Global Hepatitis Outbreak & Surveillance Technology

GHOST

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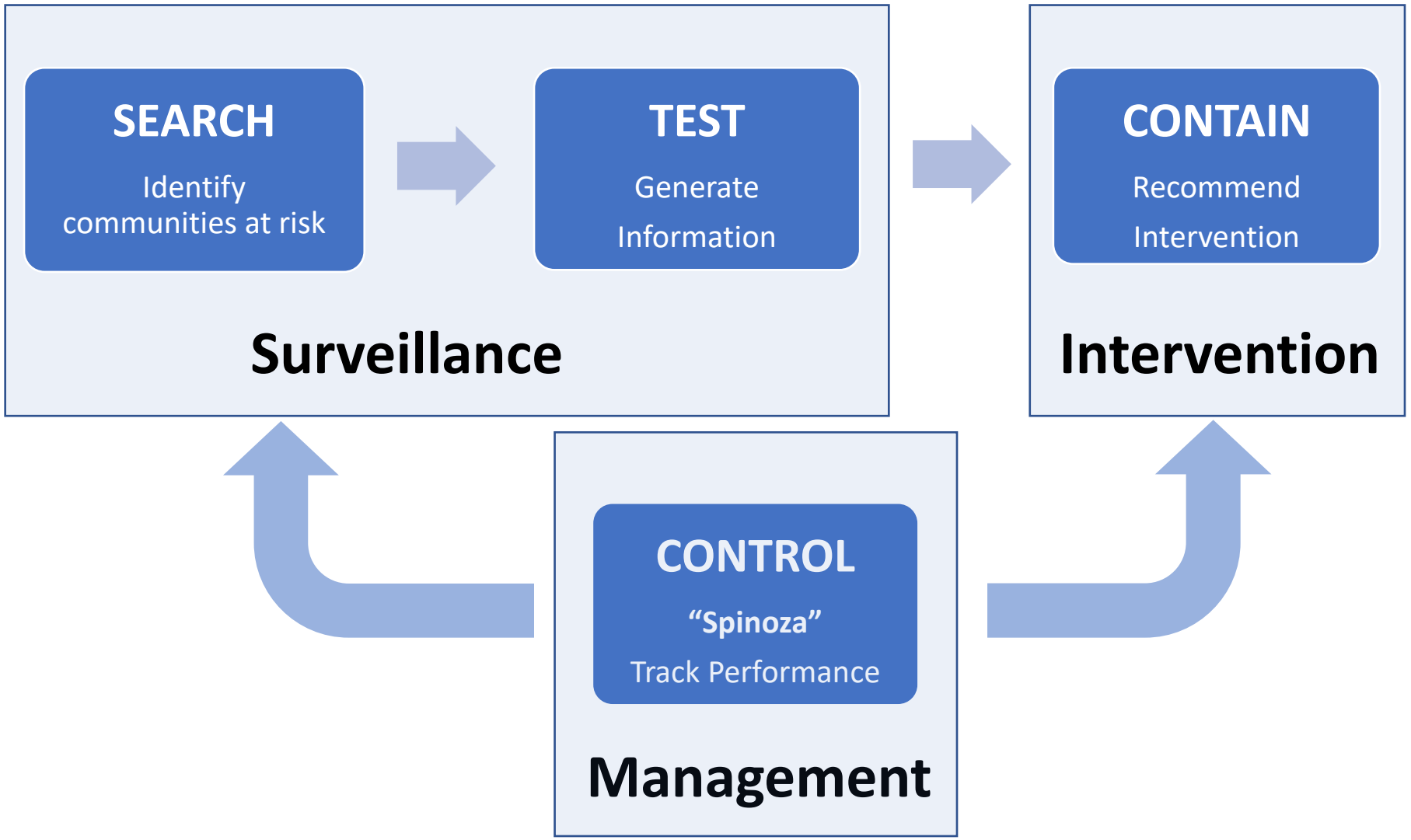
Introduction

GHOST

Global Hepatitis Outbreak Surveillance Technology

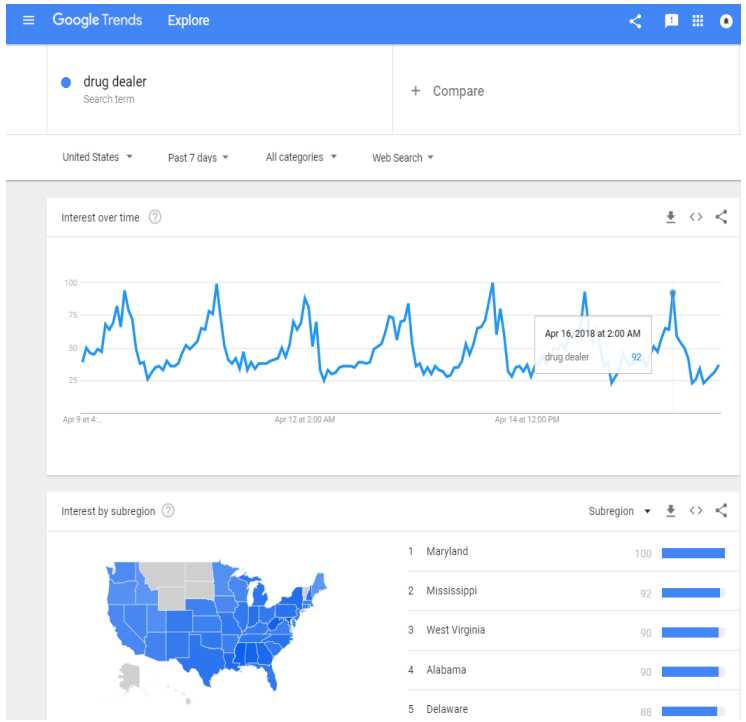
Provides accurate information for designing, guiding and monitoring public health interventions

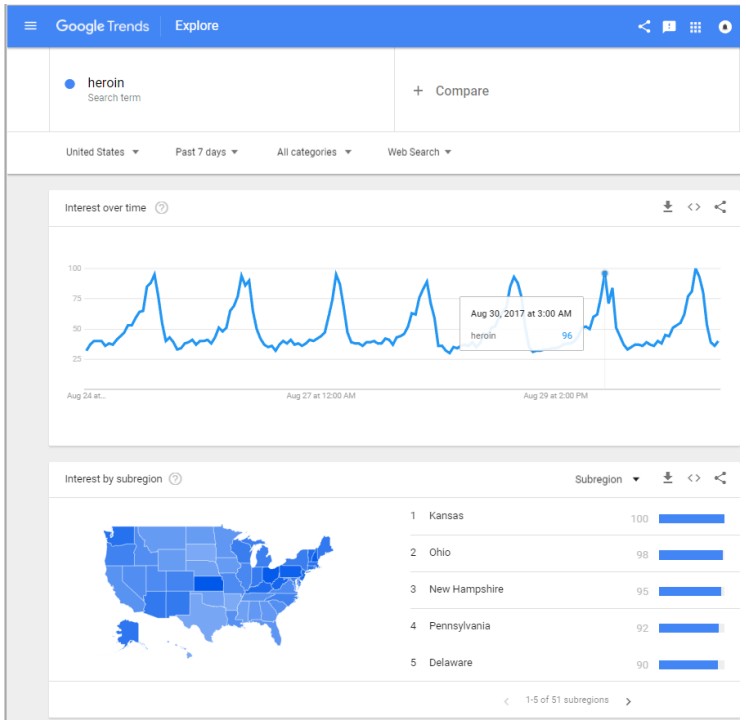


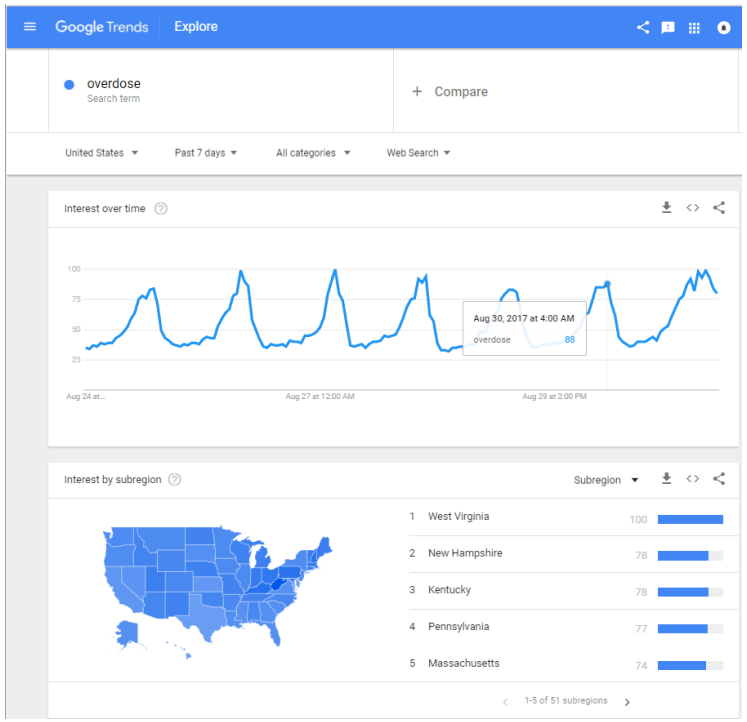
Geospatial Mapping of High-Risk Communities

