



**University  
of Manitoba**

## **Modelling pathogen introductions into jurisdictions**

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The University of Manitoba campuses are located on original lands of Anishinaabeg, Inineew, Anisinineew, Dakota and Dene peoples, and on the National Homeland of the Red River Métis.

We respect the Treaties that were made on these territories, we acknowledge the harms and mistakes of the past, and we dedicate ourselves to move forward in partnership with Indigenous communities in a spirit of Reconciliation and collaboration.

# Thanks



Clotilde Djuikem  
UM

Amy Hurford  
Memorial



- ▶ Nicolas Bajoux
- ▶ Pierre-Yves Boëlle (IPLESP, Sorbonne Université)
- ▶ Evan Milliken (University of Louisville, Kentucky, USA)
- ▶ Stéphanie Portet (University of Manitoba)
- ▶ James Watmough (University of New Brunswick)

# Outline

**Introductions**

**Probability of introductions**

**Stochastic phase of an epidemic**

**Value of travel control measures**

**Conclusions**



A surreal landscape featuring a floating island in the sky, a winding river on the ground, and a field of virus particles in the foreground. The scene is set against a backdrop of a cloudy sky and a sun. The text is overlaid on the left side of the image.

**Introductions**

**Probability of introductions**

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**Value of travel control measures**

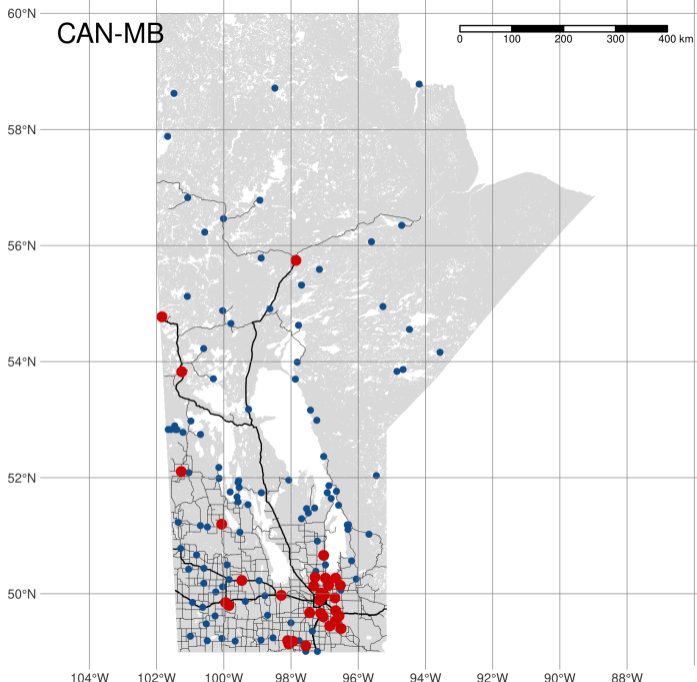
**Conclusions**



## Why small jurisdictions?

MB is very unbalanced, population-wise

Province	Largest	Second Largest	Ratio
AB	Calgary (CMA)	Edmonton (CMA)	1.04
NB	Moncton (CMA)	Saint John (CMA)	1.2
SK	Saskatoon (CMA)	Regina (CMA)	1.27
ON	Toronto (CMA)	Ottawa-Gatineau (CMA)	4.17
PE	Charlottetown (CA)	Summerside (CA)	4.75
NS	Halifax (CMA)	Cape Breton (CA)	4.97
QC	Montréal (CMA)	Québec City (CMA)	5.11
BC	Vancouver (CMA)	Victoria (CMA)	6.66
NL	St. John's (CMA)	Corner Brook (CA)	7.14
MB	Winnipeg (CMA)	Brandon (CA)	8.76



# Northern Manitoba chiefs call for immediate federal action on health-care crisis

Recent deaths linked to inadequate medical care include mother of 5 from Manto Sipi Cree Nation, chief says

CBC News · Posted: Apr 03, 2023 3:20 PM CDT | Last Updated: April 3, 2023



A group of Manitoba chiefs is calling for immediate action from the federal government to address what they call a health-care crisis causing preventable deaths on northern First Nations in the province.

That action needs to start with ensuring nursing stations in remote communities are staffed adequately with nurses and have a full-time doctor available, said Michael Yellowback, chief of Manto Sipi Cree Nation (previously known as God's River).

Right now, the community only has two of the three nurses it's supposed to, and doctors only visit every two weeks, he said.



## 'It's not working'

With a nursing shortage and no hospital,  
Island Lake First Nations communities  
face health-care struggle



## 'A lengthy process to get help here'

Wasagamack is one of four First Nations communities that make up Island Lake, an area in northeastern Manitoba dotted with hundreds of small islands.

Island Lake has a population of at least 15,000, according to Scott Harper, the grand chief of Anisininew Okimawin, which represents the four communities.

Despite having a population roughly the size of Thompson, and having diabetes and hospitalization rates well above provincial averages, Island Lake has no hospital of its own. The region is accessible only by air, boat and an unreliable winter road.

