Introduced cases and spread of infection in a community

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The University of Manitoba campuses are located in Treaty 1 Territory on original lands of Anishinaabeg, Ininew, Anisininew, 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.

Outline

Why introductions matter in isolated communities

Modelling introductions

Thanks

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- Stéphanie Portet (University of Manitoba)
- James Watmough (University of New Brunswick)


Why introductions matter in isolated communities
Modelling introductions

Why small jurisdictions?

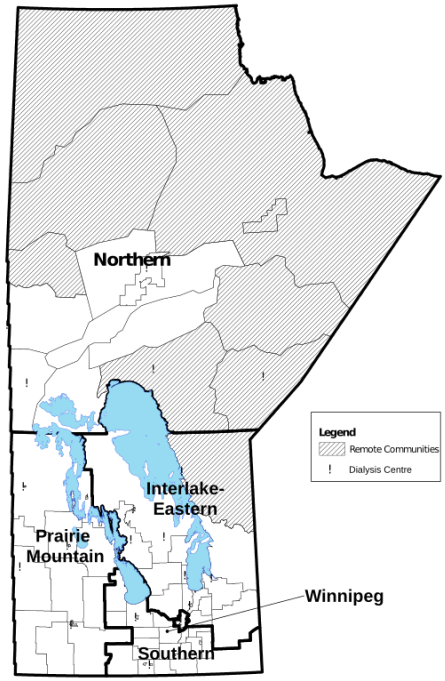
MB is very unbalanced, population-wise

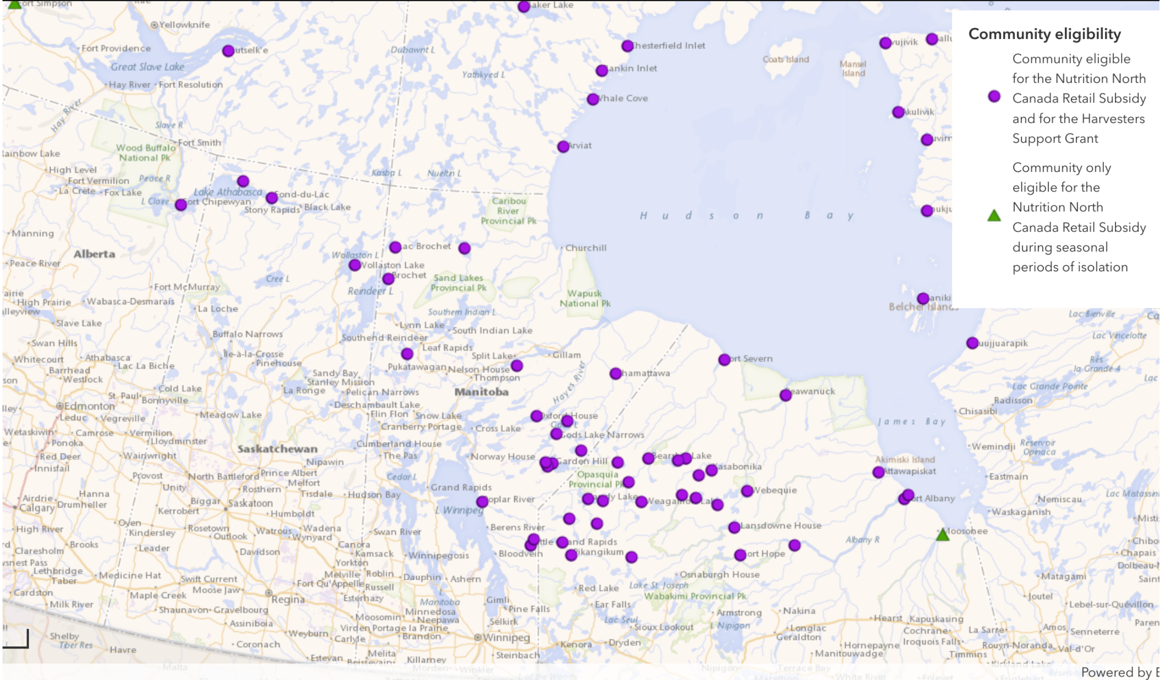
Province	Largest	Second Largest	Ratio
AB	Calgary (CMA)	Edmonton (CMA)	1.04
NB	Moncton (CMA)	Saint John (CMA)	1.2
SK	Saskatoon (CMA)	Regina (CMA)	1.27
ON	Toronto (CMA)	Ottawa-Gatineau (CMA)	4.17
PE	Charlottetown (CA)	Summerside (CA)	4.75
NS	Halifax (CMA)	Cape Breton (CA)	4.97
QC	Montréal (CMA)	Québec 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