Daily Patterns of Web Searches

Google Trends







Drug dealer

The volume of searches shows a daily pattern, peaking around **2am**

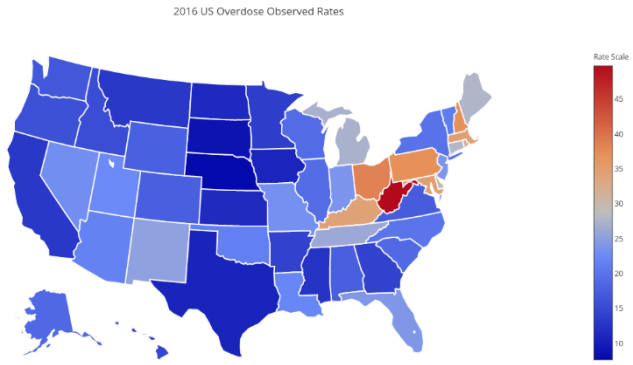
Heroin

The volume of searches shows a daily pattern, peaking around **3am**

Overdose

The volume of searches shows a daily pattern, peaking around **4am**

The following search terms have the highest correlation with real overdose rates (2015)



Death rates per 100,000 population
https://www.cdc.gov/drugoverdose/data/statedeaths.html

- the web-search term that is the most correlated with real overdose rates is “overdose”

- Many other have an obvious association with drugs.

Google Correlate

overdose deaths, 2015 × Search correlations Edit this data

Compare US states
Compare weekly time series
Compare monthly time series

Documentation
Comic Book
FAQ
Tutorial
Whitepaper
Correlate Algorithm

Correlate Labs
Search by Drawing

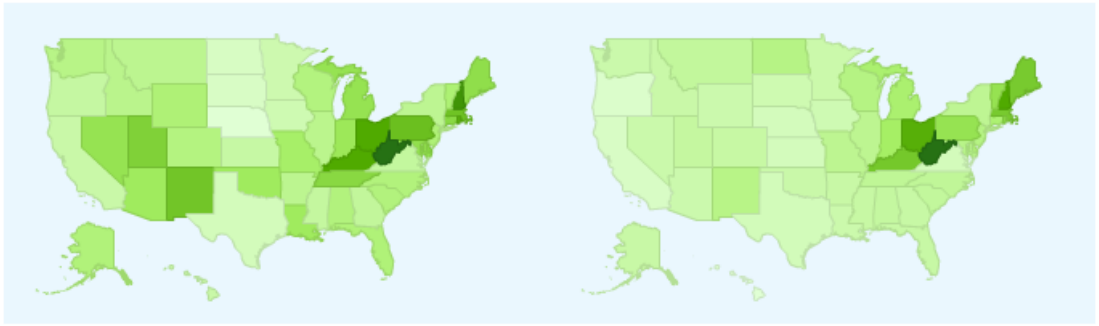
Correlated with **overdose deaths, 2015**

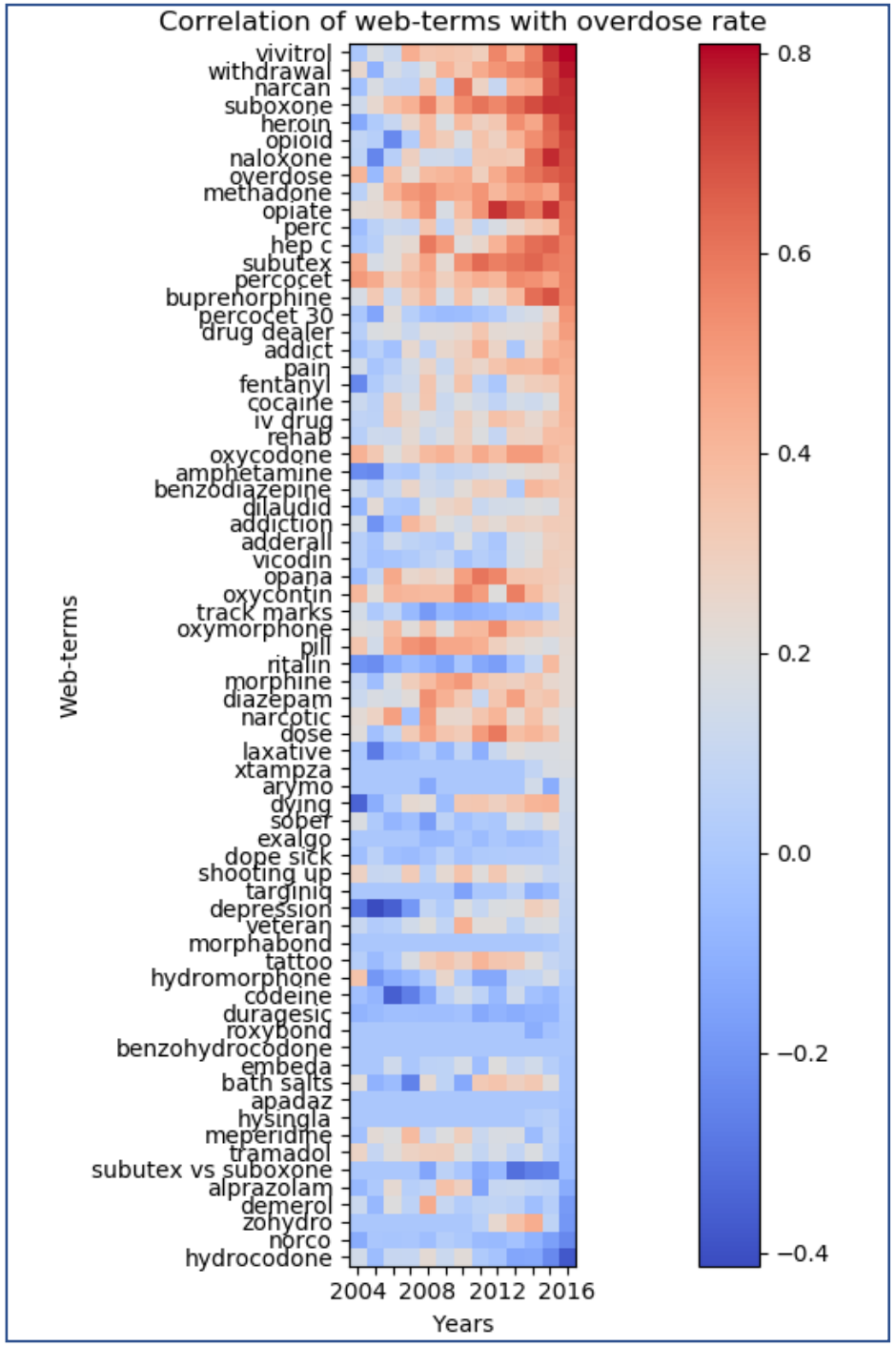
0.8549	overdoses
0.8309	drug overdoses
0.8265	overdose statistics
0.8230	drug addicts
0.8202	overdose deaths
0.8126	drug overdose
0.8123	suboxone side effects
0.8109	suboxone withdrawal
0.8093	narcan
0.8071	drug addiction
0.8041	naloxone
0.8018	track marks
0.8013	subutex vs suboxone
0.7897	suboxone
0.7863	suboxone use
0.7821	narcan cost
0.7805	nosferatu
0.7796	city and colour lyrics
0.7762	vivitrol
0.7746	drug overdose deaths

