Aspects stochastiques

CIMAD N'Djaména 2025 – Cours 03

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The University of Manitoba campuses are located 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

At the beginning of the COVID-19 crisis

- I was working under contract with the Public Health Agency of Canada on *COVID-19 importation risk assessment*

- Produced daily report with list of countries most likely to next report cases of COVID-19

- Used ensemble runs of a fitted global deterministic metapopulation model

- Very very long days (18-20 hours, 7 days a week)

- including a lot of time waiting for the “cluster” to finish

$\Longrightarrow$ PHAC gave me money for a cluster (yay Threadrippers !!!)

$\Longrightarrow$ Also thought about whether my model was really adequate as our focus switched from thinking about movement on a planetary scale to movement within Canadian provinces

What is wrong with deterministic models ?

- I pointed out yesterday that SARS-CoV-2 is one *single* realisation of a stochastic process

- Deterministic models “operate on averages” over a large ($\to \infty$) number of realisations

- If we want to get a better sense of what could happen, not only on average, then we need to see what can indeed happen

My new focus – Introductions

- I started thinking in particular about **introductions** (or importations) of pathogens into new populations

- Indeed, introductions are an obligatory step in spatial spread

First piece of evidence

In real life, introductions of pathogens does not always follow the patter

$$\{\mathcal{R}_0 < 1 \implies \rightarrow \text{DFE} \mid \mathcal{R}_0 > 1 \implies \text{epidemic or} \rightarrow \text{EEP}\}$$

Aging and Disease
www.aginganddisease.org

Early access date: October 28, 2022
http://dx.doi.org/10.14336/AD.2022.0820

Short Communication

SARS-CoV-2 in Nursing Homes: Analysis of Routine Surveillance Data in Four European Countries

Tristan Delory[1,2*], Julien Arino[3], Paul-Emile Haÿ[4], Vincent Klotz[4], Pierre-Yves Boëlle[1]

[1] Sorbonne Université, INSERM, Institut Pierre Louis d'Épidémiologie et de Santé Publique, IPLESP, F-75012, Paris, France. [2]Centre Hospitalier Annecy Genevois, France. [3]Department of Mathematics, University of Manitoba, Winnipeg, Manitoba, Canada. [4]Groupe Colisee.

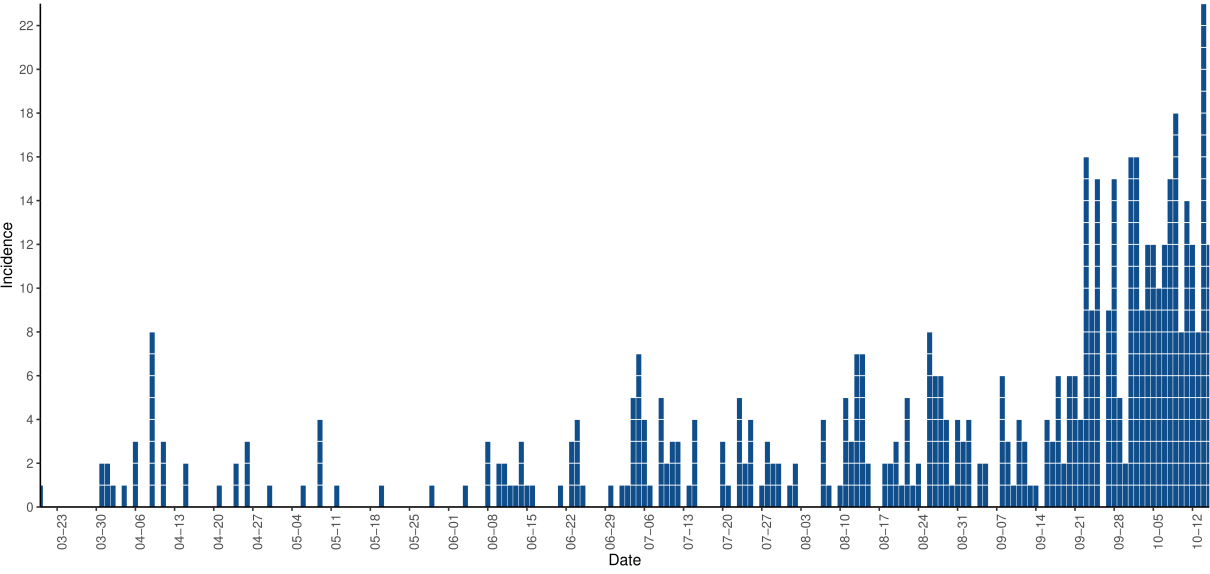
Table 1. Effect of vaccination scaling-up on the probability of successful viral introduction.