The nursing station in Wasagamack First Nation, which has about 2,300 people, according to federal government data, typically operates short-staffed, with only two or three of five registered nurses working on any given rotation and a fly-in doctor who comes weekly.

## For First Nation and Métis Communities

**Remote** describes a **geographical area** where a community is **located over 350 km** from the **nearest service centre having year-round access** by land and/or water routes normally used in all weather conditions

**Isolated** means a **geographical area** that has **scheduled flights** and good telephone service, but is **without year-round access** by land and/or water normally used in all weather conditions

**Remote-Isolated** means a **geographic area** that has **neither scheduled flights nor year-round access** by land and/or water routes normally that can be used in all weather conditions, irrespective of the level of telephone and radio service available

## For Inuit communities

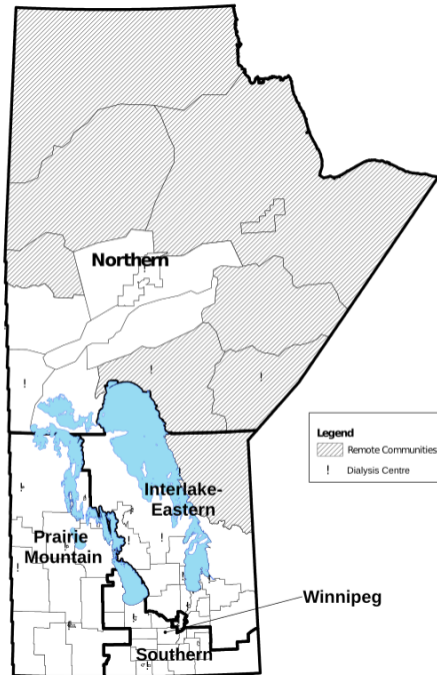
Inuit Communities to be referred to as **Inuit Nunangat**, not remote and isolated communities to respect the unique language and culture of Inuit regions, as well as the common challenges in social determinants of health, access to care, and infrastructure found across all Inuit communities

## MB remote communities

**Remote communities** are communities in Manitoba that **do not have permanent road access** (i.e., no all-weather road), are **more than a four-hour drive** from a major rural hospital (and a dialysis unit), or **have rail or fly-in access only**. This includes Norway House, Lynn Lake, Leaf Rapids, Gillam, and Cross Lake. If most communities in a health district are designated as "remote", the entire district is designated as "remote". In Manitoba, remote districts include:

- ▶ Northern Health Region: NO23, NO13, NO25, NO16, NO22, NO26, NO28, NO31, and
- ▶ Interlake-Eastern Health Region: IE61.

Chartier M, Dart A, Tangri N, Komenda P, Walld R, Bogdanovic B, Burchill C, Koseva I, McGowan K, Rajotte L. Care of Manitobans Living with Chronic Kidney Disease. Winnipeg, MB. Manitoba Centre for Health Policy, December 2015



**Northern**

**Interlake-Eastern**

**Prairie Mountain**

**Southern**

**Legend**  
Remote Communities  
! Dialysis Centre

Winnipeg



## One interesting paradox

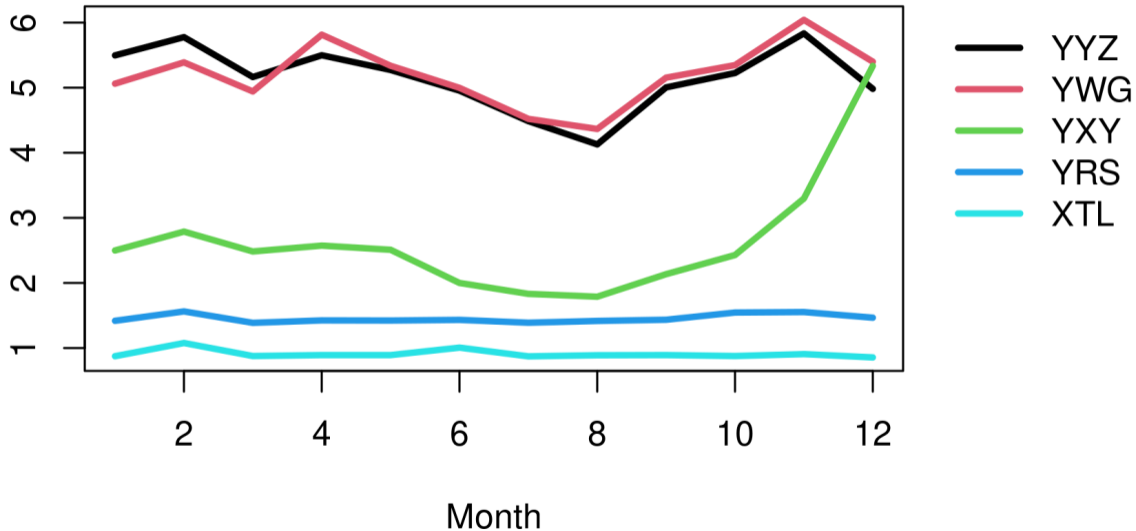
Think about travel to/from remote or isolated communities..

How do you think this compares to travel in non-remote/isolated communities ?