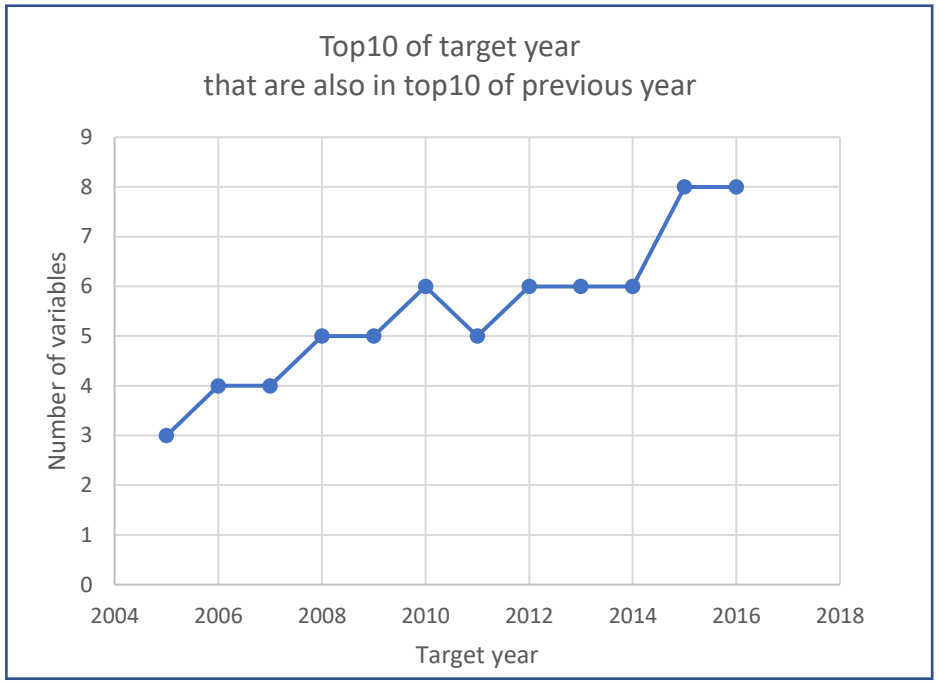
Show more Export data as CSV | Share:

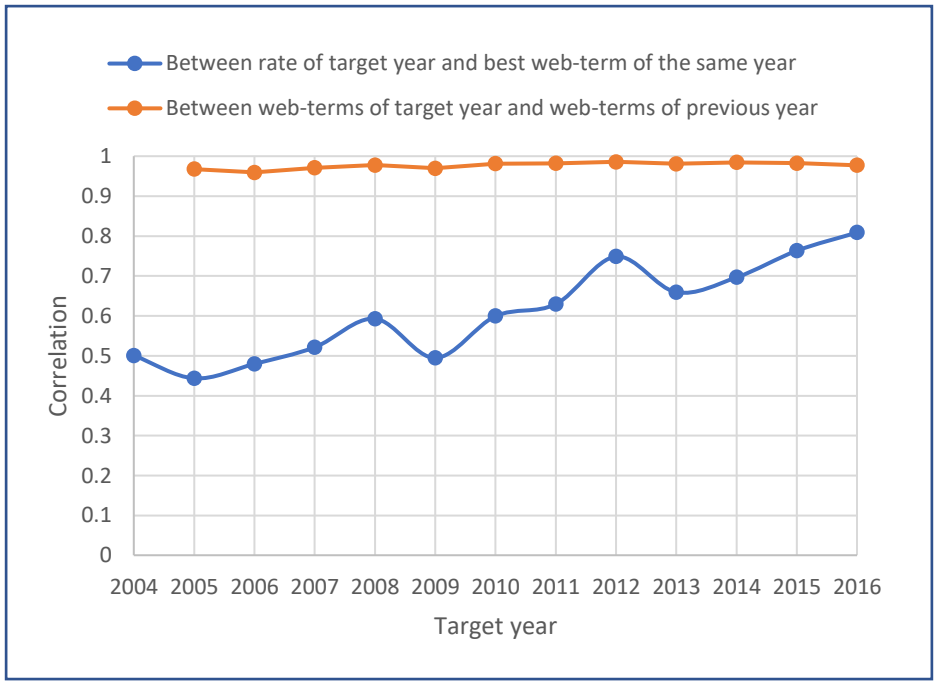
Direct relation with drugs

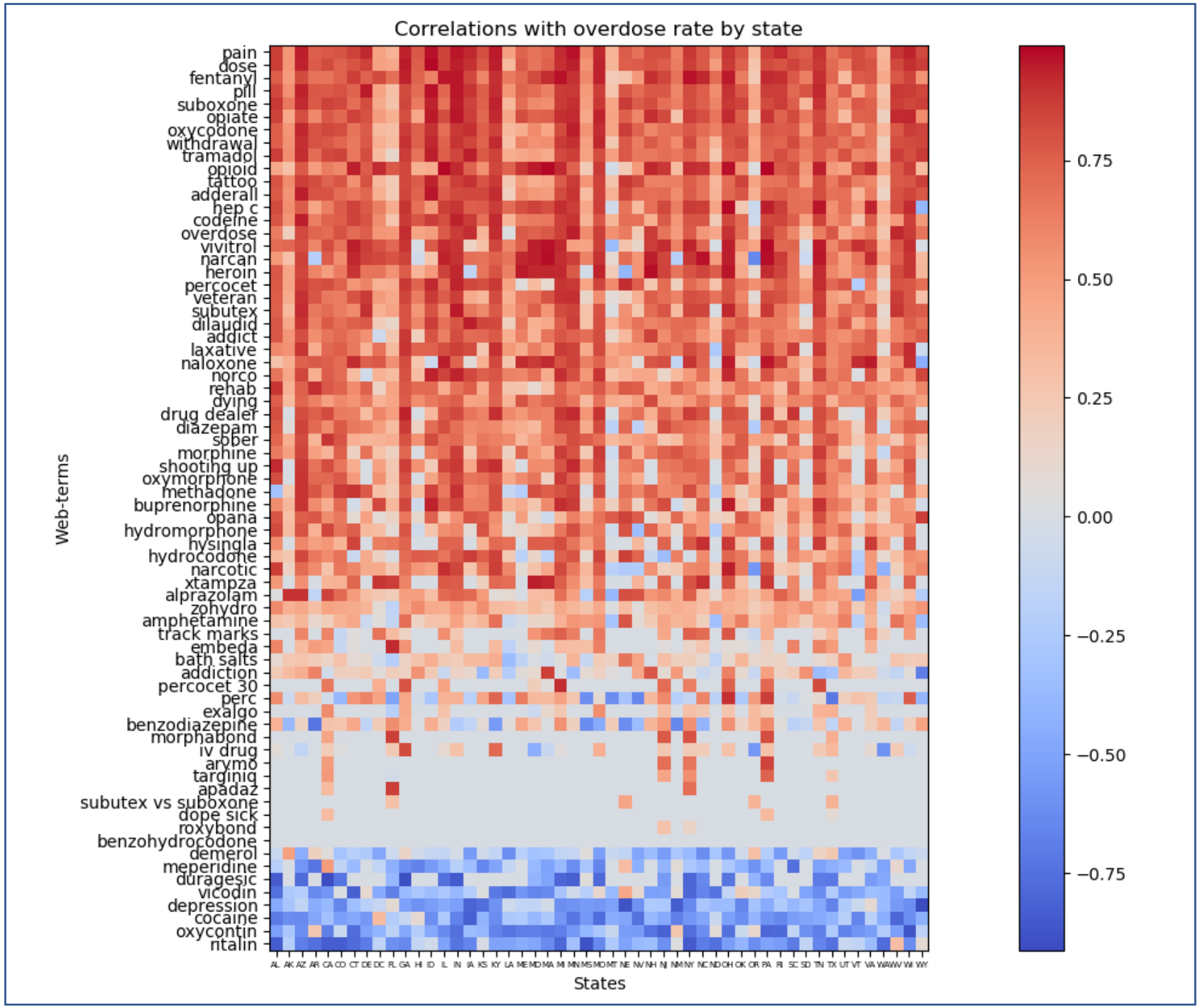
User uploaded activity for **overdose deaths, 2015** and United States Web Search activity for **overdoses** (r=0.8549)
State maps Scatter plot




Correlation of web-terms with overdose rate
vivitrol
withdrawal
narcan
suboxone
heroin
opioid
naloxone
overdose
methadone
opiate
perc
hep c
subutex
percocet
buprenorphine
percocet 30
drug dealer
addict
pain
fentanyl
cocaine
iv drug
rehab
oxycodone
amphetamine
benzodiazepine
dilaudid
addiction
adderall
vicodin
opana
oxycontin
track marks
oxymorphone
pill
ritalin
morphine
diazepam
narcotic
dose
laxative
xtampza
arymo
dying
sober
exalgo
dope sick
shooting up
targiniq
depression
veteran
morphabond
tattoo
hydromorphone
codeine
duragesic
roxybond
benzohydrocodone
embeda
bath salts
apadaz
hysingla
meperidine
tramadol
subutex vs suboxone
alprazolam
demerol
zohydro
norco
hydrocodone
Web-terms
2004 2008 2012 2016
Years
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4


Top10 of target year
that are also in top10 of previous year
Number of variables
0
1
2
3
4
5
6
7
8
9
2004 2006 2008 2010 2012 2014 2016 2018
Target year