Period	Failed N = 136	Successful N = 366	aOR*	95%CI	P-value
Before vaccination	94 (69.1%)	311 (85.0%)	Ref		
January 15 to January 31	12 (8.8%)	37 (10.1%)	0.89	0.42 – 1.92	0.770
February 01 to February 15	17 (12.5%)	14 (3.8%)	0.23	0.10 – 0.52	<0.001
February 16 to February 28	13 (9.6%)	4 (1.1%)	0.08	0.02 - 0.29	<0.001

* Adjusted on study period, country, staffing ratio, cumulative attack rate at onset of introduction, and number of PCR per 1000-residents or 1000-staff members, at onset of introduction, and nursing home maximal capacity.

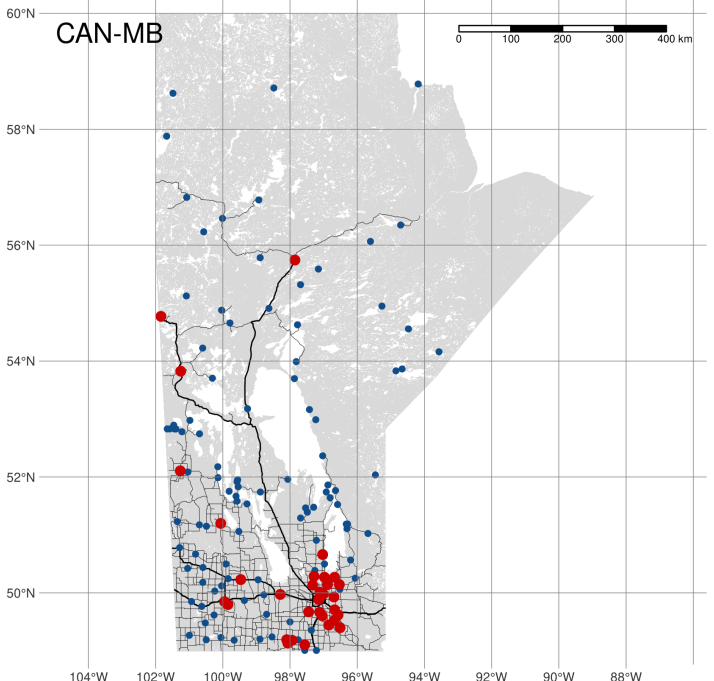
Second piece of evidence

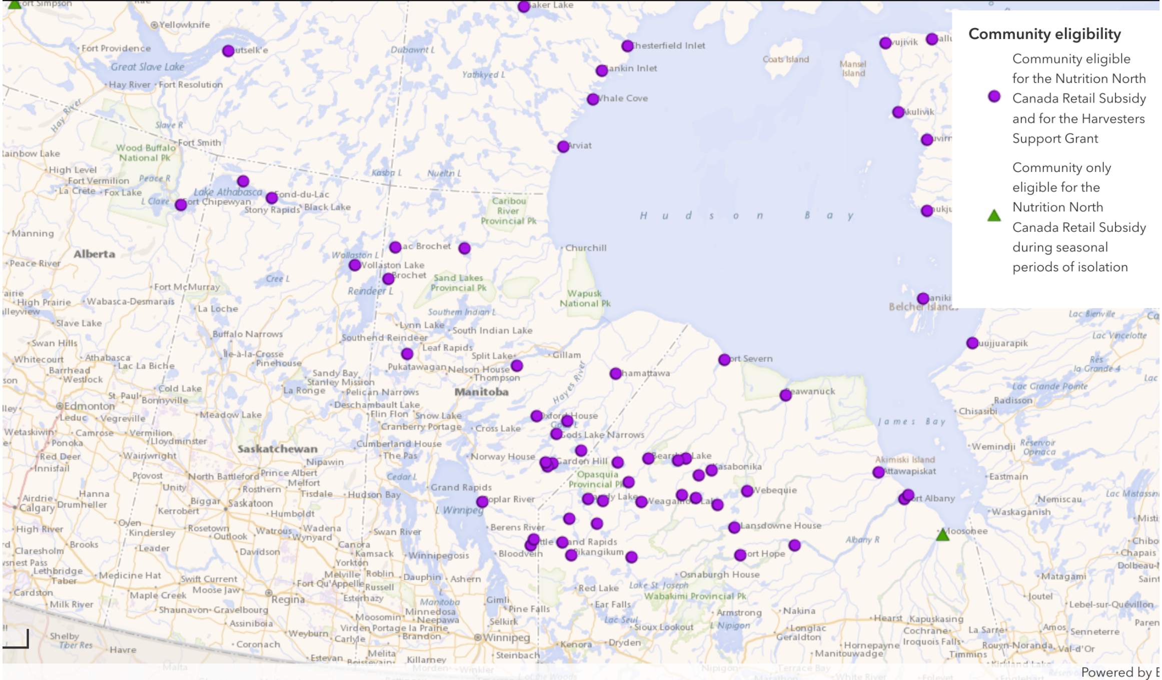
The start of an outbreak can be extremely slow, with very few cases for quite a while


