

MODELLING THE LOCAL HETEROSEXUAL HIV EPIDEMIC: UNDERSTANDING DISPARITIES AND SUPPORTING PREVENTION PLANNING

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Outline

- History of these activities
- What this project is about
 - Goals
 - Data we will be using
 - A bit about the model
 - Timeline
- Related project: Darcy White's dissertation on local modeling for MSM

History: CAMP, WHAMP, SHAMP

- UW Network modeling group has developed software for HIV transmission modeling: statnet and EpiModel
 - Unique capabilities for modeling transmission network dynamics
 - Designed to be practical: works with egocentrically sampled network data
- First project(s) to use it for policy related modeling: CAMP (2014)
 - *Coalition for Applied Modeling for Prevention*
 - CDC funded collaboration btwn UW and Emory University
 - Focused on building models to evaluate PrEP in MSM

CAMP model components

Model Component	Governs:
Sexual network	Partnership formation/dissolution dynamics
Behavior within partnerships	Coital frequency, condom use, HIV status disclosure
Natural history of within-host HIV infection	Viral load, CD4, symptoms and infectivity
Clinical care cascade (ART)	Testing, referral, adherence, suppression
Demographics	Entries and Exits into the population (pop'n growth, mortality and in/out migration)

CAMP model components: **LOCAL DATA NEEDED**

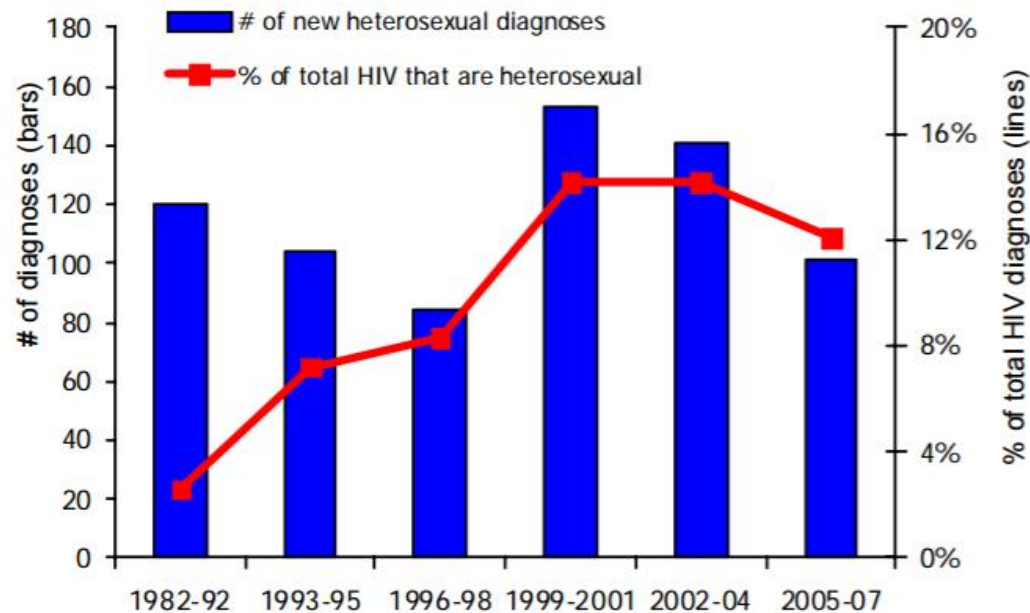
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... WHAMP and SHAMP

- Shared goal is to use these tools to support LOCAL prevention planning
 - By using LOCAL DATA to inform key model components
- WHAMP : Washington HIV/AIDS Modeling for Prevention (2015)
 - Leverage the CAMP MSM model
 - Used a little SPRC funding to review the locally available data
 - Funded Darcy Rao (Epi) to do the modeling as part of her PhD
- SHAMP: Seattle HIV/AIDS Modeling for Prevention (2016)
 - Build a model for the heterosexual part of the epidemic
 - Funded by NIH as a 2 year pilot project, Jul 2016 - 2018

Heterosexual HIV in Seattle/King Co

Figure 1: Number and percent of new HIV diagnoses among heterosexuals (1982-2007)



HIV incidence (Figures 2 and 3): The number of people diagnosed with HIV infection attributed to heterosexual transmission is level at about 40 diagnoses annually from 2000-2007.

- A small fraction of new Dx.
 - Different than in the SE US, where Het Dx comprises up to ~30% of case
- Possible evidence of declining trend?
 - Are we close to the threshold for eradication?

Heterosexual HIV in Seattle/King Co

Table 1: Place of birth, sex, and race among King County residents living with HIV/AIDS (June 2008)

	White	Black	Hispanic	API	Total ¹
Total Number HIV+	4,299	1,041	593	197	6,283
Foreign-born	2%	35%	52%	66%	15%
U.S.-born	93%	62%	39%	26%	81%
Of Foreign-born, % Female	13%	46%	9%	12%	25%
Of U.S.-born, % Female	5%	20%	6%	10%	7%

¹Total includes 67 people of multiple or unknown race, and 288 persons with unknown birthplace

- In addition to the universal racial disparities we see in HIV Dx
- The foreign born subgroup for both Black and Hispanic Dx is substantial.