Residence time (the lake ecology version): theoretic time an average water or comparable molecule spends in a lake, considering inflow into and outflow from the lake

# Residence times in months

Residence time (months)



## The paradox of travel to/from remote/isolated communities

Travel volumes small but movement rates high

ICs are highly connected to the urban centre(s) they are subordinated to

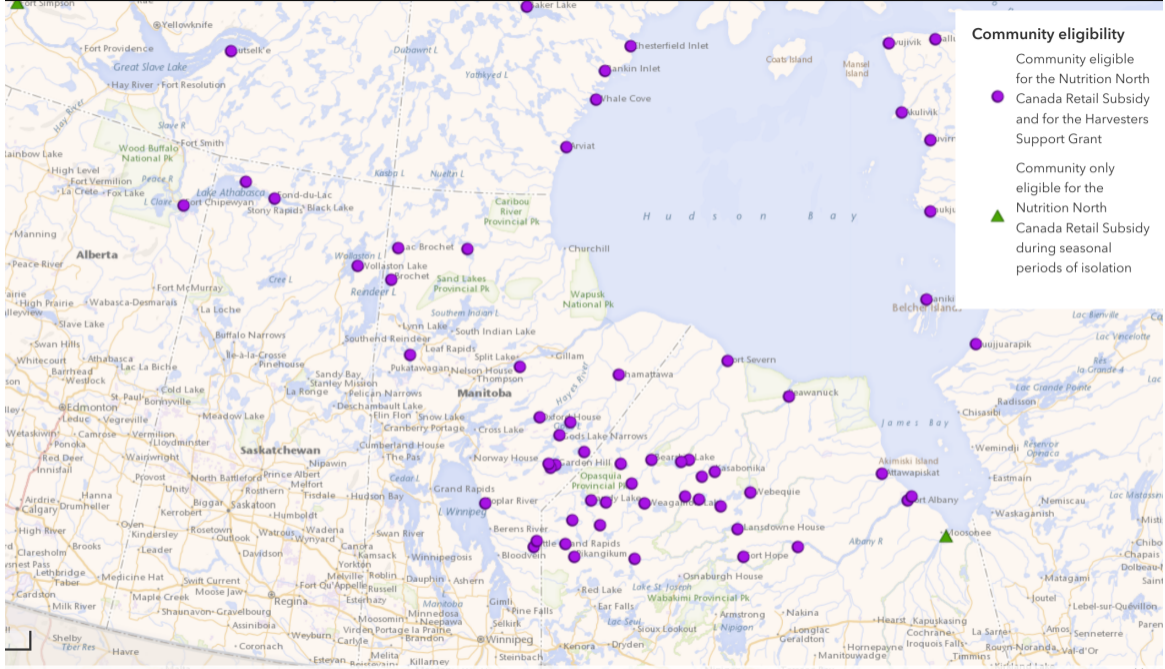
Further reinforced in Winnipeg by urban indigenous population (102,075 or 12.45% of metro population), meaning many family connections exist



[Home](#) » [About](#)

## About the WRHA

The WRHA serves residents of the city of Winnipeg, as well as the northern community of Churchill and the rural municipalities of East and West St. Paul, representing a total population of more than 750,000. The WRHA also provides health-care support and specialty referral services to nearly half a million Manitobans who live beyond these boundaries, as well as residents of northwestern Ontario and Nunavut, who often require the services and expertise available within the WRHA.



### Community eligibility

Community eligible for the Nutrition North and for the Harvesters Support Grant

Community only eligible for the Nutrition North Canada Retail Subsidy during seasonal periods of isolation



As the Kivalliq Inuit Centre struggled to keep up with the ever-increasing needs for medical travellers, Sakku Investments Corporation has now purchased the Clarion Hotel in Winnipeg to become its new medical boarding facility.

The facility hosts 139 rooms, 40,000 square feet of commercial office space, event areas, a pool, spa and much more.

“There are a lot of amenities that are available throughout the building that we currently don’t have with the existing location,” said David Kakuktinniq, president and CEO of Sakku Investments Corporation.

The Kivalliq Inuit Centre, the previous location for medical travellers, is a 44-room facility with 120 beds, but with the arrangement of three beds per room, there were often challenges making use of the space and housing everyone who needed it.

Kakuktinniq said 200 people per day are being processed for medical, which meant some would be sent to overflow facilities when the Kivalliq Inuit Centre became full. That, in turn, led to significant stresses for medical travellers, their escorts and the staff charged with getting them to appointments and making sure their needs were taken care of.

## Travel restrictions/interruptions

During COVID, travelling above 53 north in MB was forbidden for anyone not resident above 53 north

If you wanted to fly to Nunavut, you needed to spend two weeks in quarantine in a hotel in Edmonton, Ottawa or Winnipeg

Canada implemented two weeks quarantine when IB from abroad (with exceptions)

Canada interrupted travel from a variety of places

# Questions

- ▶ What is the probability that an introduction is successful?  
(note: I am judging things from the perspective of the pathogen)
  
- ▶ How long is the stochastic phase following an introduction?  
(what Amy called the “stuttering period”)
  
- ▶ What do the different control measures do, how good are they?