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".*

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
Winnipeg
Southern
Legend
Remote Communities
Dialysis Centre

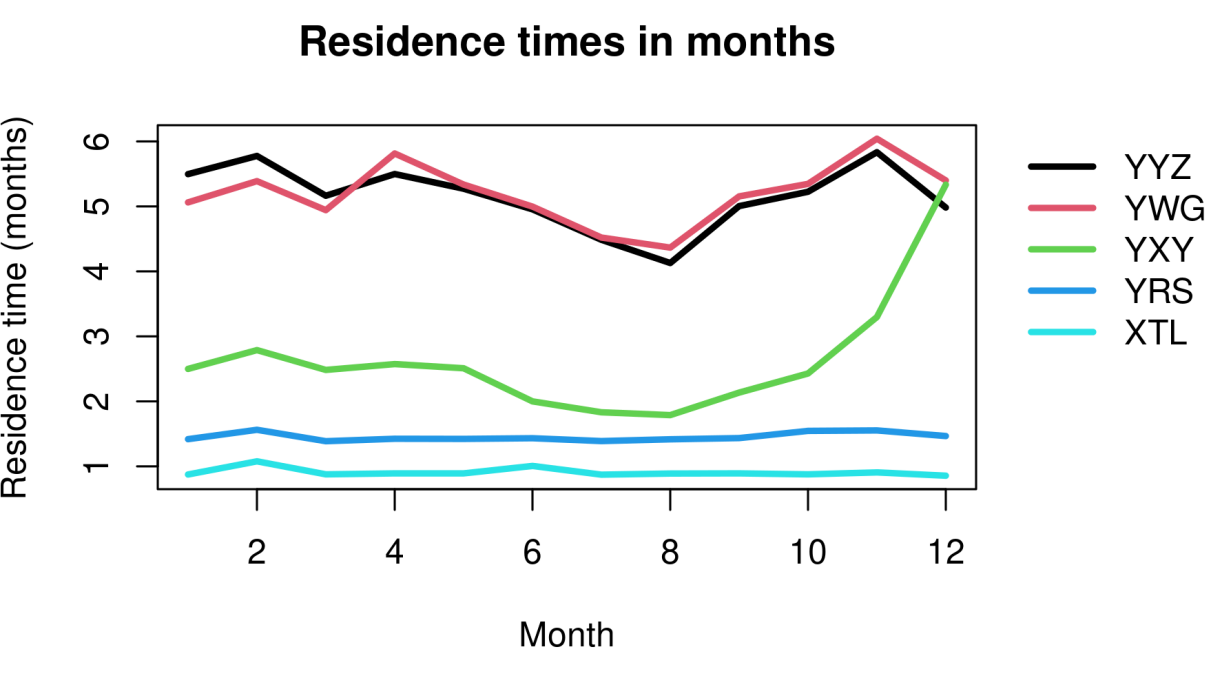

Community eligibility
Community eligible for the Nutrition North Canada Retail Subsidy and for the Harvesters Support Grant
Community only eligible for the Nutrition North Canada Retail Subsidy during seasonal periods of isolation
Hudson Bay
James Bay
Alberta
Saskatchewan
Manitoba
Yellowknife
Great Slave Lake
Lake Athabasca
Fond-du-Lac
Black Lake
Stony Rapids
Wollaston Lake
Churchill
Arviat
Whale Cove
Chesterfield Inlet
Rankin Inlet
Baker Lake
Edmonton
Calgary
Saskatoon
Regina
Winnipeg
Lac Brochet
Brochet
Oxford House
Gods Lake Narrows
Garden Hill
Poplar River
Berens River
Bloodvein
Pikangikum
Sandy Lake
Weagamow Lake
Kasabonika Lake
Bearskin Lake
Webequie
Lansdowne House
Fort Hope
Fort Severn
Peawanuck
Shamattawa
Attawapiskat
Fort Albany
Moosonee
Kuujjuarapik
Akulivik
Ivujivik
Sanikiluaq
Belcher Islands
Wapusk National Park
Caribou River Provincial Pk
Sand Lakes Provincial Pk
Wood Buffalo National Pk
Powered by E

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)
1
2
3
4
5
6
2
4
6
8
10
12
Month
YYZ
YWG
YXY
YRS
XTL

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

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 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.

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 calls the "stuttering period")
- What do the different control measures do, how good are they?
- When is it worth cutting travel?