Incidence
0
2
4
6
8
10
12
14
16
18
20
22
03–23
03–30
04–06
04–13
04–20
04–27
05–04
05–11
05–18
05–25
06–01
06–08
06–15
06–22
06–29
07–06
07–13
07–20
07–27
08–03
08–10
08–17
08–24
08–31
09–07
09–14
09–21
09–28
10–05
10–12
Date

Why this is relevant

Far from the only reason, but as an example : Canada has remote/isolated communities that are vulnerable to introductions of pathogens


CAN-MB
0
100
200
300
400 km
60°N
58°N
56°N
54°N
52°N
50°N
104°W
102°W
100°W
98°W
96°W
94°W
92°W
90°W
88°W


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
Great Slave Lake
Lake Athabasca
Wood Buffalo National Pk
Caribou River Provincial Pk
Sand Lakes Provincial Pk
Wapusk National Pk
Opasquia Provincial Pk
Wabakimi Provincial Park
Yellowknife
Arviat
Churchill
Edmonton
Calgary
Regina
Winnipeg
Powered by

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.

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

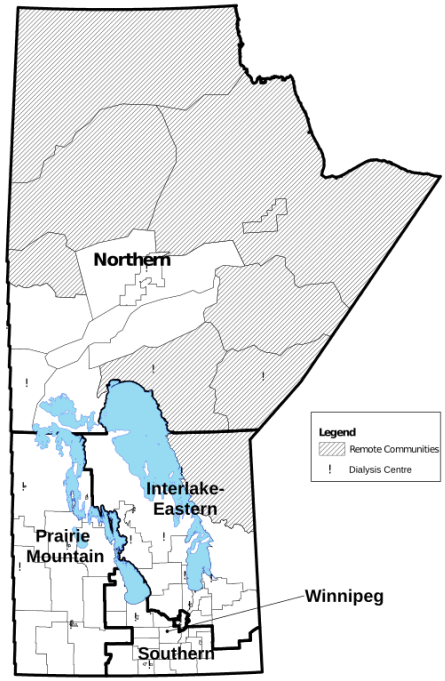
Inuit Communities to be referred to as **Inuit Nunangat**, not remote and isolated communities to respect the unique language and culture of Inuit regions, as well as the common challenges in social determinants of health, access to care, and infrastructure found across all Inuit communities

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
Winnipeg
Southern
Legend
Remote Communities
Dialysis Centre