SHAMP project goals

- Build a prototype network model for exploring local transmission dynamics among Heterosexuals in SKC
 - Racial disparities are central
 - And immigration plays an important role in these disparities here
- Evaluate the available local data for informing/validating the model
 - If we have the data needed, we will run and evaluate the models
 - If not, we will identify the gaps, and work with PHSKC/WADOH to determine whether we can collect the data we need

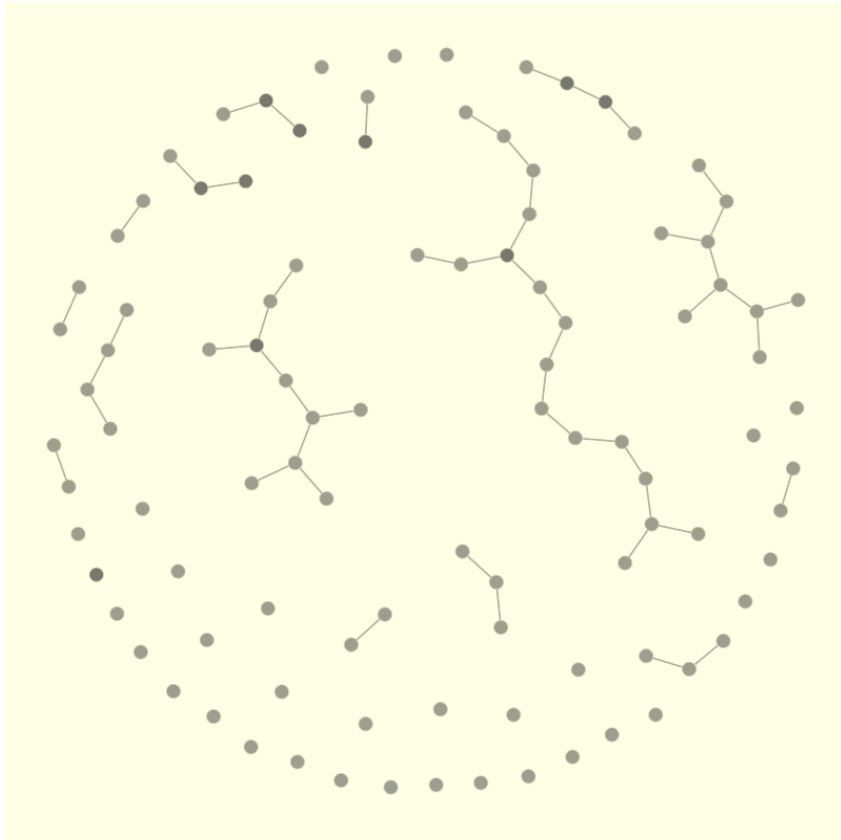
SHAMP project team

- UW
 - Martina Morris (overall project PI): national datasets
 - Jeanette Birnbaum: data harmonization, descriptive reports, simulation analyses
 - Deven Hamilton: code modifications, simulation analyses
- UW/PHSKC bridge
 - Sara Glick: local surveillance data
 - Roxanne Kerani: local immigration data
- Advisory Board
 - Matt Golden, David Katz, Susan Buskin, Amy Bennett, Katelynn Toren, Jason Carr