Why introductions matter in isolated communities

Modelling introductions

Modelling introductions

- Our initial model
- Improving the model

Epidemiology and Infection

cambridge.org/hyg

Original Paper

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Quarantine and the risk of COVID-19 importation

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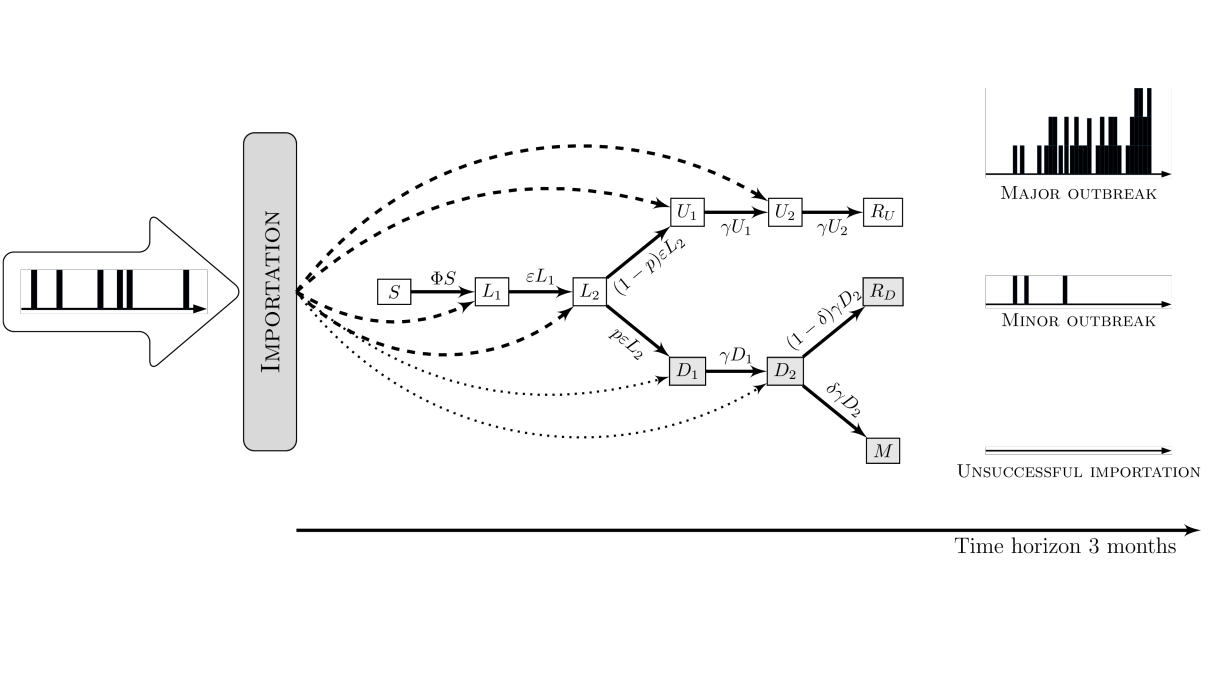
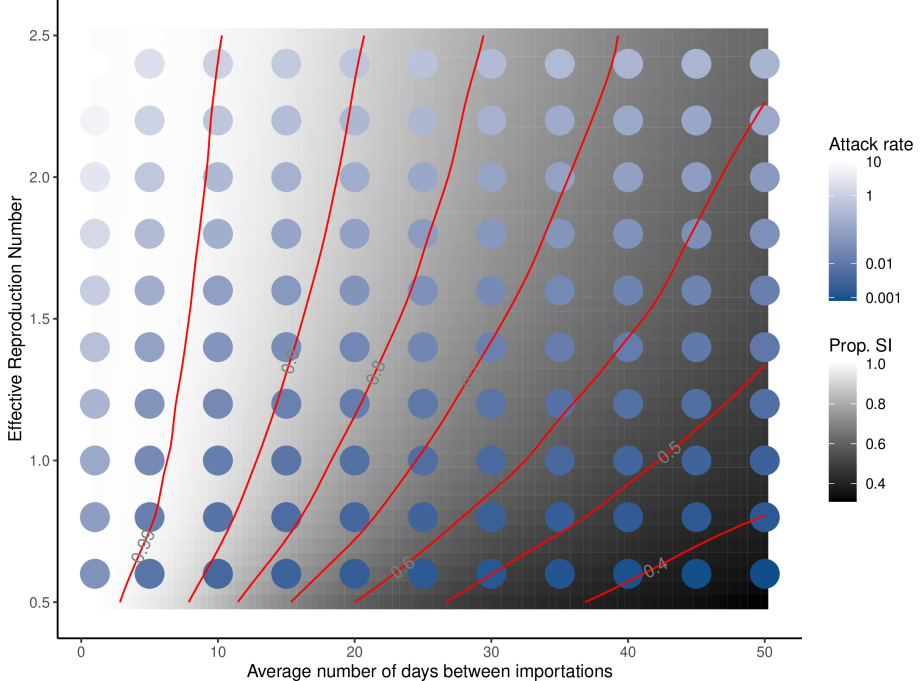
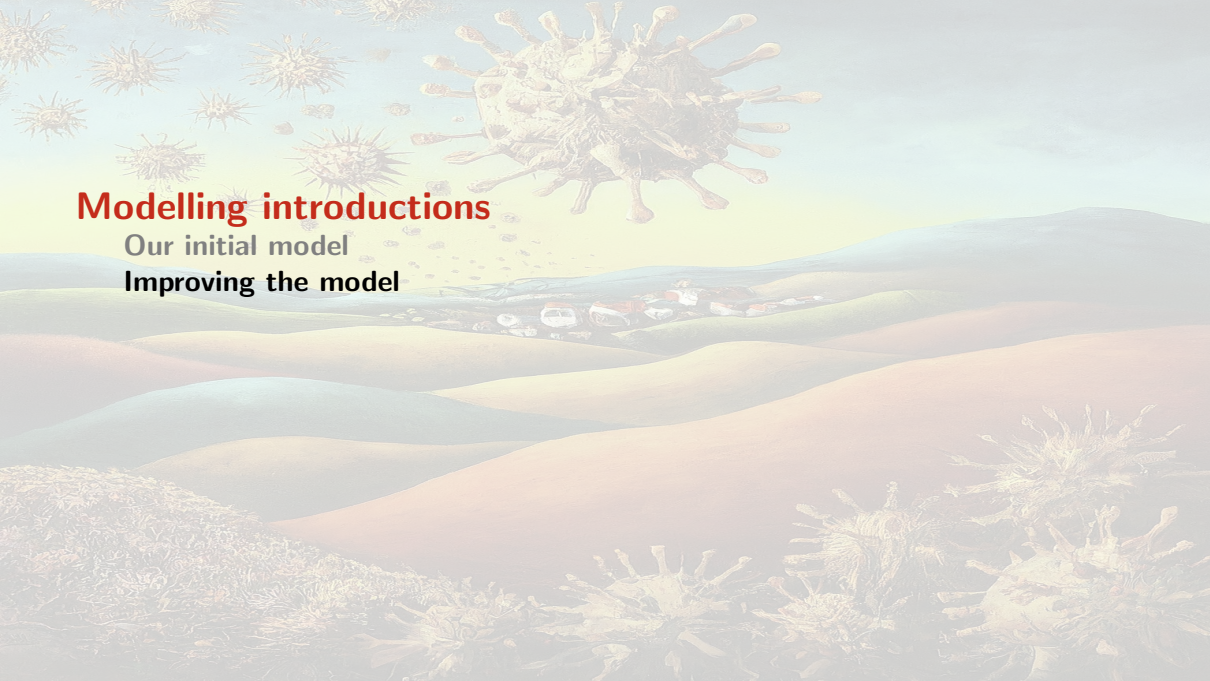
Abstract