Between rate of target year and best web-term of the same year
Between web-terms of target year and web-terms of previous year
Correlation
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016
Target year

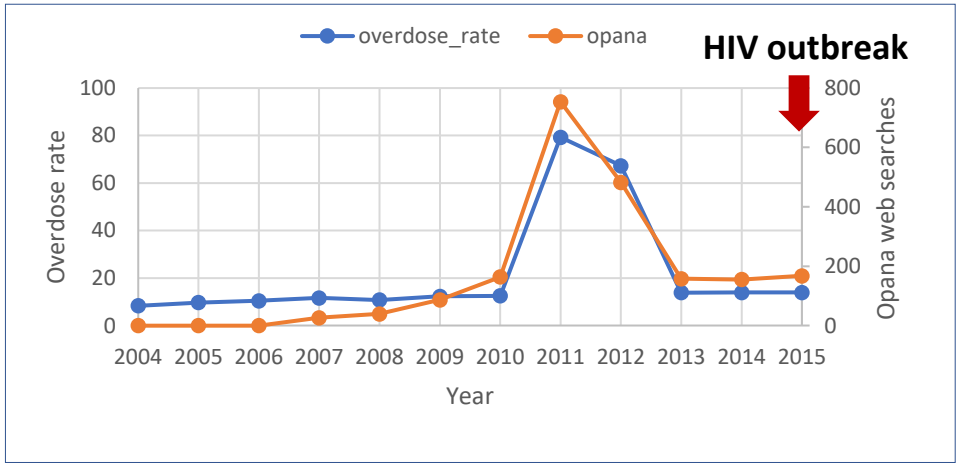

Correlations with overdose rate by state
Web-terms
pain
dose
fentanyl
pill
suboxone
opiate
oxycodone
withdrawal
tramadol
opioid
tattoo
adderall
hep c
codeine
overdose
vivitrol
narcan
heroin
percocet
veteran
subutex
dilaudid
addict
laxative
naloxone
norco
rehab
dying
drug dealer
diazepam
sober
morphine
shooting up
oxymorphone
methadone
buprenorphine
opana
hydromorphone
hysingla
hydrocodone
narcotic
xtampza
alprazolam
zohydro
amphetamine
track marks
embeda
bath salts
addiction
percocet 30
perc
exalgo
benzodiazepine
morphabond
iv drug
arymo
targiniq
apadaz
subutex vs suboxone
dope sick
roxybond
benzohydrocodone
demerol
meperidine
duragesic
vicodin
depression
cocaine
oxycontin
ritalin
AL AK AZ AR CA CO CT DE DC FL GA HI ID IL IN IA KS KY LA ME MD MA MI MN MS MO MT NE NV NH NJ NM NY NC ND OH OK OR PA RI SC SD TN TX UT VT VA WA WV WI WY
States
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75

Dynamic Overdose Vulnerability Estimator (DOVE)

Early Detection of Vulnerable Communities

Scott County, IN

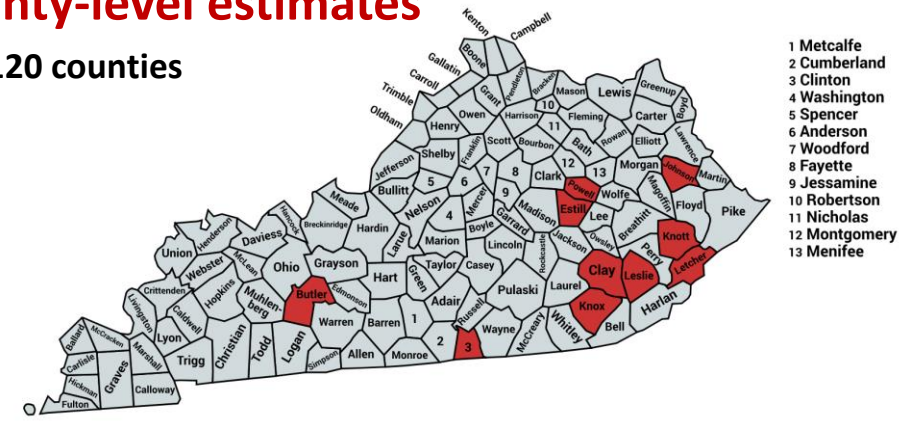
HIV/HCV outbreak among PWID associated with opana, 2015



- "Opana" correlates with overdose rates by DOVE (R = 0.95)
- Peak of opana searches - February 2012

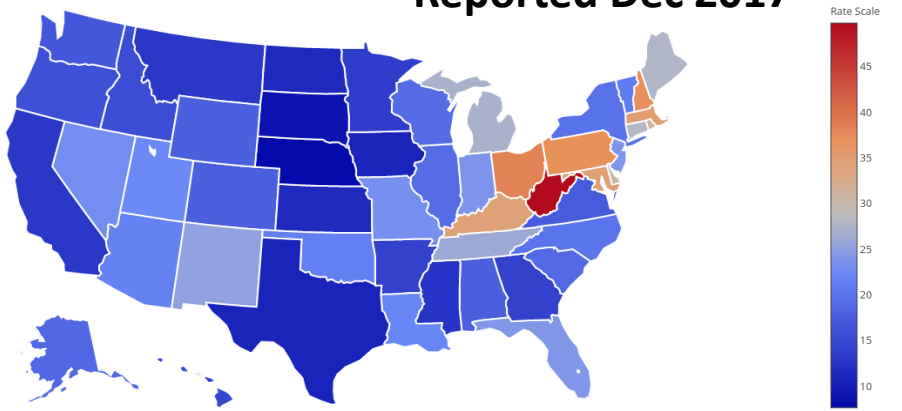
County-level estimates

KY: 120 counties

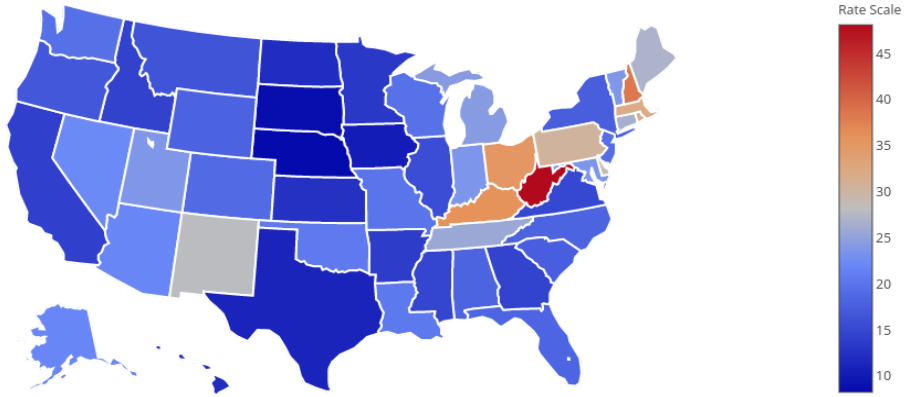


2016 US Overdose Rates

Reported Dec 2017



Estimated Jan 1st 2017

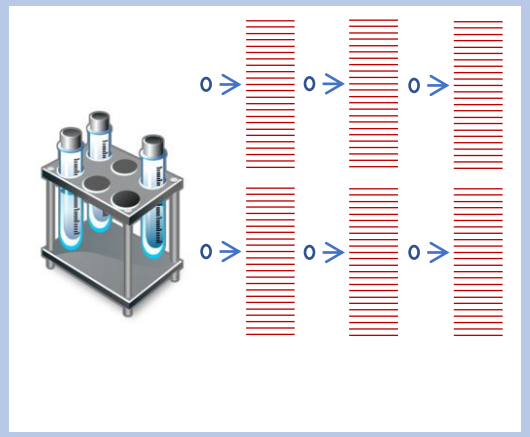


DOVE accuracy – 93%

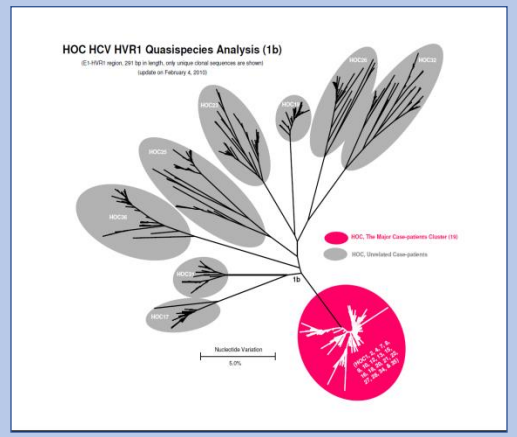
Network-Guided Molecular Surveillance

Global Hepatitis Outbreak & Surveillance Technology (GHOST)