The model

We start here, to get a sense of the data inputs needed

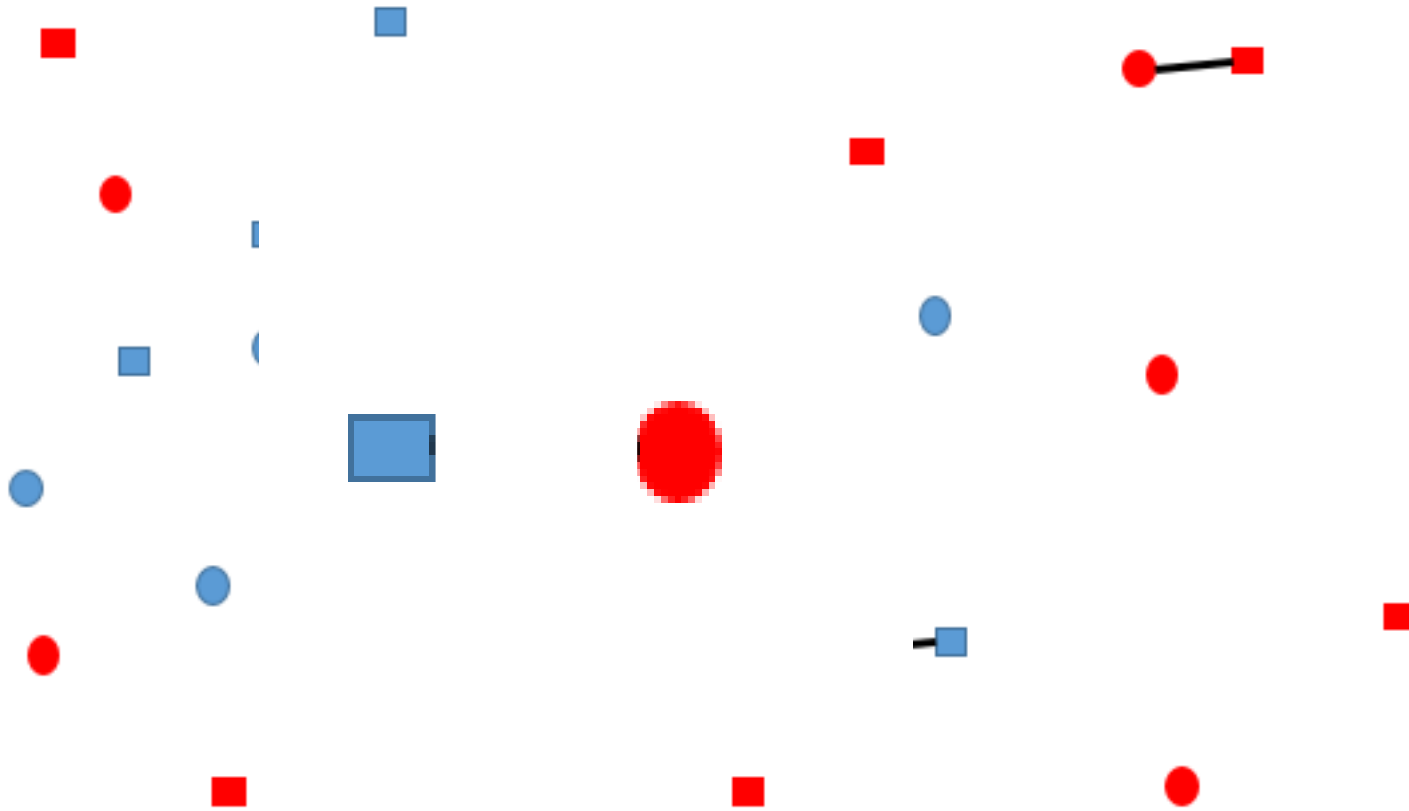
Multiple levels of dynamics to represent



- Population dynamics
 - Births/Deaths/Aging
 - Different sexes
 - Different races
- Network dynamics
 - Partnership formation/dissolution
 - Different types of relationships
- Disease dynamics
 - Infection and progression
- Care continuum dynamics
 - Testing, linkage, retention, suppression

Population level outcomes (network connectivity, HIV incidence and prevalence) are an emergent property of individual and pair-specific behavior

Dyad-level processes



- Stay in the relationship
- End a relationship
- Form a relationship
- Engage in sex
 - Use a Condom
- If HIV+ disclose status

Individual-level processes

- Get an HIV test
- If HIV +
 - Start treatment
 - Stop treatment



Within-individual processes

- Viral load
 - Suppression if on treatment
- CD4
- Stage progression



And interventions?

- These are typically modeled as the resulting changes in individual behavior
 - e.g., changes in testing rates, linkage and retention rates, suppression, etc.
- The economic costs associated with this will not be part of this project
 - But can be added after, if this pilot demonstrates feasibility


Steps in the modeling process

- Estimate a network model
 - Input: egocentrically sampled network data
 - Output: a model that can be used to simulate a complete dynamic network
 - The simulated networks will have the properties of the observed network that are in the model

- Simulate the transmission dynamics (stochastically)

Begin with a random starting network consistent with the model

- Simulate the partnership changes (formations/dissolutions) for one “time step”
- For each discordant partnership, simulate behavior and transmission
- For HIV+ persons: update disease progression indicators (VL, CD4)
- For all persons: update care continuum indicators (testing, adherence)
- Update population demographics (entries, exits, aging)
- Repeat for the desired number of time steps



Repeat entire simulation to observe variations in possible outcomes

Data Needed

... we'll start with an overview of the data sources we are reviewing

Important consideration

- Accurate modeling requires representative data inputs
- Some model components are **population level**
 - e.g., the sexual network data – this should represent the entire population at risk, not just the persons who get tested, or persons at high risk
- Other model components are **subgroup specific**
 - e.g., treatment adherence – only applies to HIV+ persons
- Need to evaluate the coverage and representativeness of every data source

SHAMP Relevant Datasets

Data Sets	Gatekeeper
LOCAL DATA	
Seattle Sex Survey (RDD)	CDC
PHSKC HIV core surveillance	PHSKC, HIV/STD Epi
PHSKC partner services	PHSKC, HIV/STD Epi
PHSKC STD clinic kiosk data	PHSKC, HIV/STD Epi
National HIV Behavioral Surveillance (NHBS)	PHSKC, HIV/STD Epi
Medical Monitoring Project (MMP)	WA DOH
Migration data supplement to PS	Roxanne Kerani
NATIONAL DATA	
National Survey of Family Growth (NSFG)	Public (CDC)
National Survey of Adolescent Health (Add Health)	Public (NIH/UNC)
National Health and Social Life Survey (NHSLs)	Public (NORC)