Using a stochastic model, we assess the risk of importation-induced local transmission chains in locations seeing few or no local transmissions and evaluate the role of quarantine in the mitigation of this risk. We find that the rate of importations plays a critical role in determining the risk that case importations lead to local transmission chains, more so than local transmission characteristics, i.e. strength of social distancing measures (NPI). The latter influences the severity of the outbreaks when they do take place. Quarantine after arrival in a location is an efficacious way to reduce the rate of importations. Locations that see no or low-level local transmission should ensure that the rate of importations remains low. A high level of compliance with post-arrival quarantine followed by testing achieves this objective with less of an impact than travel restrictions or bans.


Importation
S
ΦS
L_1
εL_1
L_2
$(1-p)\varepsilon L_2$
$p\varepsilon L_2$
U_1
γU_1
U_2
γU_2
R_U
D_1
γD_1
D_2
$(1-\delta)\gamma D_2$
R_D
$\delta\gamma D_2$
M
Major outbreak
Minor outbreak
Unsuccessful importation
Time horizon 3 months

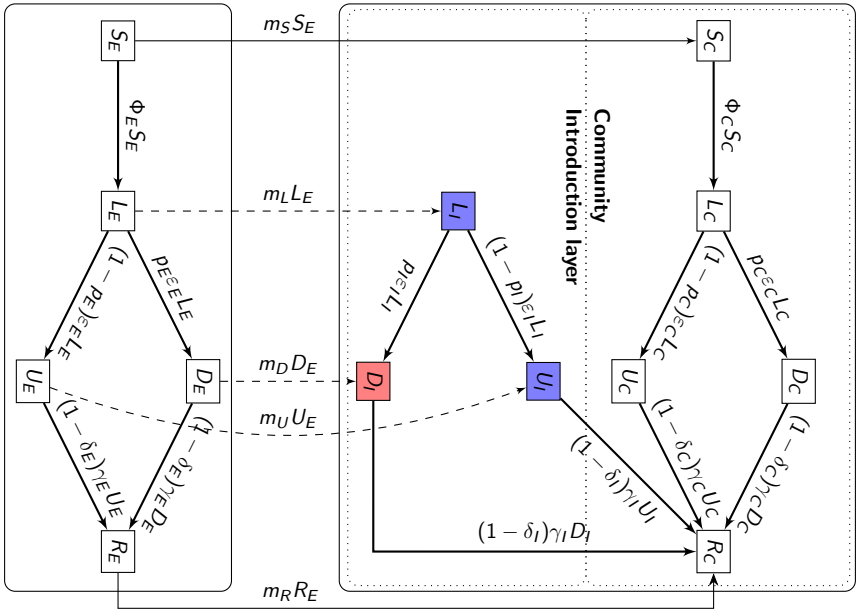

Effective Reproduction Number
2.5
2.0
1.5
1.0
0.5
0
10
20
30
40
50
Average number of days between importations
0.95
0.8
0.6
0.5
0.4
Attack rate
10
1
0.01
0.001
Prop. SI
1.0
0.8
0.6
0.4



Modelling introductions

Our initial model

Improving the model


Exporter
Importer
Community
Introduction layer
$m_S S_E$
$\Phi_E S_E$
$m_L L_E$
$p_{E\varepsilon} \varepsilon_E L_E$
$(1-p_E)\varepsilon_E L_E$
$m_D D_E$
$m_U U_E$
$(1-\delta_E)\gamma_E U_E$
$(1-\delta_E)\gamma_E D_E$
$m_R R_E$
$p_{I\varepsilon} L_I$
$(1-p_I)\varepsilon_I L_I$
$(1-\delta_I)\gamma_I U_I$
$(1-\delta_I)\gamma_I D_I$
$\Phi_C S_C$
$p_{C\varepsilon} \varepsilon_C L_C$
$(1-p_C)\varepsilon_C L_C$
$(1-\delta_C)\gamma_C U_C$
$(1-\delta_C)\gamma_C D_C$
S_E
L_E
U_E
D_E
R_E
L_I
D_I
U_I
S_C
L_C
U_C
D_C
R_C