Until Recently

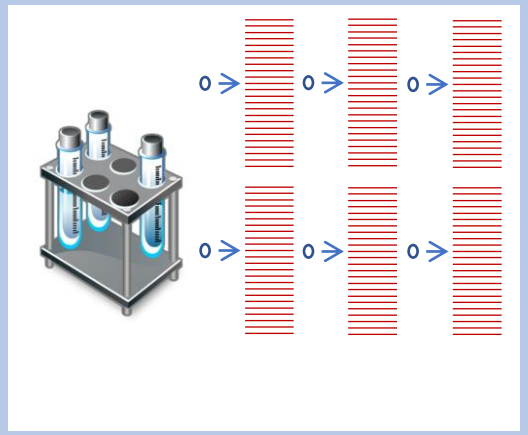


Sequences

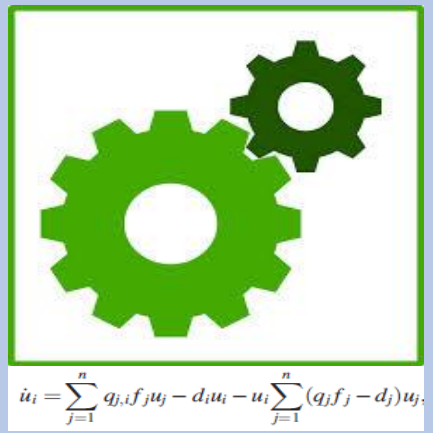


Computer model

GHOST Detection

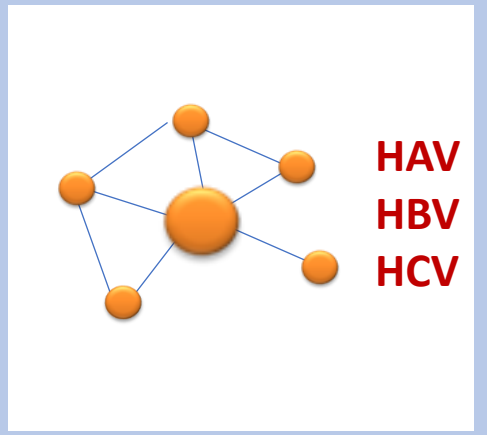


Sequences



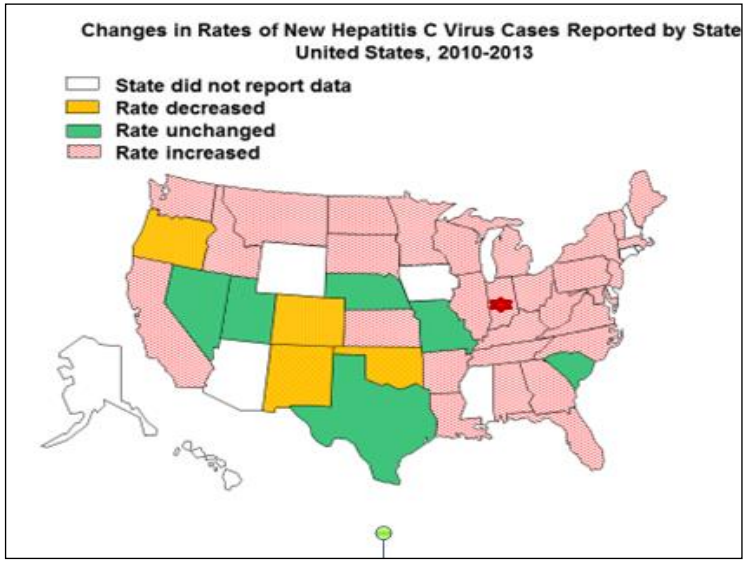
$$\dot{u}_i = \sum_{j=1}^{n} q_{j,i} f_j u_j - d_i u_i - u_i \sum_{j=1}^{n} (q_j f_j - d_j) u_j$$

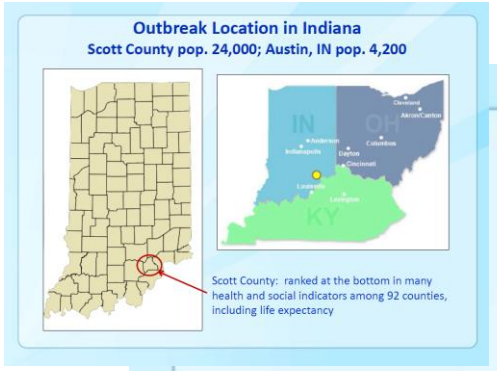
Computer model
(*Cyber*-Assay)