Local data and populations covered

Data Set	Population
Seattle Sex Survey	18-39 year olds in Seattle (2003-2004)
PHSKC HIV core surveillance	Persons with diagnosed HIV infection
PHSKC partner services	Persons with diagnosed HIV/STD
PHSKC STD clinic kiosk data	PHSKC STD clinic attendees + Gay City STD testing clients
National HIV Behavioral Surveillance (NHBS-Het)	Persons at increased risk for heterosexually-acquired HIV (i.e., low SES per CDC, three rounds available)
Medical Monitoring Project (MMP)	Adults diagnosed with HIV

← Only data source with representative data from the general het population

National data and populations covered

Data Set	Population
National Survey of Family Growth (NSFG)	15-49 (2006-15)
National Survey of Adolescent Health (Add Health)	18-25 (2000)
National Health and Social Life Survey (NHSLS)	18-59 (1994)

Data needed: Population/demographics

- Age, race/ethnicity/immigrant and sex distributions for Seattle/King Co
 - Age: 18-59 (>90% of new HIV Dx)
 - Race/ethnicity: 4 or 5 groups
 - Non-Hispanic Black (US born)
 - Non-Hispanic Black (immigrant)
 - Non-Hispanic White
 - Hispanic (US born)
 - Hispanic (immigrant)
 - Sex (binary)
- Source: Census and CPS

Data needed: Partnership Network

- Duration – types of partnerships
 - Determines dissolution rates for partnerships
 - May need different rates for different types (we'll show some data on this below)
- Momentary degree
 - How many active partnerships on a given day
 - May need to break this down by type
- Mixing by race/ethnicity/immigration status and sex
 - May need to break this down by type
- The data need to be collected in partner-specific modules
 - The last 3 partners in the last year (this is the standard)
 - Requires 6 questions about each partner

Network model – data we have locally

	Seattle RDD	NHBS (last partner)	Partner Services
Momentary degree			
Partnership still active?			X
Duration			
Type of partner	X	cas/main	
Date of first sex or how long	X	X	X
Mixing			
Age of partner	X	(o/y/same)	X
Race/ethnicity (immigration status of partner)	X (n)	X (n)	X (n)
Sex of partner	X	X	X

None of the sources has all of the information we need, but more importantly
 RDD is old (2003) and NHBS and Partner Services are not representative samples

But ...

The national datasets have everything we need

- **Best: National Survey of Family Growth (NSFG, 2006-15)**

- Annual enrollment (mostly cross-sectional)
- 15-49 years old, men and women
- Last 3 partners (since 2006)
- Combined sample size: ~40K

And the NSFG has data on indicators of high risk: drug use, sex for money, and STI Dx

- **National Health and Social Life Survey (NHSL 1994)**

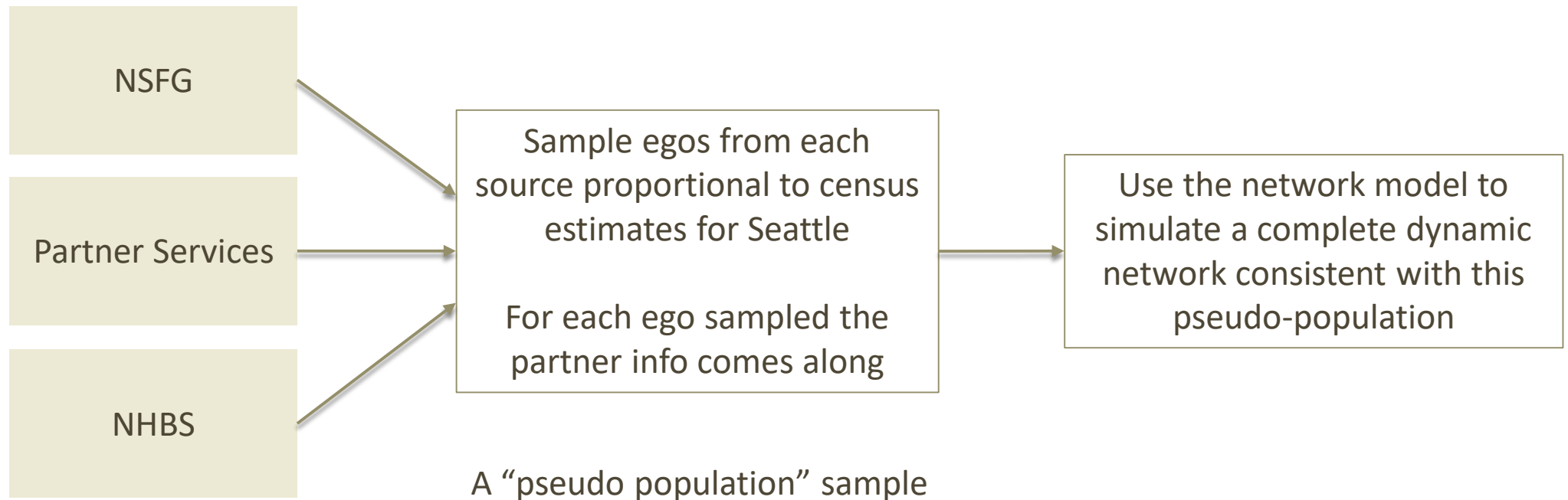
- To supplement age range to 59

High risk subgroups

- Even with 40K respondents, NSFG does not have many who report high risk behaviors
- For these subgroups, we have much richer data locally
 - NHBS
 - Partner Services
- We can use the best of both worlds to inform network model