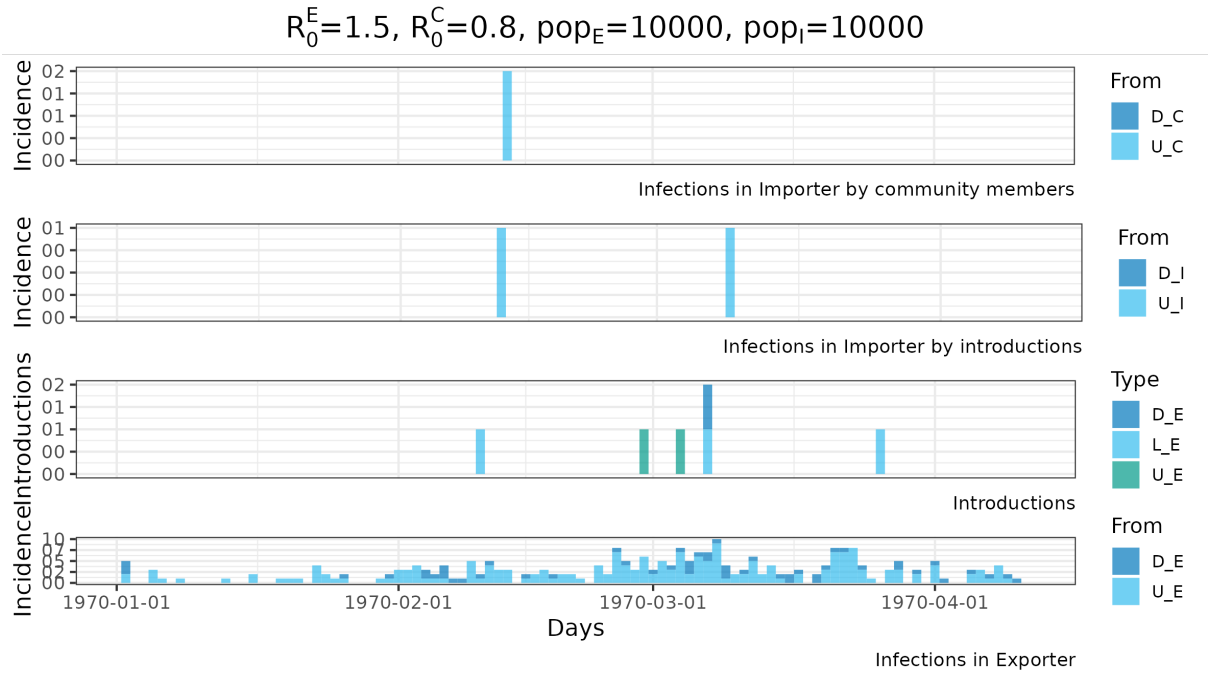
Forces of infection

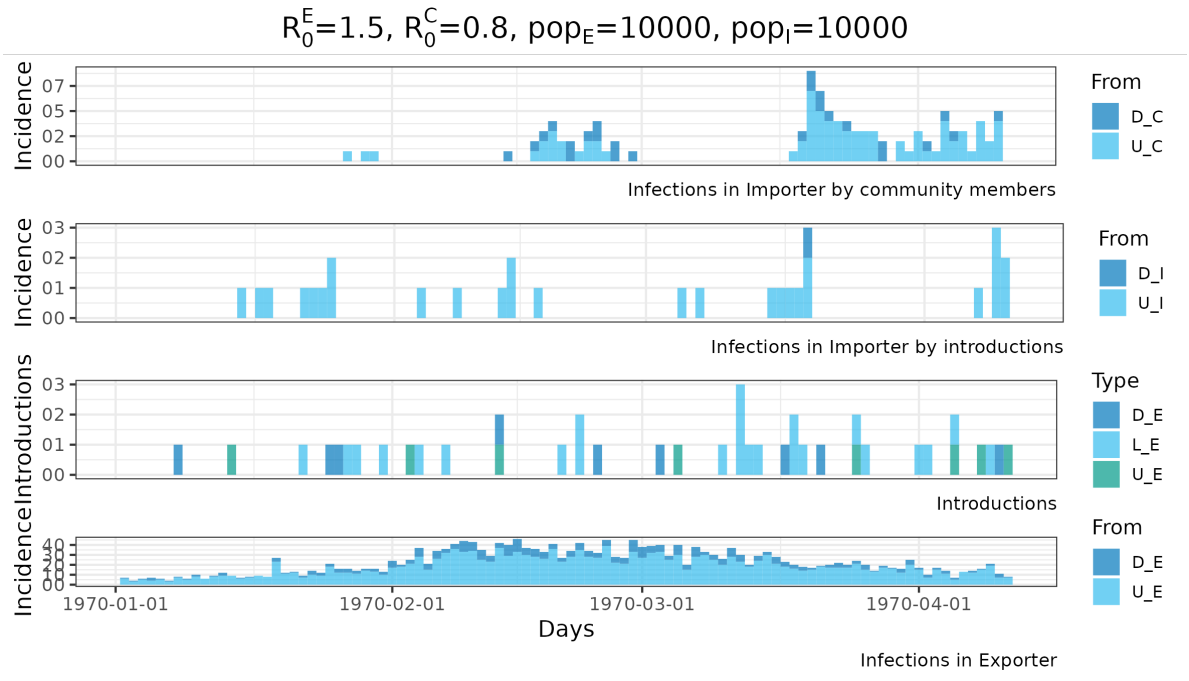