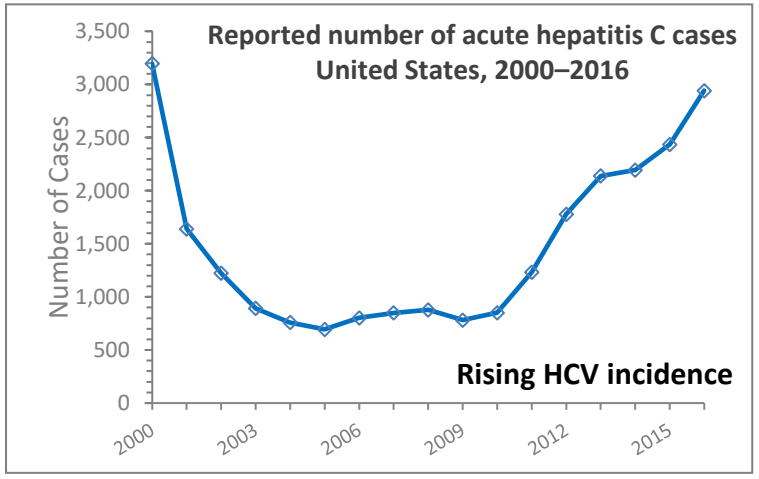


Transmission Links

HIV OUTBREAK
Scott County, IN
2015

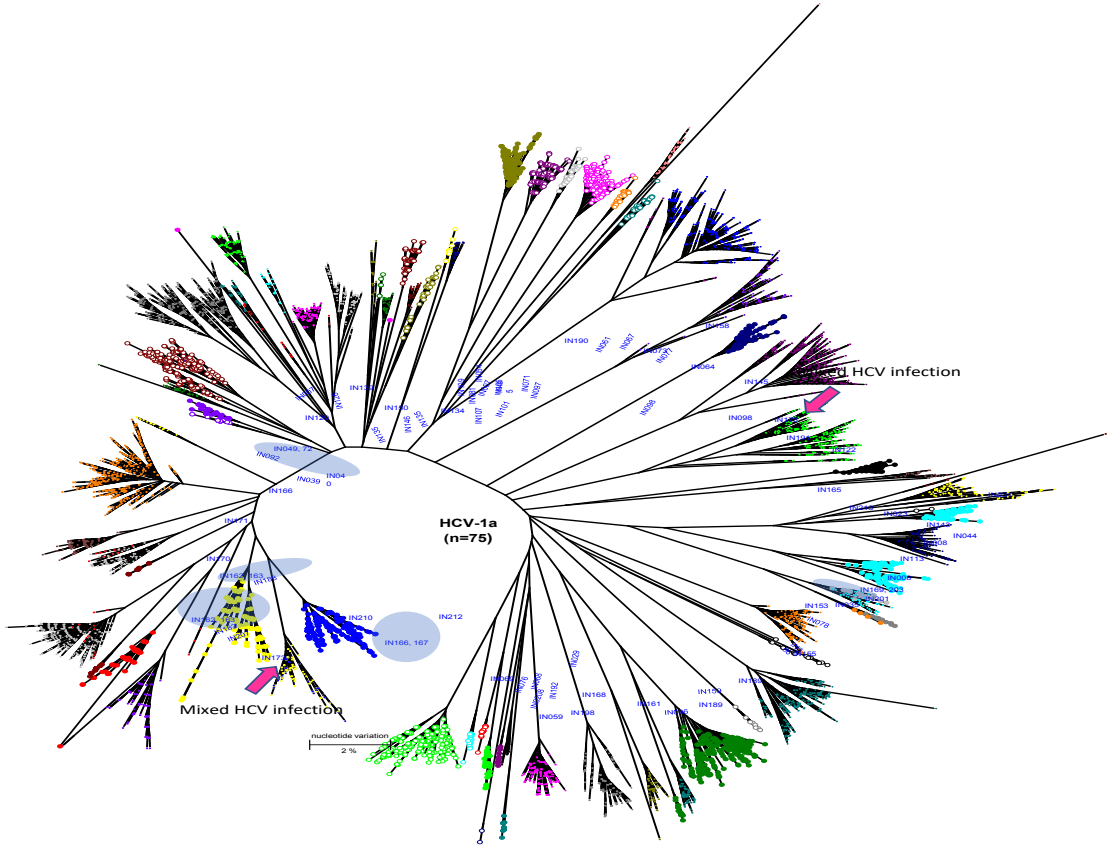




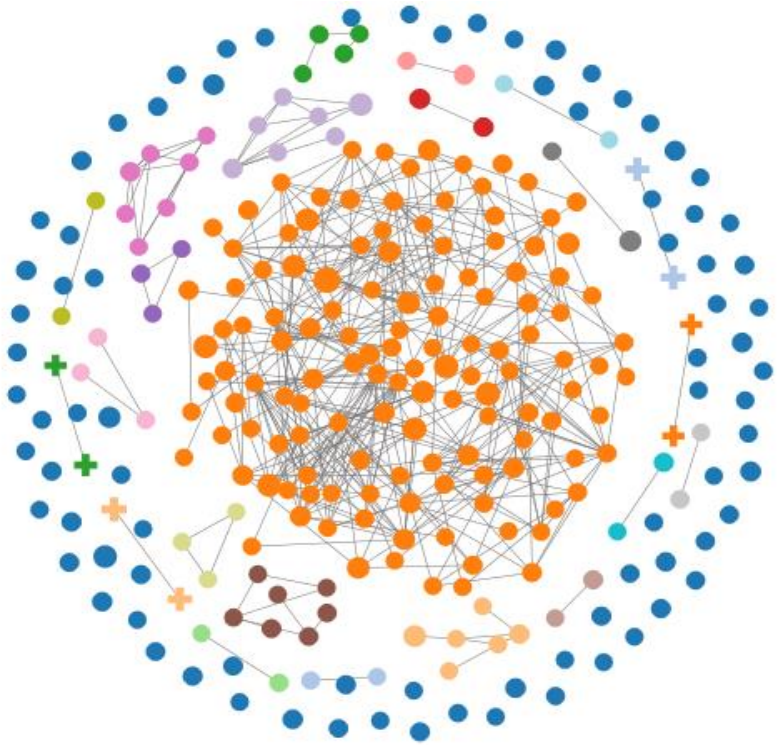


CDC, National Notifiable Diseases Surveillance System (NNDSS)

Phylogenetic Analysis



GHOST Network



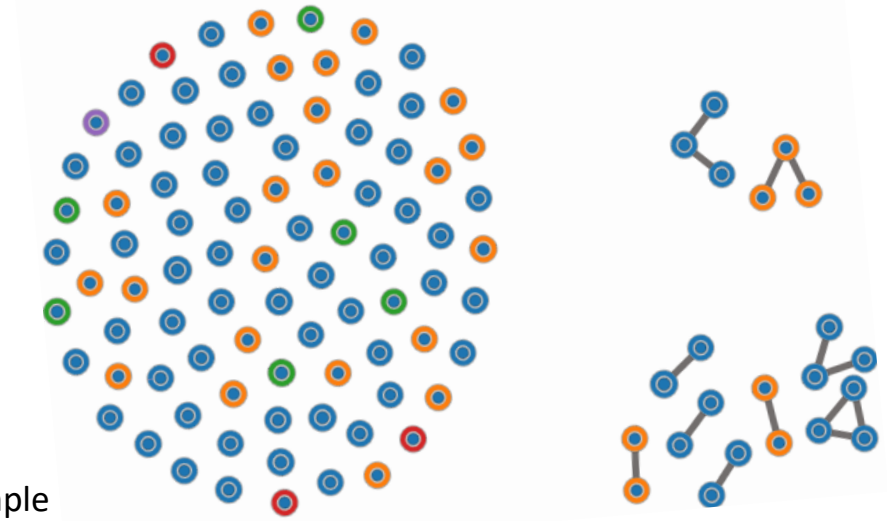
Node = 1 patient
Links = Sharing of variants among patients (>96.3% identity)

Groups	Clusters	Cases	%
Clusters	23	198	70.46
Unrelated	0	83	29.54
Total	23	281	100