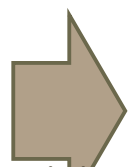
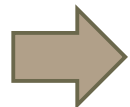
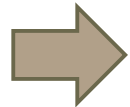
Combining information from different sources

The network modeling tools were designed to be used with egocentrically sampled data – so we sample from the different data sources



We can also pool, and sample from, NHBS-HET

Note key
differences
in sample
composition



	HET1 – 2007 N=450	HET2 – 2010 N=459	HET3 – 2013 N=451
Recruitment	Venue-based	Respondent-driven	Respondent-driven
Field Site(s)	Primarily Central District	SE Youth and Family Services (Rainier Valley)	King Street Center (Pioneer Square)
Age < 40 years	76%	62%	44%
Persons of color	81%	93%	83%
Female	52%	52%	38%
Income <\$20,000/yr	64%	81%	81%
Currently homeless	13%	23%	34%

Data needed: Migration

This will be the major new component of the model

- Permanent immigration
 - Rate by sex and age at entry
- Cyclical migration
 - Travel to/from country of origin, (by sex? age?)
 - Sexual activity here/there
- Sources: Census, Kerani supplements to PS data, MMP, NHSLs?

Immigration data collected in Partner Services Interviews

IMMIGRATION HX

66.

	Yes	No	Unknown	Refused	If so, where?
Were you born outside the U.S? <i>Birthplace 1</i>	<i>1</i>	<i>0</i>	<i>99</i>	<i>77</i>	<i>Birthplace - specify 1</i>

67. When did you move to the U.S.? *move US*
(MM/DD/YYYY)

68. Did you ever test for HIV prior to moving to the US? *test before US*
☒ Yes. Last time: *test before US date* (MM/DD/YYYY) *0* No *99* Unknown *77* Refused

69. What was the result of that test? *test before US result*
☒ Positive *2* Negative *3* Indeterminate *99* Unknown *77* Refused

70. Have you been back to your home country/area since moving to the US?
☒ Yes *0* No *99* Unknown *77* Refused *home country return*

71. Did you have sex while back in your home area?
☒ Yes *0* No *99* Unknown *77* Refused *home country return sex*

72. Have you tested HIV negative since you last had sex in your home country?
☒ Yes *0* No *99* Unknown *77* Refused *Neg Home Country sex*

73. How many people have you had sex with since moving to the US?
0 Number: *99* Unknown *77* Refused *sex partners US*
sex partners US number

Added in
2010

MMP: Also has some migration data

And this would be linked to:

D6. In what country or territory were you born? *[DON'T READ CHOICES. CHECK ONLY ONE.]*
[CO_BORN]

United States.....	<input type="checkbox"/>	1	} Skip to D7
Puerto Rico.....	<input type="checkbox"/>	2	
Mexico.....	<input type="checkbox"/>	3	
Cuba	<input type="checkbox"/>	4	} Skip to D7
Other (<i>Specify:</i> _____)	<input type="checkbox"/>	5 <i>[OTCTRY]</i>	
Refused to answer.....	<input type="checkbox"/>	7	
Don't know.....	<input type="checkbox"/>	8	

D6a. How many years have you been living in the United States? *[US_YRS]*

- Partner-specific sexual behavior
 - Partner gender, age, race, commitment
 - Anal/vaginal sex frequency
 - Condom use
 - Serostatus disclosure
 - Partner status
 - Partner PrEP use
- HIV and STI test history
- Clinical HIV indicators

Local sources again limited by sample constraints

- Partner services and MMP restricted to persons with STI and/or HIV Dx
- NHSLS *may* have some additional data

