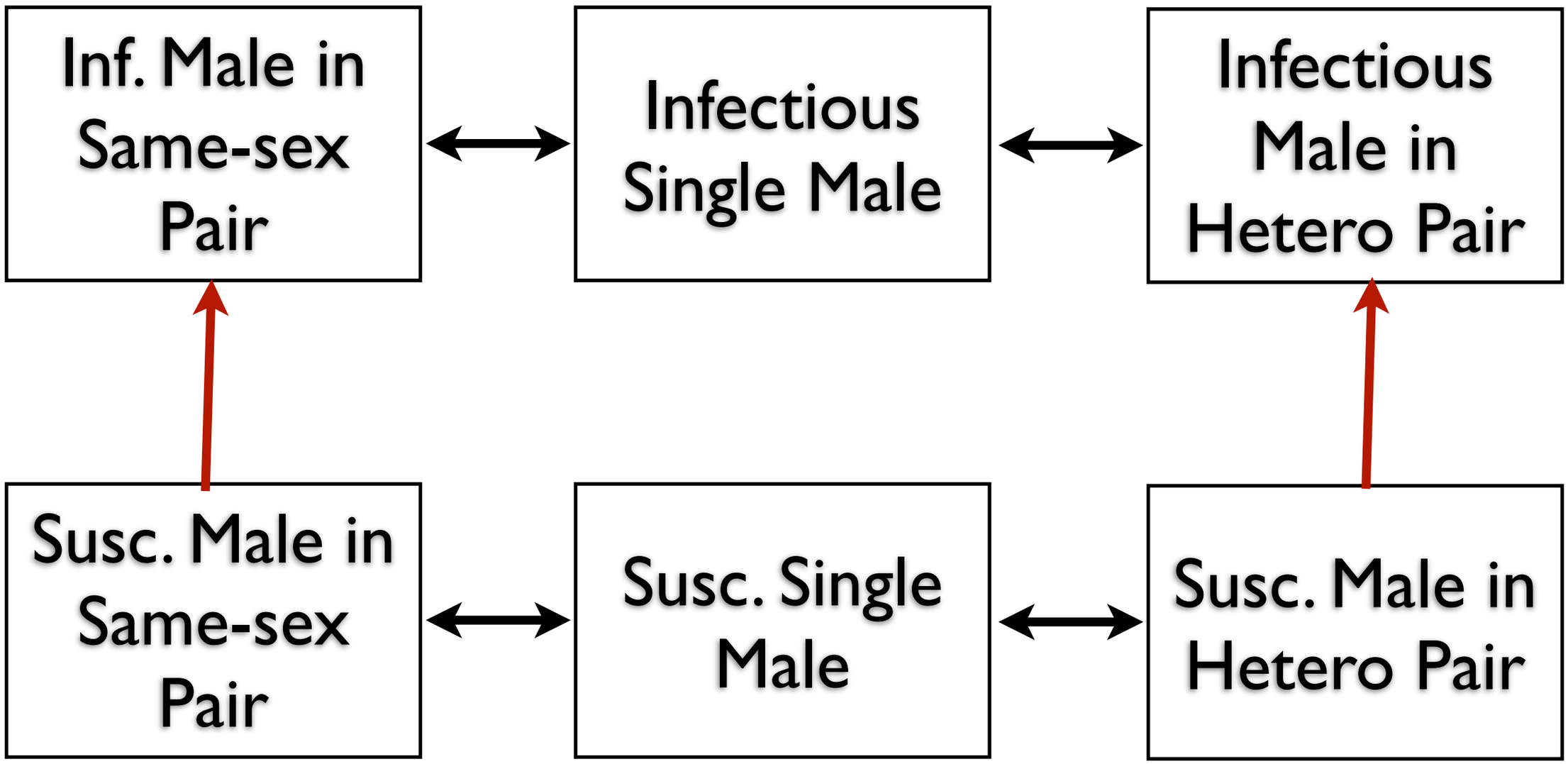


Infection Dynamics



Infection Dynamics

Infection Dynamics



Parameters

- per-person pair-formation rate
- per-pair breakage rate
- pairwise transmission rate
  - sharing frequency
  - transmission probability
- immigration rate and removal rate (e.g. hospitalization, death)
- male/female ratio

Missing Crucial Info

- pair formation and breakage rates
- rate of sharing within partnership
- immigration & removal rates

A major problem in both the literature and our current study

Basic Reproduction No.

$$\mathcal{R}_0 = \beta \left(\frac{A}{2} + \sqrt{\left(\frac{A}{2}\right)^2 + BC} \right)$$

- β : prob. transmission occurs before pair breaks
- A: expected total time an avg infectious male will spend in sharing partnership with a male
- B: expected total time an avg infectious female will spend ... with a male
- C: expected total time an avg infectious male will spend ... with a female

Results

- R_0 increases and saturates with transmission rate
- R_0 increases with pair formation rate
- R_0 initially increases with partnership duration, but then decreases (for fixed pair formation rate)
  - potentially accessible as novel control strategy

Conclusions

- Victoria syringe-sharing clients have optimal sharing behavior
  - *So why is there above average prevalence?*
    - Hypothesis: sharing behaviors were riskier in the past, creating a higher than average prevalence.