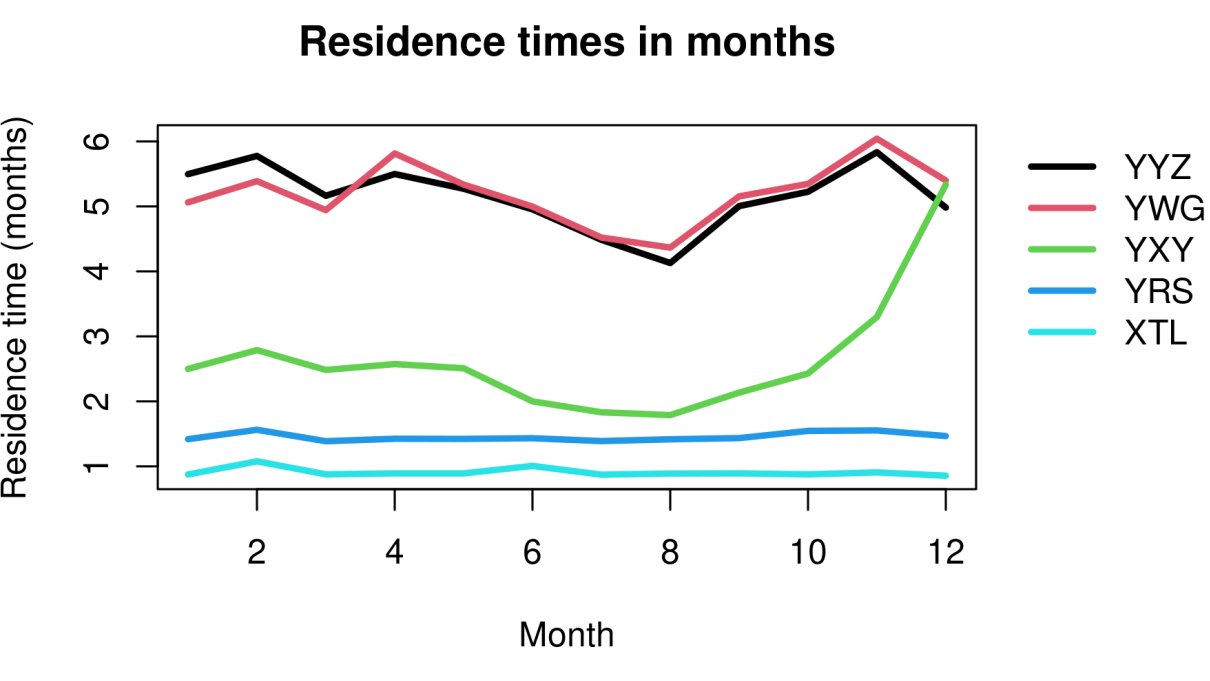
Travel to/from remote or isolated communities

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

Think of residence times in these communities : what is the average time a person spends in a remote or isolated community before leaving it ?

The **residence time in a location** is the total number of trips inbound into and outbound from location over a duration of time (1 month here) divided by the normal population in the location


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

See in particular the work of Horst Thieme

If one considers time of sojourn in compartments from a more detailed perspective, one obtains integro-differential models

We use here continuous random variables. See chapters 12 and 13 in Thieme's book for arbitrary distributions

Time to events

We suppose that a system can be in two states, A and B

- At time $t = 0$, the system is in state A
- An event happens at some time $t = \tau$, which triggers the switch from state A to state B

Let us call T the random variable
"time spent in state A before switching into state B"

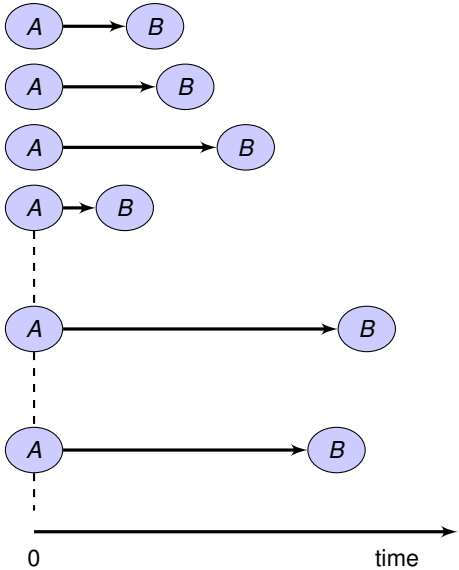
The states can be anything :

- A : working, B : broken
- A : infected, B : recovered
- A : alive, B : dead
- ...

We take a collection of objects or individuals that are in state A and want some law for the **distribution** of the times spent in A, i.e., a law for T

For example, we make light bulbs and would like to tell our customers that on average, our light bulbs last 200 years...

We conduct an **infinite** number of experiments, and observe the time that it takes, in every experiment, to switch from A to B


A
B
A
B
A
B
A
B
A
B
A
B
0
time

A distribution of probability is a model

From the sequence of experiments, we deduce a model, which in this context is called a **probability distribution**

We assume that T is a **continuous** random variable