Data needed: Care Cascade

- Testing rates
- Linkage to care
- Adherence/Retention
- Viral Suppression

Ideally, broken down by

- Age
- Race/Ethnicity/Immigration status
- Sex

Care Cascade





Data	HIV tests in the last 2 years	Last HIV (-) Test Date	First HIV (+) Test Date	Treatment / Time to treatment	CD4 Count	CD4 Test Date	VL	VL Test Date	ARV	PrEP
HIV(OP)	Negative tests	Self Report	Self Report	Ever taken ARV Date last taken	Self Report binned count		Self Report Undetectable		Self Report Ever Date first taken Date last taken Current	
STD(OP)		Self Report	Self Report		Self Report binned count		Self Report Undetectable		Self Report Ever Date first taken Date last taken Current	
Partner Services										
Case Report EHRs/HIV		Self Report and Chart validated	Self Report and Chart validated	- Patient received/ is receiving ARV therapy? - If yes, the earliest date started ARV. - Earliest Positive antibody test	LAB Most recent Earliest <200	LAB Most recent Earliest <200	LAB Count Undetectable Most recent Earliest	LAB Most recent Earliest	Self Report Ever taken Date-first taken Date of last use	
NHBS	Self Report	Self Report	Self Report				Self Report Binned Count	Self Report Most recent	Self Report Current	Self Report In the last 12 months have you taken anti-HIV medicines before sex to avoid getting HIV
RDD		Self Report ~ 6 months	Self Report ~ 6 months		Self Report Binned count	Self Report How long ago Most recent ~ 6 months	Self Report Binned count Undetectable	Self Report How long ago Most recent ~ 6 months	Self Report Current	Self Report Ever taken anti-HIV medicines before sex to avoid getting HIV.
PHSKC KIOSK	5/6/2019				Self Report		Self Report Binned count		Self Report Current	Self Report Ever taken anti-HIV medicines before sex to avoid getting HIV

Data Access Issues

- A key **strength** of this project is **collaboration** with **local health department epidemiologists**.
 - Have access to the data
 - Know the data
 - Vested in the outcome
- Can SHAMP investigators access individual-level data?
 - NHBS as an example
 - Will be discussing with the Advisory Board after this presentation

Possible solution: Simulate from aggregate stats?

INDIVIDUAL LEVEL

ID	AGE	HIV	PTRS
	35	1	10
	20	0	2
	29	0	0
	48	1	1

5/6/2019

AGGREGATE

<i>Legal pad</i> RIFLE PAPER CO. NOTEPAD 75 Sheets MADE IN USA
AGE Distribution mean= 33 range={20-48}
HIV = 50%
PTRS Distribution mean = 3.3 range={0-10}
Correlation matrix
PHSKC/SPRC Lunchbox Talk

Simulate individual level data that will have the same aggregate characteristics

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Current data analyses

How many relationship types do we need to model

- Relationships have a wide range of lengths: from 1 night to 30+ yrs
- The rate of dissolution is a basic parameter in the network model
 - Is there just a single rate (so one type of partnership)
 - Or different rates (in the CAMP MSM model there are 3 different types)



Estimating this from data

- Basic idea:

- Say there is only one type of partnership
- With a “constant hazard” of dissolving at each time step
- The partnership duration distribution will be exponential
- And if we sample partnerships on any particular day, the distribution of their current age will be [JKB]
- Does a one-type model fit our data?
- If not, how many types would we need to fit the data we observe?

Data source: NSFG



National Survey of Family Growth

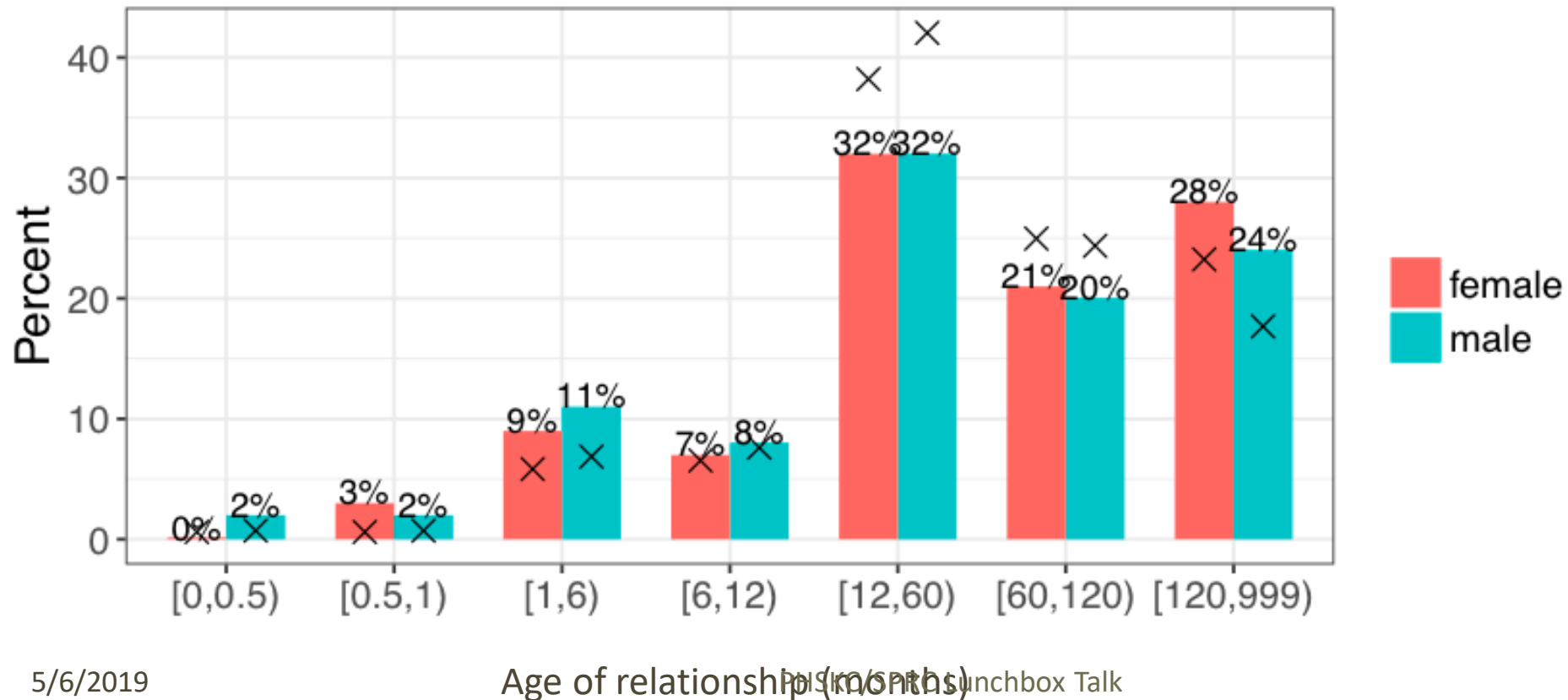
[CDC](#) > [NCHS](#) > [National Survey of Family Growth](#)