Conclusions (cont)

- A new model describing the current Victoria IDU population and disease dynamics
  - supporting stable relationships and personal risk networks may decrease secondary infections

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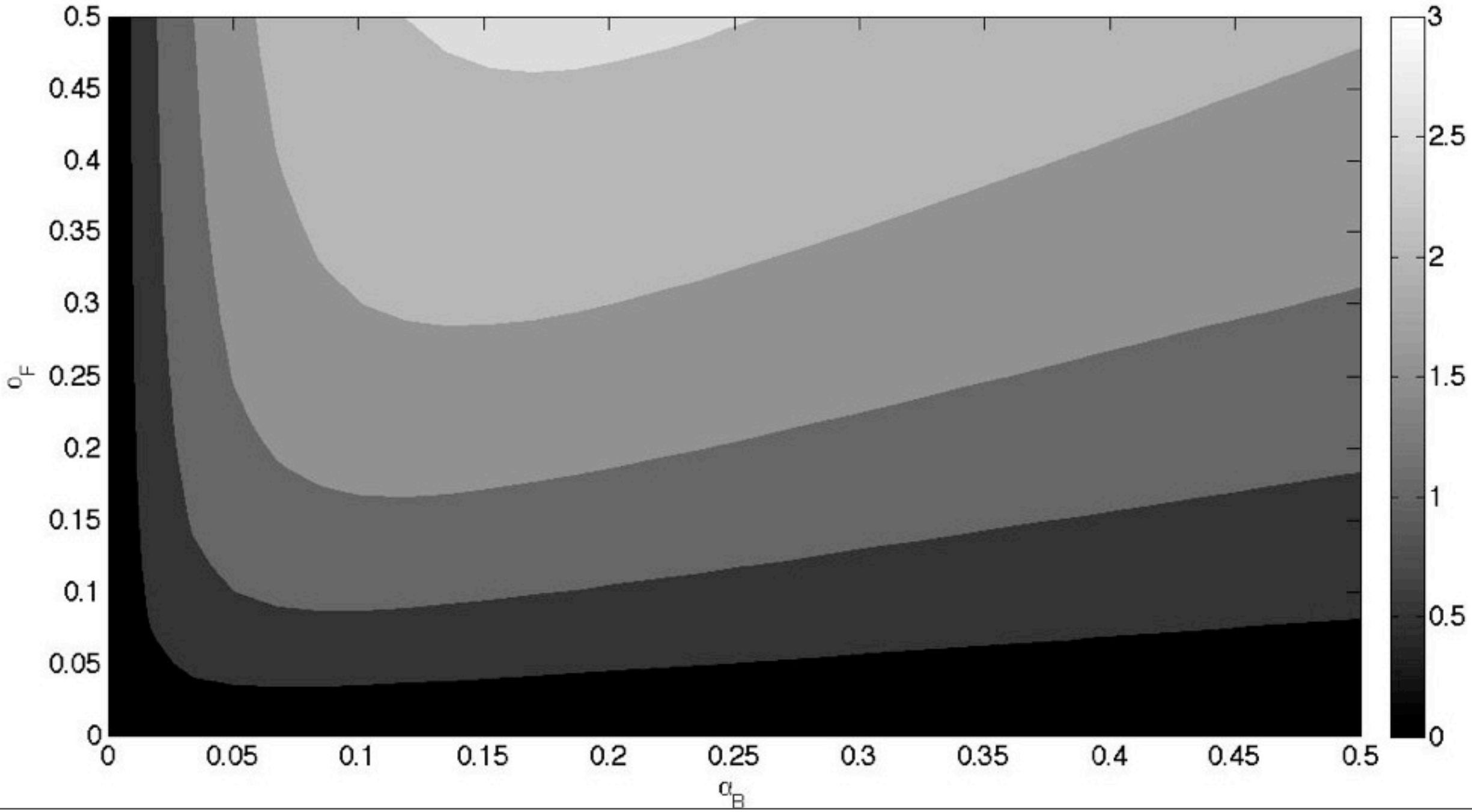
Discussion: Public Health Issues

- IDU are a partially hidden population
  - population size?
  - how to reach them?
- Is there universal access to health resources for IDU?
- Are there control or intervention strategies beyond syringe exchange or abstinence counseling?

Discussion: Modeling

- How do we reconcile the parameters needed with the data available (identifiability)?
- How do we model syringe-sharing?
  - What type(s) of models are appropriate for a particular population?
  - How does the sharing network evolve?
- How do we model education & behavior change?

R_0 Contours


0.5
0.45
0.4
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σ_F
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0.05
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0.4
0.45
0.5
α_B
3
2.5
2
1.5
1
0.5
0