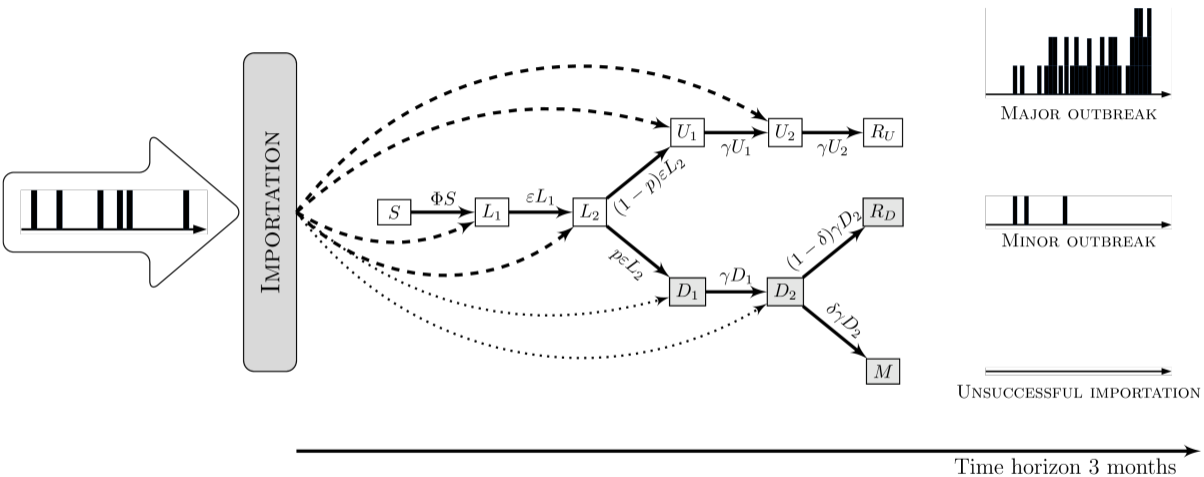
**Introductions**

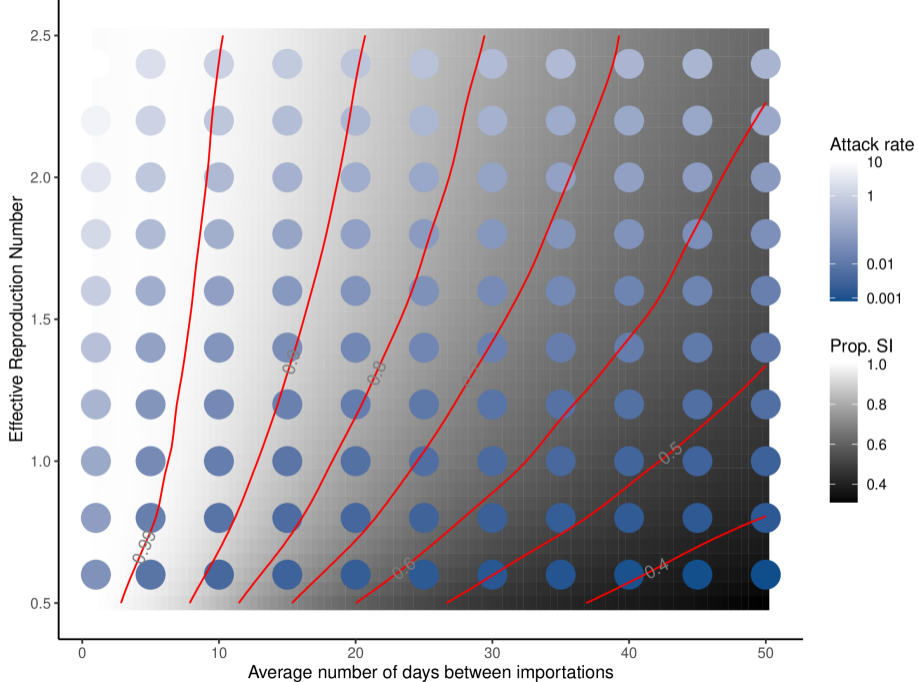
**Probability of introductions**

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A surreal landscape featuring several giant mushrooms with thick, textured stems and large, flat caps. The mushrooms are set in a rolling, hilly terrain with a small village of simple houses in the foreground. The sky is filled with vibrant, swirling patterns of colors like blue, green, yellow, and orange, creating a dreamlike atmosphere.