In the **Exporter**

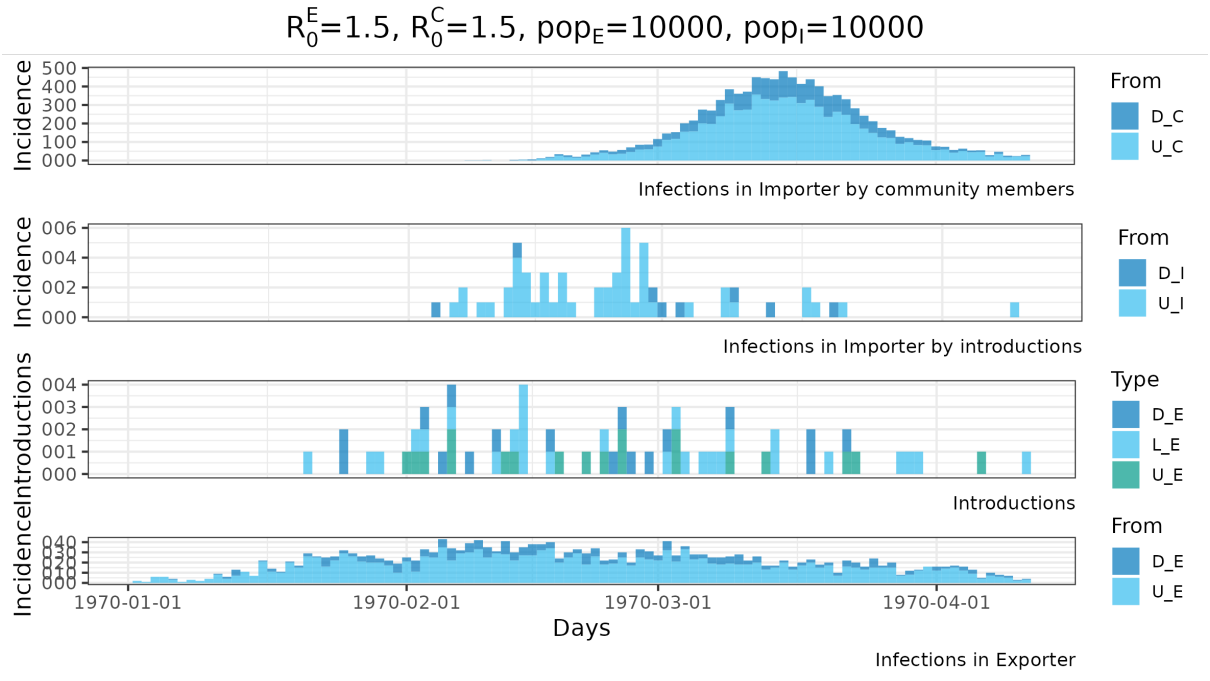
$$\Phi_E = \beta_E(\xi_E D_E + U_E) \tag{1}$$