Groups	n
Major HCV cluster	130
HIV coinfections	43
Mixed HCV infections	50

Guided Molecular Surveillance

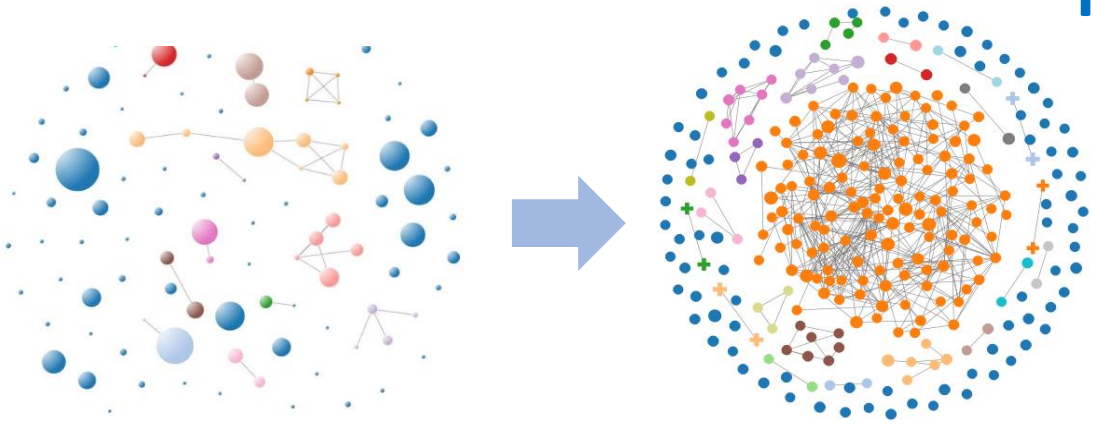
Random Sampling



Example

Improving sampling

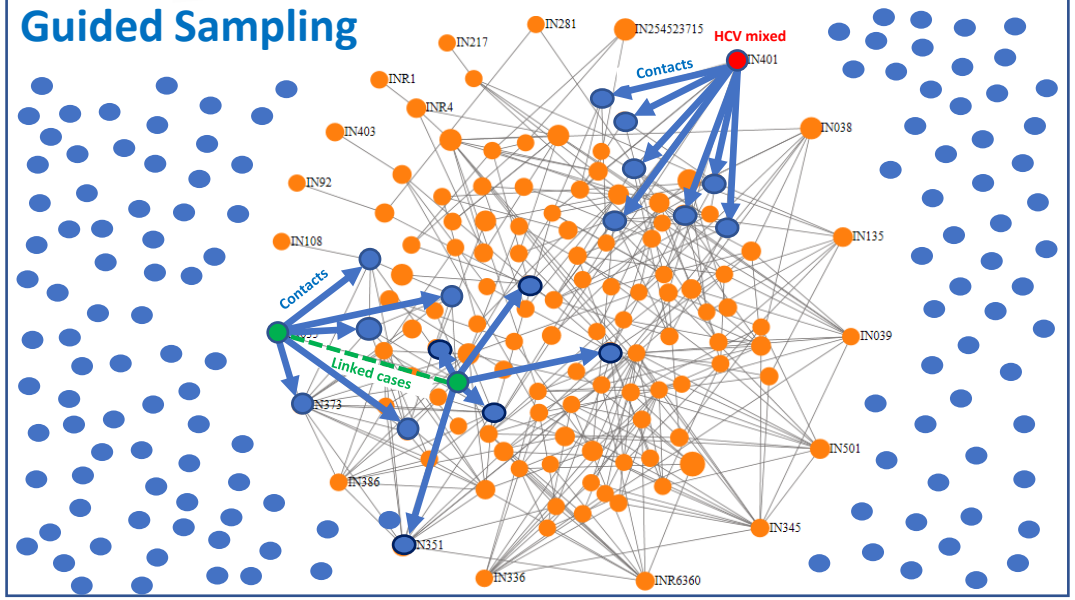
IN



Limited sampling

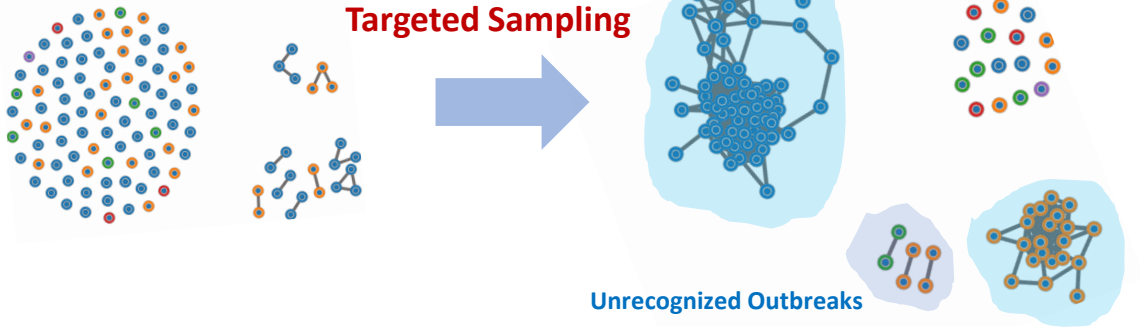
Improved sampling

Guided Sampling



PWID Network of Transmission

Improving case identification



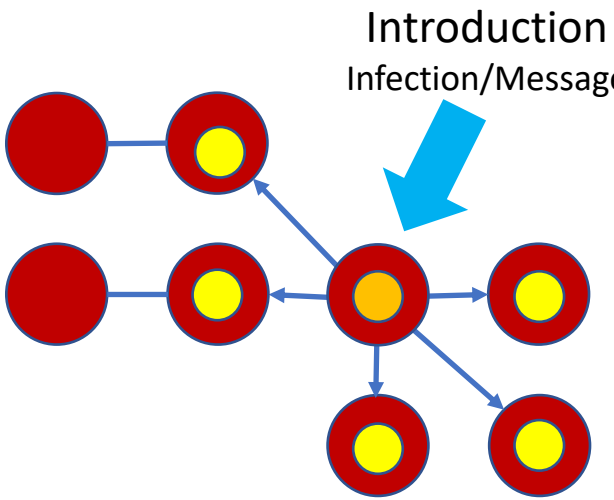
Example

Network-Guided Public Health Interventions

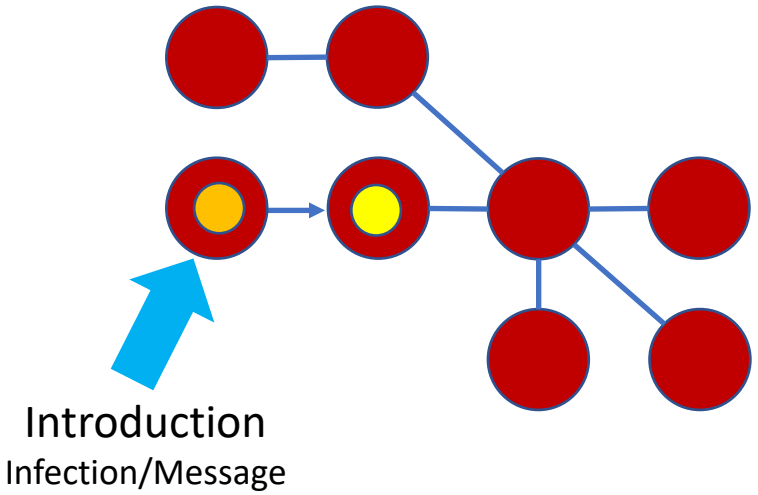
Network structure affects spread of infections and public health information

- **Infection among members of a high-risk contact network**
- **Rate of spread through network is affected by:**
  - **Network structure**
  - **Position of the node introducing infection to the network**

- **Peer education as "infection" of network with public health messages**
- **The rate of education dissemination and adoption is affected by position of a peer-educator in network**



Strong effect



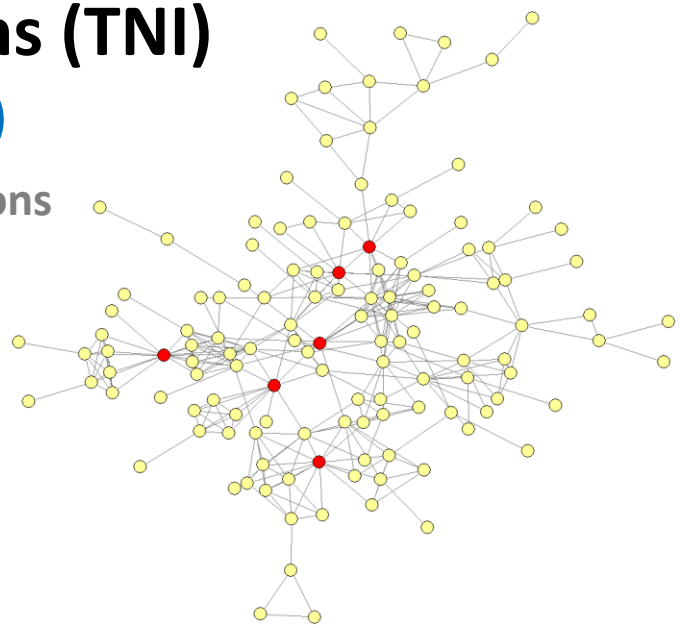
Weak effect

Targeted Network-based Interventions (TNI)

Intelligent Network DisRuption Analysis (INDRA)

guiding and monitoring efficacy of public health interventions

- Detects *transmission networks* in a near-real time
- Guides most *efficient and cost-effective intervention*
- Provides *new instant measures* for monitoring efficiency of public health intervention
- *Personal/Community benefits*: rapid reduction of probability to be infected with HCV

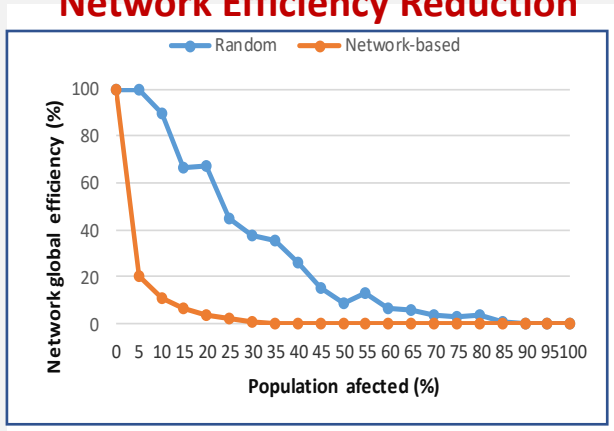


Red nodes to be removed to reduce network efficiency by half

INDRA: Ranking Nodes for Interventions

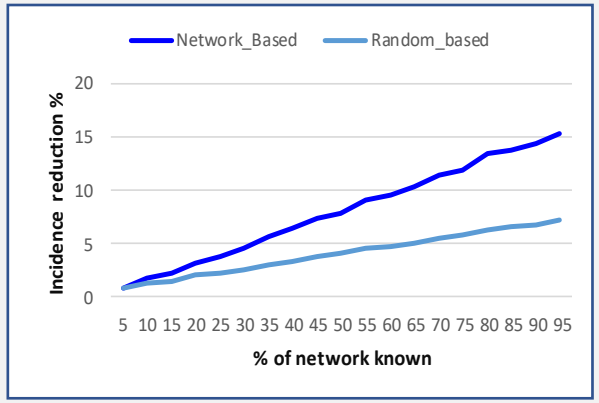
ID	Rank	Efficiency
IN373	1	0.820151
INR6360	2	0.694935
IN136	3	0.603052
IN084	4	0.537548
IN365	5	0.490244
IN384	6	0.451528
….	….	….

Network Efficiency Reduction



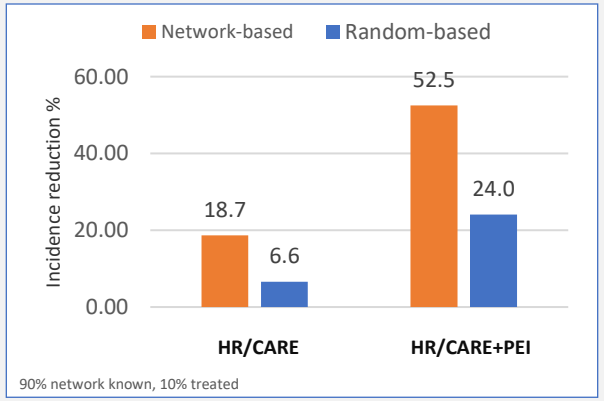
Linkage to Harm Reduction/Care services of
~16% HCV-infected PWID identified by TNI
~65% HCV-infected PWID identified randomly
would result in 20x reduction of HIV spread in the Indiana PWID network

Incidence Reduction



Greater knowledge of transmission network results in a greater reduction of incidence