**Introductions**

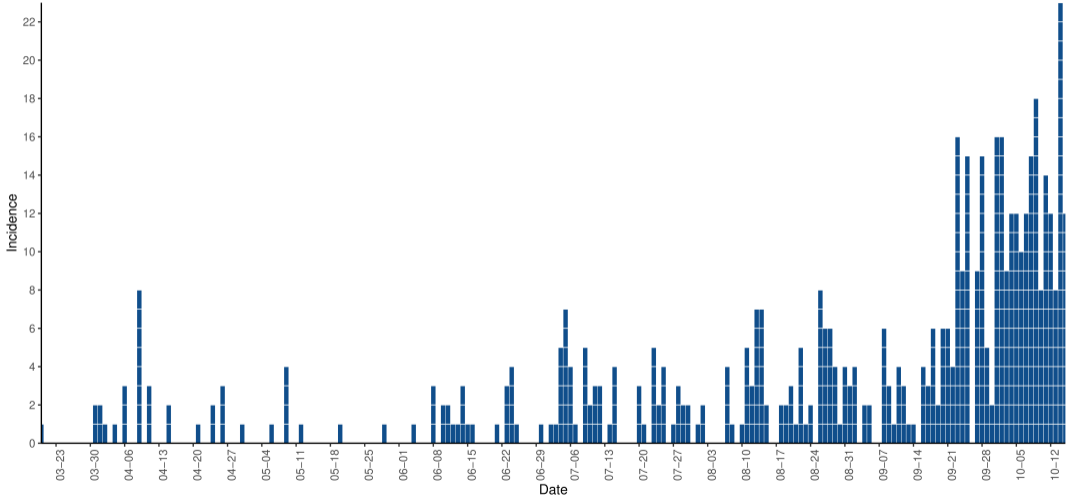
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# Campbell county, Wyoming





## Investigating outbreak types using a simple CTMC SIS

$$\mathbf{X}(t) = (S^A(t), I^A(t))$$

CTMC  $\mathbf{X}(t)$  characterized by transitions

Description	Transition	Rate
Infection	$(S^A, I^A) \rightarrow (S^A - 1, I^A + 1)$	$\beta^A S^A I^A$
Recovery	$(S^A, I^A) \rightarrow (S^A + 1, I^A - 1)$	$\gamma^A I^A$

## Investigating outbreak types using a simple CTMC SIS *with a twist*

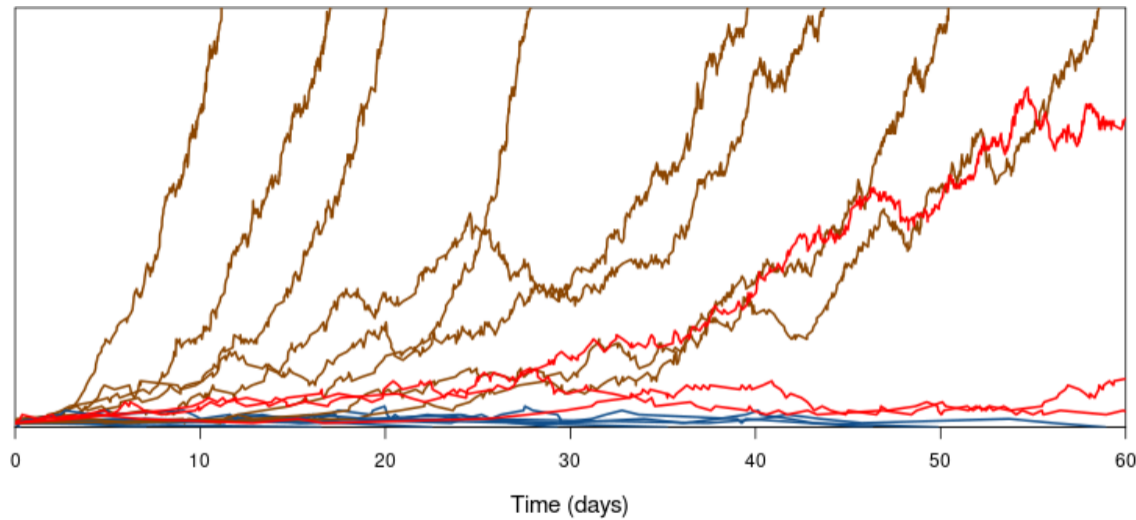
Regular chain of this type has  $I = 0$  as sole absorbing state

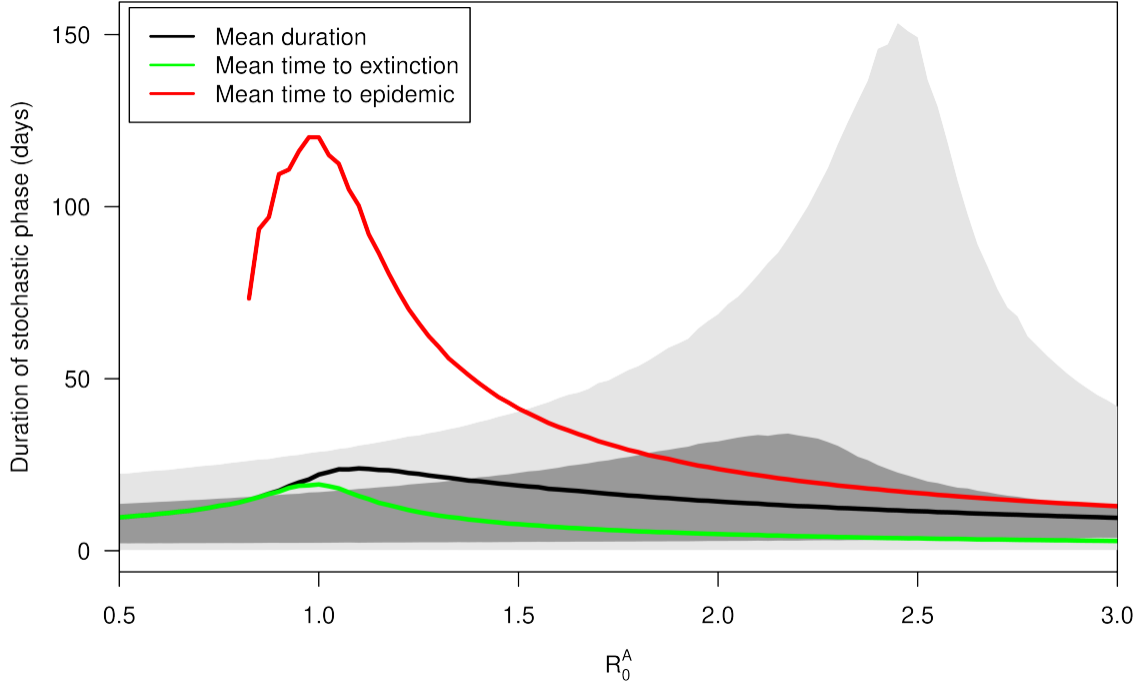
We add another absorbing state: if  $I = \hat{I}$ , then the chain has \*left\* the stochastic phase and is in a quasi-deterministic phase with exponential growth