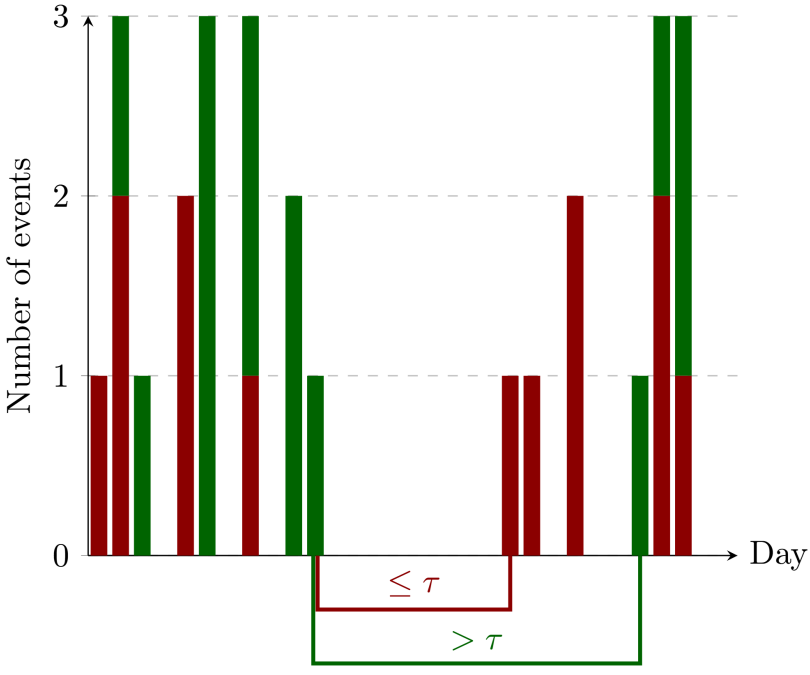
In the **Importer**

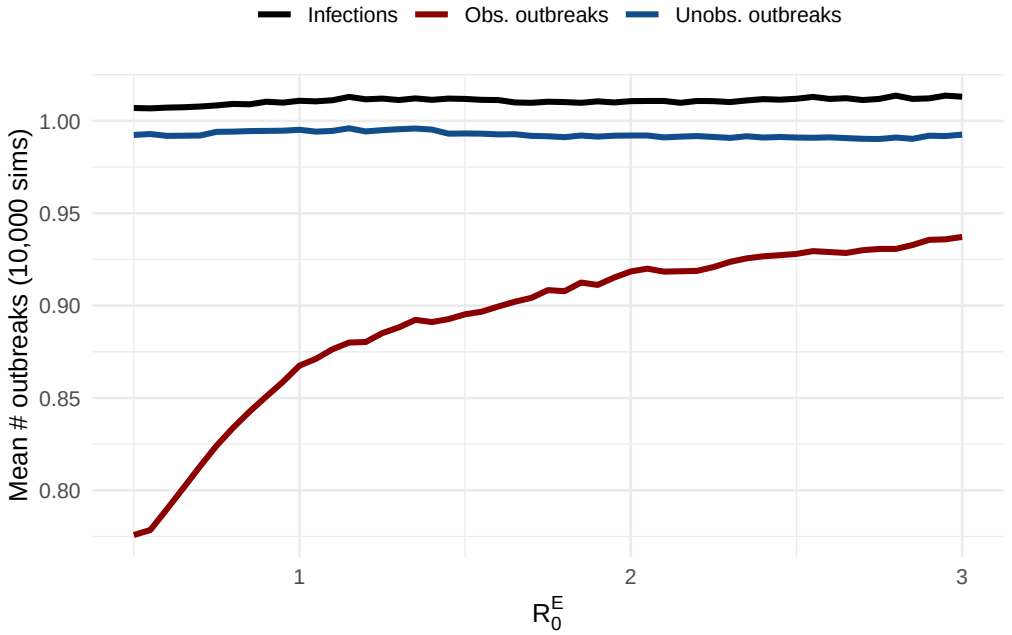
$$\Phi_C = \beta_I(\xi_I D_I + U_I) + \beta_C(\xi_C D_C + U_C) \tag{2}$$