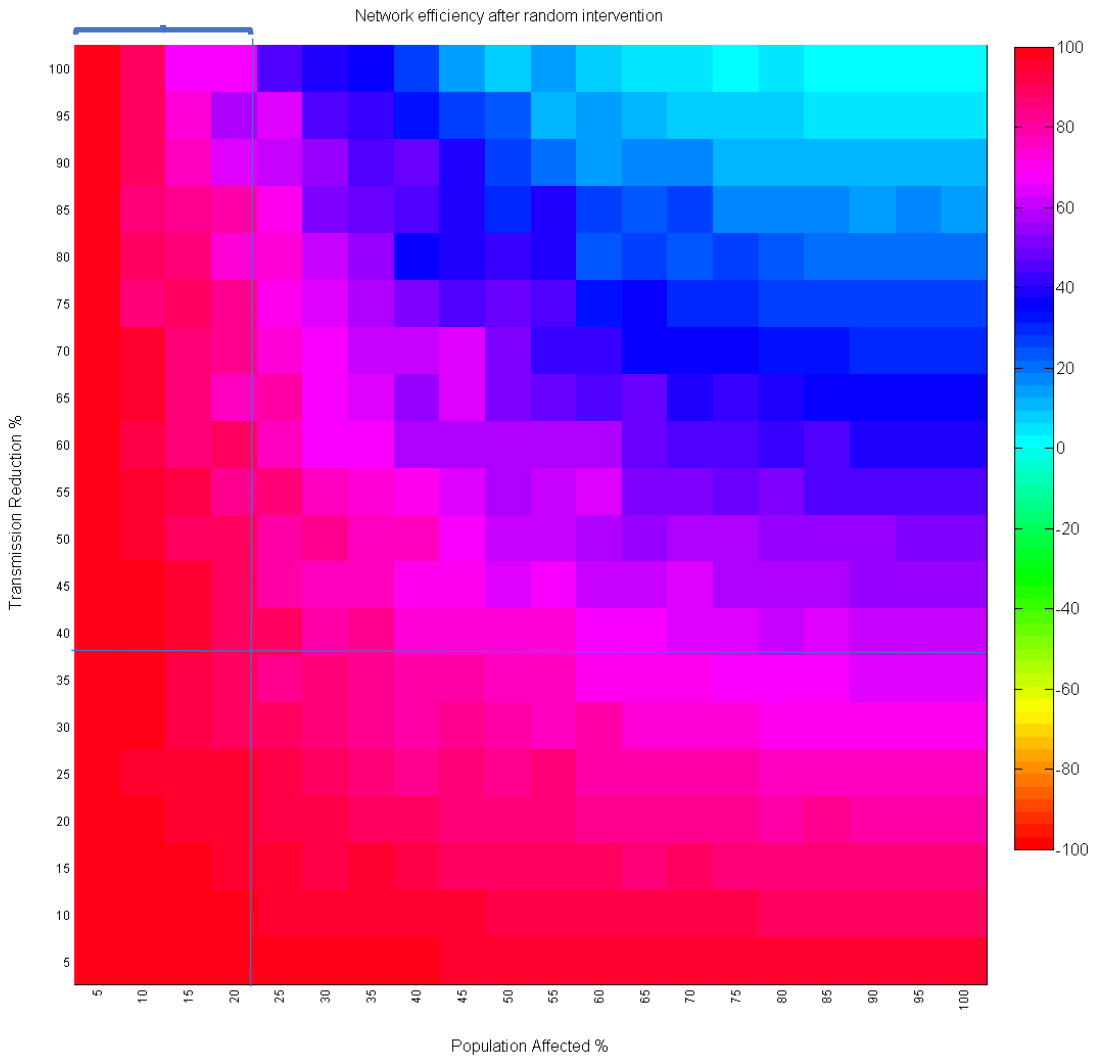
TNI is up to 12x more efficient in reduction of incidence than random strategy



Targeted Peer-Education Intervention (PEI) results in ~3-fold increase of effects of TNI vs Random interventions

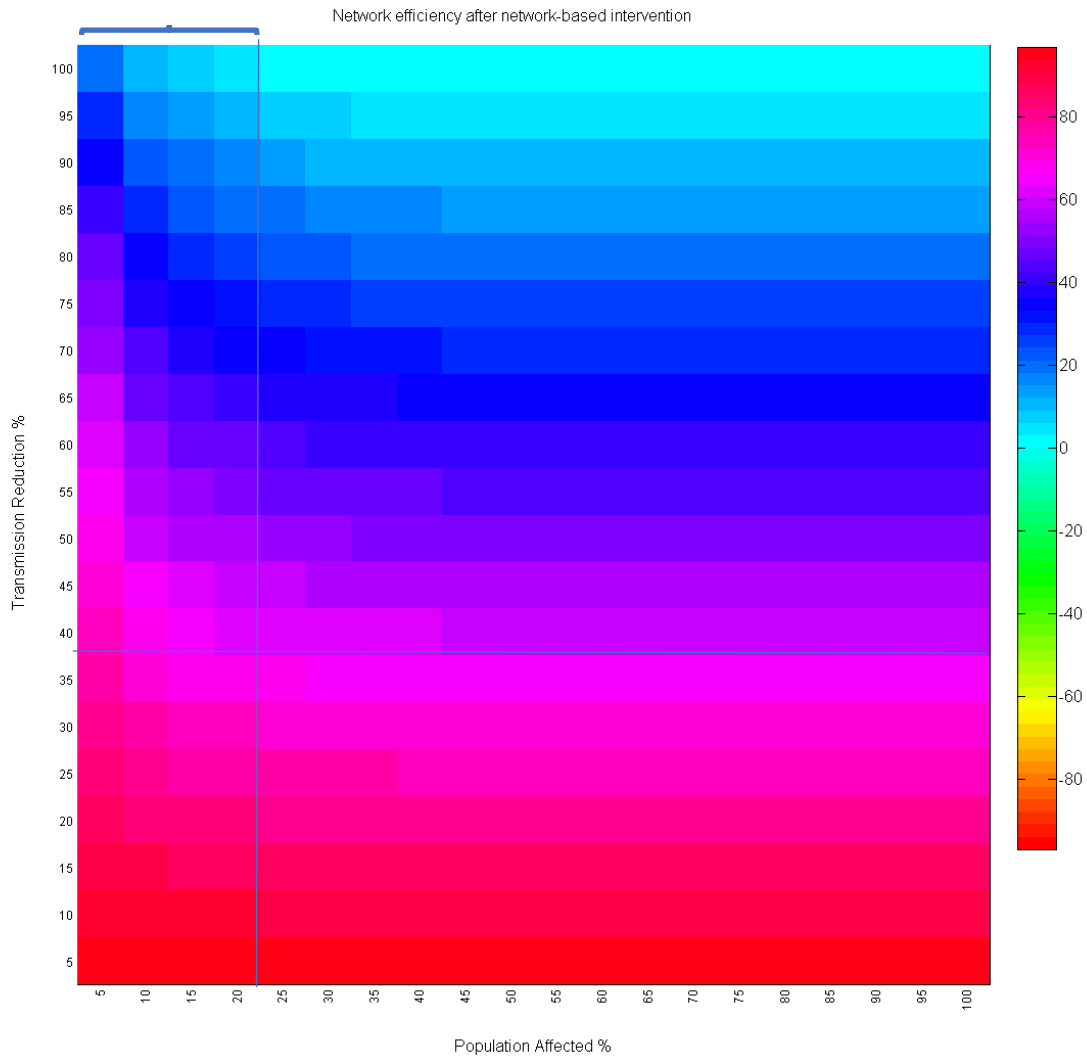
Decline in Network Efficiency at Different Levels of Transmission Reduction and Affected Population Size

Poor



Random Intervention

Good



Network-based Intervention

- Overall, network-based intervention is 1.3 times more efficient than random intervention

SUMMARY

- **Geospatial mapping**
  - To estimate numbers and rates of drug overdose death in a *near-real* time
    - "*Smoke Alarm*"
  - To help identify communities most vulnerable to acquisition of HBV, HCV and HIV

- **Network-Guided Molecular Surveillance**
  - To identify HCV infected persons from potentially high-risk populations
    - Contact tracing of the GHOST-identified high-risk persons helps to improve
      - Sampling efficiency
      - Identification of transmission networks
      - Identification of high-risk communities
      - Identification of HCV infected cases

- **Network-Guided Interventions**
  - Network structure affects individual contributions to infection dissemination
  - INDRA helps to develop network-guided public health interventions
    - Cost-effective as compared to random interventions
    - Ranks contribution of individuals to transmission
  - Network-guided interventions outperform random strategies
    - As measured by reduction in network efficiency and incidence rate

GHOST

Global
Hepatitis
Outbreak &
Surveillance
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Communication:
ghost@cdc.gov

GHOST:
BMC Genomics 2017, 18(Suppl 10): 916
BMC Bioinformatics 2118, 19(Suppl 11): 358

GHOST Networks:
EBioMedicine 2018, 37: 374-381
PloS One 2019, 14(3): e0212350

INDRA:
Infect Genet Evol 2018, 63: 204-215