Doing this, time to absorption measures become usable additionally to first passage time ones

And the question becomes: how long does the chain “linger on” (“stutter”) before it is absorbed? We define the inter-absorption trajectory as the stochastic phase

Prevalence





## Problem of the value of the upper bound $\hat{I}$

- ▶ Choose  $\hat{I}$  too small and the stochastic phase will not last long
- ▶ Choose  $\hat{I}$  too large and absorption will only be at the DFE
- ▶ So, how does one choose  $\hat{I}$  ?
  - ▶ A formula of Whittle (1955)
  - ▶ Multitype branching process (MTBP)



**Introductions**

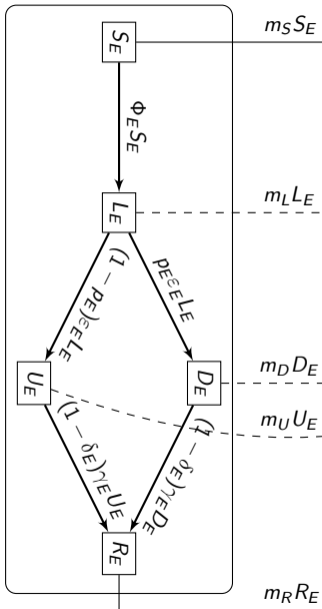
**Probability of introductions**

**Stochastic phase of an epidemic**

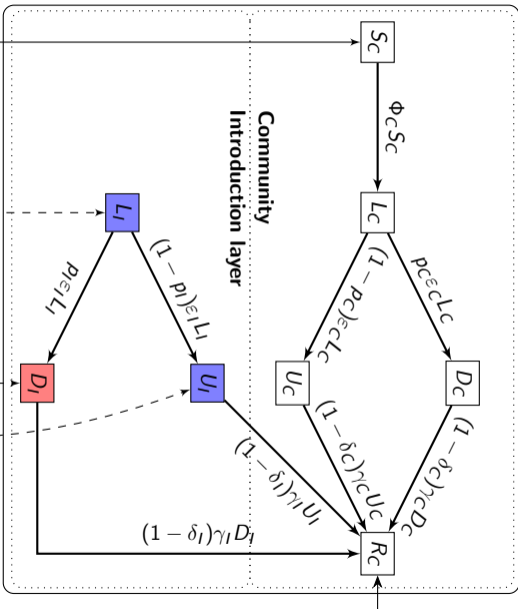