- 3 most recent sexual partners (last 12 mos)
- Observe the “age” of active partnerships on the DOI
 - Based on date of first sex
 - And whether this was a “one-time” relationship.

Model 1: One relationship type

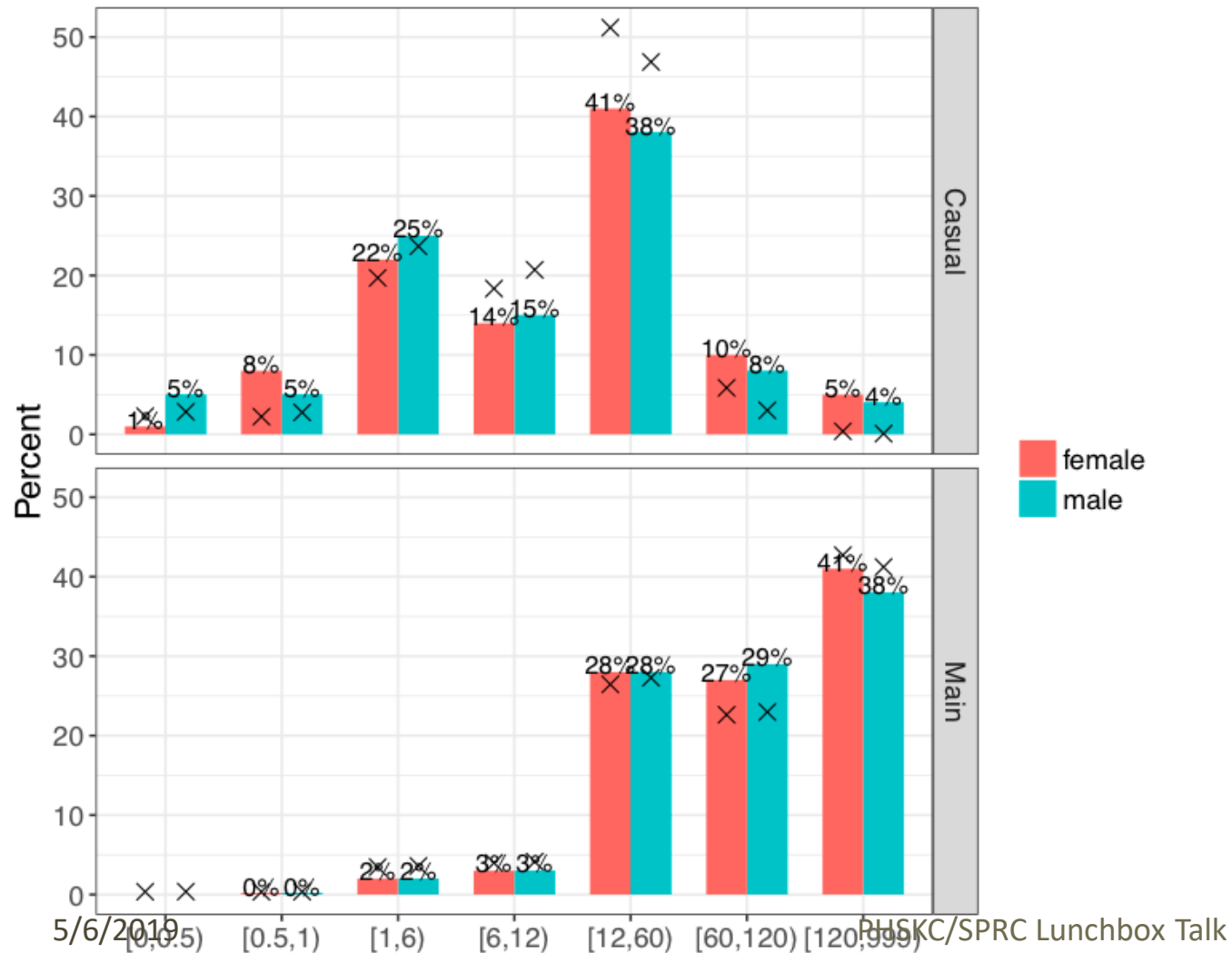
Relationships by time since first sex

Bars show NSFG data; X shows prediction from exponential distribution



Surprisingly
decent fit

Model 2: Two relationship types



Does a good job for main partners, but not very good for the casual

But ... we've just realized we need to correct for length-biased sampling. So stay tuned 😊