R_0^E=1.5, R_0^C=0.8, pop_E=10000, pop_I=10000
Incidence
Infections in Importer by community members
From
D_C
U_C
Incidence
Infections in Importer by introductions
From
D_I
U_I
IncidenceIntroductions
Introductions
Type
D_E
L_E
U_E
IncidenceIntroductions
Infections in Exporter
From
D_E
U_E
1970-01-01
1970-02-01
1970-03-01
1970-04-01
Days

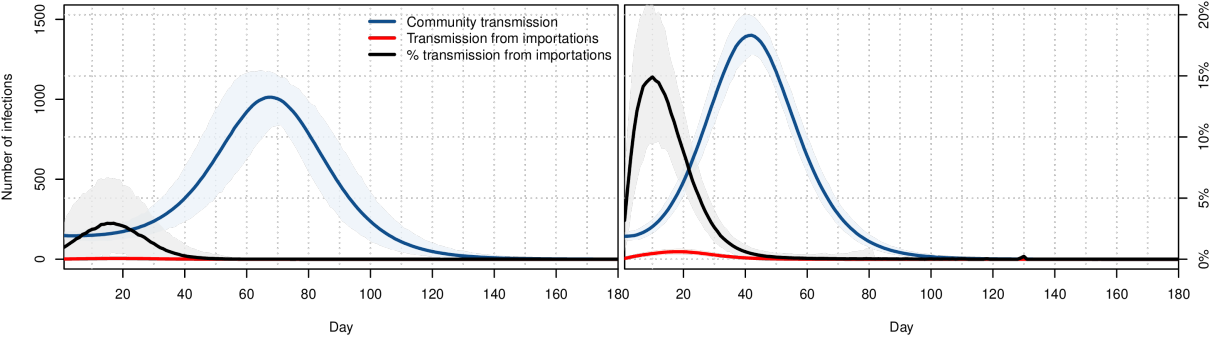

R_0^E=1.5, R_0^C=0.8, pop_E=10000, pop_I=10000
Incidence
07
05
02
00
Infections in Importer by community members
From
D_C
U_C
Incidence
03
02
01
00
Infections in Importer by introductions
From
D_I
U_I
Incidence Introductions
03
02
01
00
Introductions
Type
D_E
L_E
U_E
Incidence
40
30
20
10
00
1970-01-01
1970-02-01
1970-03-01
1970-04-01
Days
Infections in Exporter
From
D_E
U_E


R_0^E=1.5, R_0^C=1.5, pop_E=10000, pop_I=10000
Incidence
500
400
300
200
100
000
Infections in Importer by community members
From
D_C
U_C
Incidence
006
004
002
000
Infections in Importer by introductions
From
D_I
U_I
IncidenceIntroductions
004
003
002
001
000
Introductions
Type
D_E
L_E
U_E
Incidence
040
030
020
010
000
1970-01-01
1970-02-01
1970-03-01
1970-04-01
Days
Infections in Exporter
From
D_E
U_E


3
2
1
0
Number of events
Day
$\leq \tau$
$> \tau$


Infections
Obs. outbreaks
Unobs. outbreaks
Mean # outbreaks (10,000 sims)
1.00
0.95
0.90
0.85
0.80
1
2
3
R_0^E

"j'en ai découvert une démonstration véritablement merveilleuse que cette marge est trop étroite pour contenir" (Pierre de Fermat)


Community transmission
Transmission from importations
% transmission from importations
Number of infections
0
500
1000
1500
0%
5%
10%
15%
20%
20
40
60
80
100
120
140
160
180
Day
Day

In progress

- Try to work quarantine into the model in a "non-cohorty" manner
- We have a final size expression for when travel is shut down.. Study it
- MBPA to compute probability of an outbreak
- Detailed computational analysis of the CTMC