**Value of travel control measures**

**Conclusions**

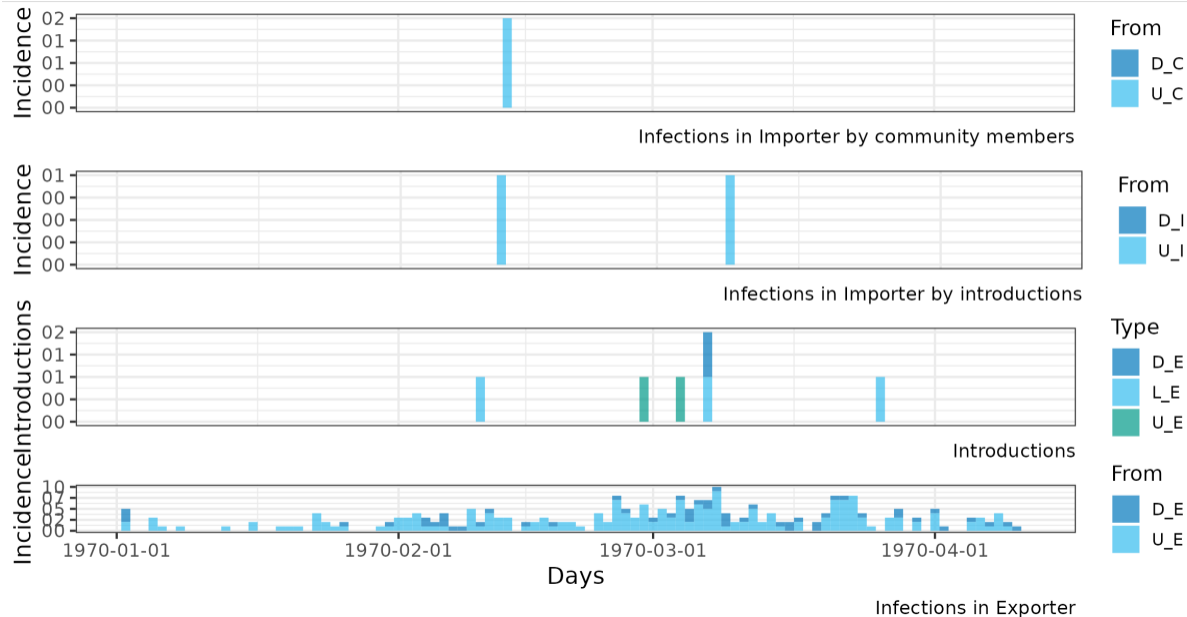
## Exporter



## Importer

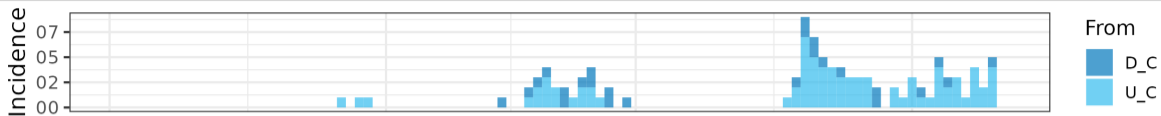


$R_0^E=1.5$ ,  $R_0^C=0.8$ ,  $pop_E=10000$ ,  $pop_I=10000$

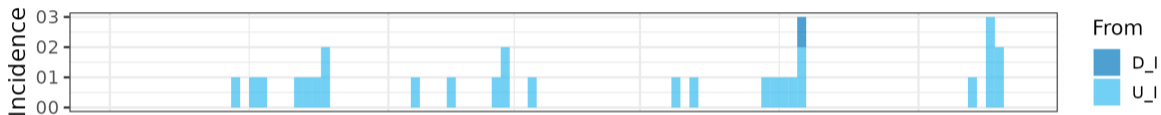




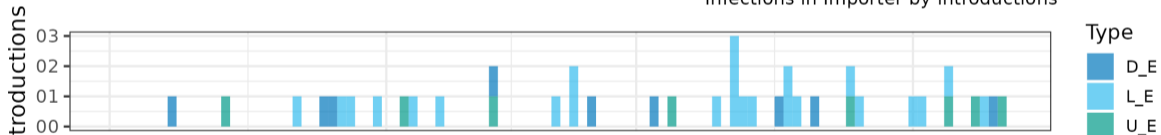
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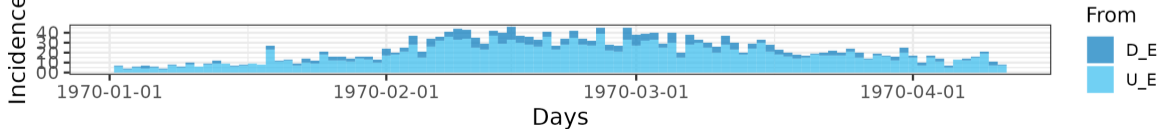
Infections in Importer by community members



Infections in Importer by introductions

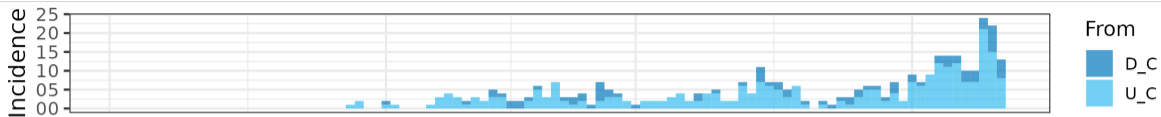


Introductions

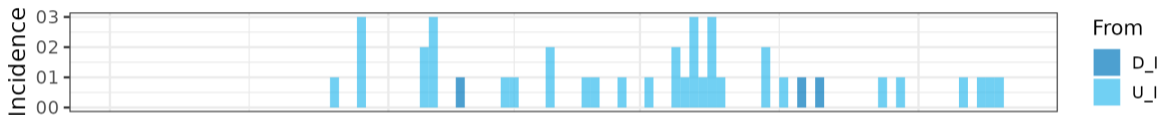


Infections in Exporter

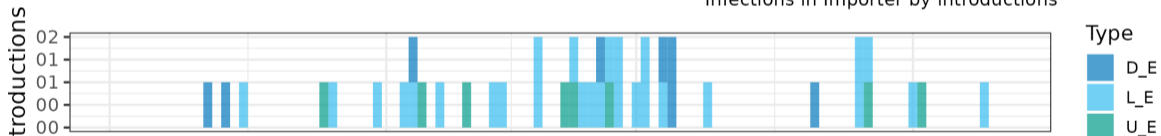
$R_0^E=1.5$ ,  $R_0^C=0.8$ ,  $pop_E=10000$ ,  $pop_I=10000$