Local MSM Model

Darcy Rao's project

Following up on WHAMP

Washington MSM Model

- **Technical aim:** Adapt existing MSM network model to Washington MSM and expand the PrEP module
- **Policy aim:** Evaluate the potential impact of PrEP in Washington State* under a range of scenarios of uptake, adherence, risk compensation, and discontinuation.
 - **Sub-aim 1:** Given current levels of ART coverage and viral suppression in Washington*, what level of PrEP uptake and adherence is needed to reduce transmission below the threshold ($R_0 < 1$)?
 - **Sub-aim 2:** How robust is the effect of PrEP to risk compensation and reintroduction from other areas?

*Seattle/King County if state-wide data are limited

Parameterization

Parameter set	Online survey*	MMP	NHBS	PHSKC Kiosk	Mobile Study	Partner services	Case reports	Pride Survey	Literature
Contact network	Dark grey	Dark grey	Light grey	Light grey	Dark grey				
Partner-specific behavior	Dark grey	Dark grey	Light grey	Light grey	Dark grey				
HIV and STI testing	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	
Clinical epidemiology		Dark grey	Light grey	Light grey		Dark grey	Dark grey		
Intrahost epidemiology									Dark grey
Interhost epidemiology									Dark grey
PrEP use	Dark grey	Light grey	Dark grey	Dark grey		Light grey		Dark grey	

*Washington HIV Prevention Project survey, to be launched mid-December

Dark grey: moderate/high correspondence to model inputs

Light grey: limited data/low correspondence to model inputs

PHSKC/SPRC Lunchbox Talk

Model building and analysis

- Leverage the structure of prior models developed by the Network Modeling Group
- Simulate HIV transmission under different scenarios of PrEP uptake, adherence, risk compensation, and discontinuation
- Estimate the most efficient and effective PrEP implementation scenarios to reduce HIV incidence in Washington MSM and identify areas for further data collection and monitoring.

Timeline

	Q4 2016	Q1 2018	Q2 2017	Q3 2017	Q4 2017	Q1 2018	Q2 2018	Q3 2018
Data collection and parameterization								
• Administer cross-sectional survey								
• Analyze survey data								
• Compile and analyze secondary data								
Model building and analysis								
• Build and calibrate the model								
• Run scenarios								
• Analyze model output								
Write manuscript(s)								

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Thank you!

EpiModelHIV Funding Support

CDC-RFA-PS14-1415 subcontract (Goodreau) 01/01/2015- 09/29/2020

Centers for Disease Control & Prevention

Economic Modeling for HIV, Viral Hepatitis, STD TB and School Health

NIH/NICHD R21 HD080523 (Cassels) (7/2015 – 6/2017)

Mathematical models to inform effective home-use HIV testing strategies for MSM

NIH R21 AI124789-01A1 (Morris) (06/2016 – 05/2018)

Seattle HIV/AIDS modeling for Prevention

R01 A110347-01 (Graham / Sanders) 07/01/16-06/30/20

Impact of a Novel Screening Program to Detect Acute and Prevalent HIV Infection and Reduce HIV Transmission

EpiModelHIV publications

- Impact of the Centers for Disease Control's HIV Preexposure Prophylaxis Guidelines for Men Who Have Sex With Men in the United States - Jenness S, Goodreau S, Rosenberg E, Beylerian E, Hoover K, Smith D, Sullivan P
- Effectiveness of combination packages for HIV-1 prevention in sub-Saharan Africa depends on partnership network structure: a mathematical modelling study - Samuel M Jenness, Steven M Goodreau, Martina Morris, Susan Cassels
- Goodreau SM; Rosenberg ES, Jenness SM, Luisi N, Stansfield SE, Millett GA, Sullivan PS. Isolating the sources of racial disparities in HIV prevalence among men who have sex with men (MSM) in Atlanta, GA: A modeling study. The Lancet HIV (under review)
- Jenness SM, Sharma A, Goodreau SM, Rosenberg ES, Hoover K, Smith D, Sullivan PS. Individual Risk versus Population Impact of Risk Compensation after HIV Preexposure Prophylaxis Initiation among MSM. PLoS One.
- Samuel M. Jenness, Kevin M. Weiss, Steven M. Goodreau, Thomas Gift, Harrell Chesson, Karen W. Hoover, Dawn K. Smith, Albert Y. Liu, Patrick S. Sullivan, Eli S. Rosenberg, Incidence of Gonorrhea and Chlamydia Following HIV Preexposure Prophylaxis among Men Who Have Sex with Men: A Modeling Study