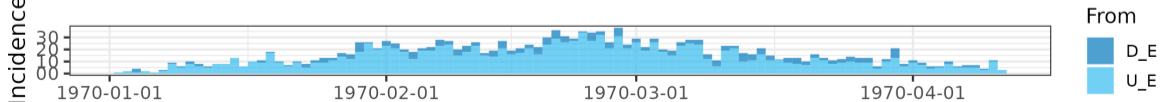
Infections in Importer by community members



Infections in Importer by introductions

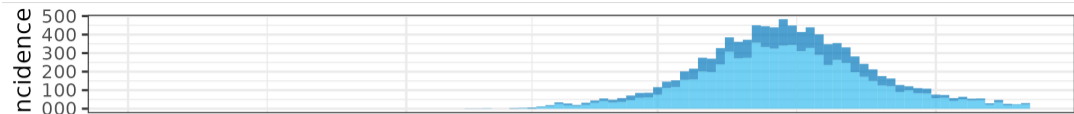


Introductions



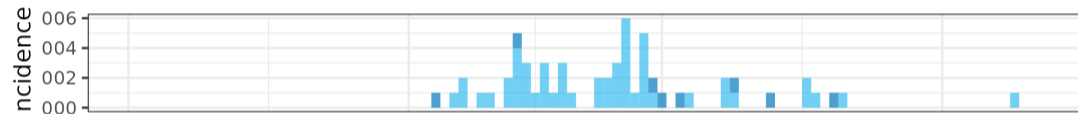
Infections in Exporter

$R_0^E=1.5$ ,  $R_0^C=1.5$ ,  $pop_E=10000$ ,  $pop_I=10000$



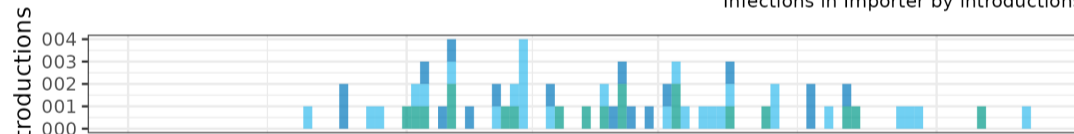
Infections in Importer by community members

From



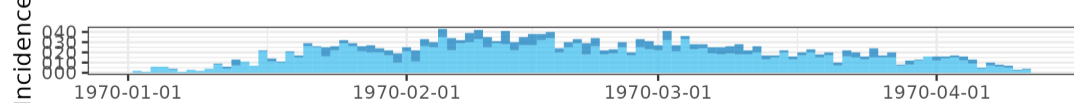
Infections in Importer by introductions

From



Introductions

Type

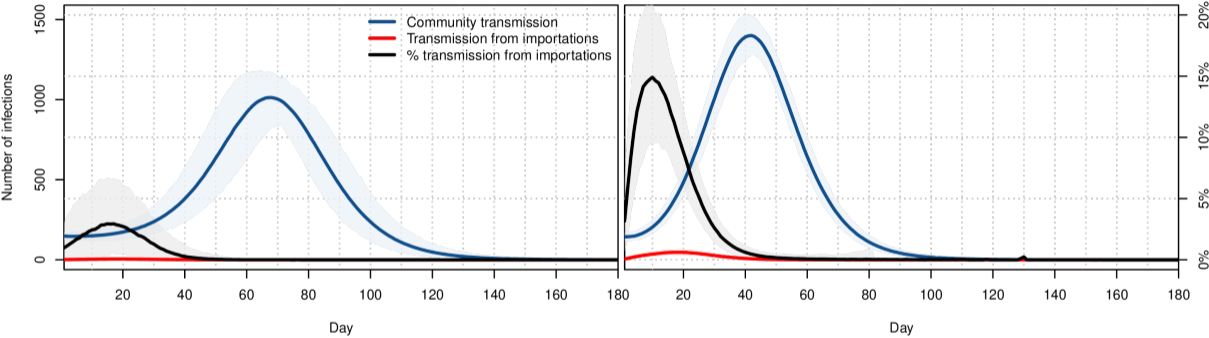


Days

From



Infections in Exporter



**Introductions**

**Probability of introductions**

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**Conclusions**

A large, green, spiky virus particle with orange protrusions is shown holding a wooden sign that says "CONCLUSIONS". The virus particle is positioned in the center of the image, with its arms raised to hold the sign. The background is a desert landscape with sand dunes and a blue sky.

**CONCLUSIONS**

## To do

- ▶ Try to work quarantine into the model in a “non-cohorty” manner
- ▶ MBPA to compute probability of an outbreak
- ▶ Detailed computational analysis of the CTMC

## One last thought for the road

V. Chetail. Crisis without borders: What does international law say about border closure in the context of Covid-19? *Frontiers in Political Science*, 2 (12) (2020)

*[..] a powerful expression of state's sovereignty, immigration control provides a typical avenue for governments to reassure their citizens and bolster a national sense of belonging, while providing an ideal scapegoat for their own failure or negligence.*