The modelling advancements needed to support future pandemic preparedness in Canada

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Introduction

- Infectious disease modelling is essential to support public health decisions and its value was highlighted during the recent COVID-19 pandemic.

- However, models intended to support national or large jurisdictions may not support the decisions, policy, or situational awareness needs of small jurisdictions.

Introduction

- As an example, from 2020-22 Atlantic Canada and the territories experienced long periods with no community spread of SARS-CoV-2.
- Reported cases consisted mostly of travel-related cases.
- An elimination strategy, that reduces infection incidence to zero was feasible. In some circumstances, travel measures were likely appropriate in smaller jurisdictions, while this may not necessarily have been the case in larger jurisdictions or Canada as a whole.

Introduction

- Support for the novel modelling needs of Canada’s smaller jurisdictions was provisioned ad hoc, and to support future pandemic preparedness this support needs to be planned.
- Healthcare decision-making in Canada is decentralized so the majority of decisions during the pandemic occurred at the provincial- and territorial-level
- Small jurisdictions need to be supported with specific modelling approaches, some of which are yet to be developed

Epidemiology in Atlantic Canada and the territories was different

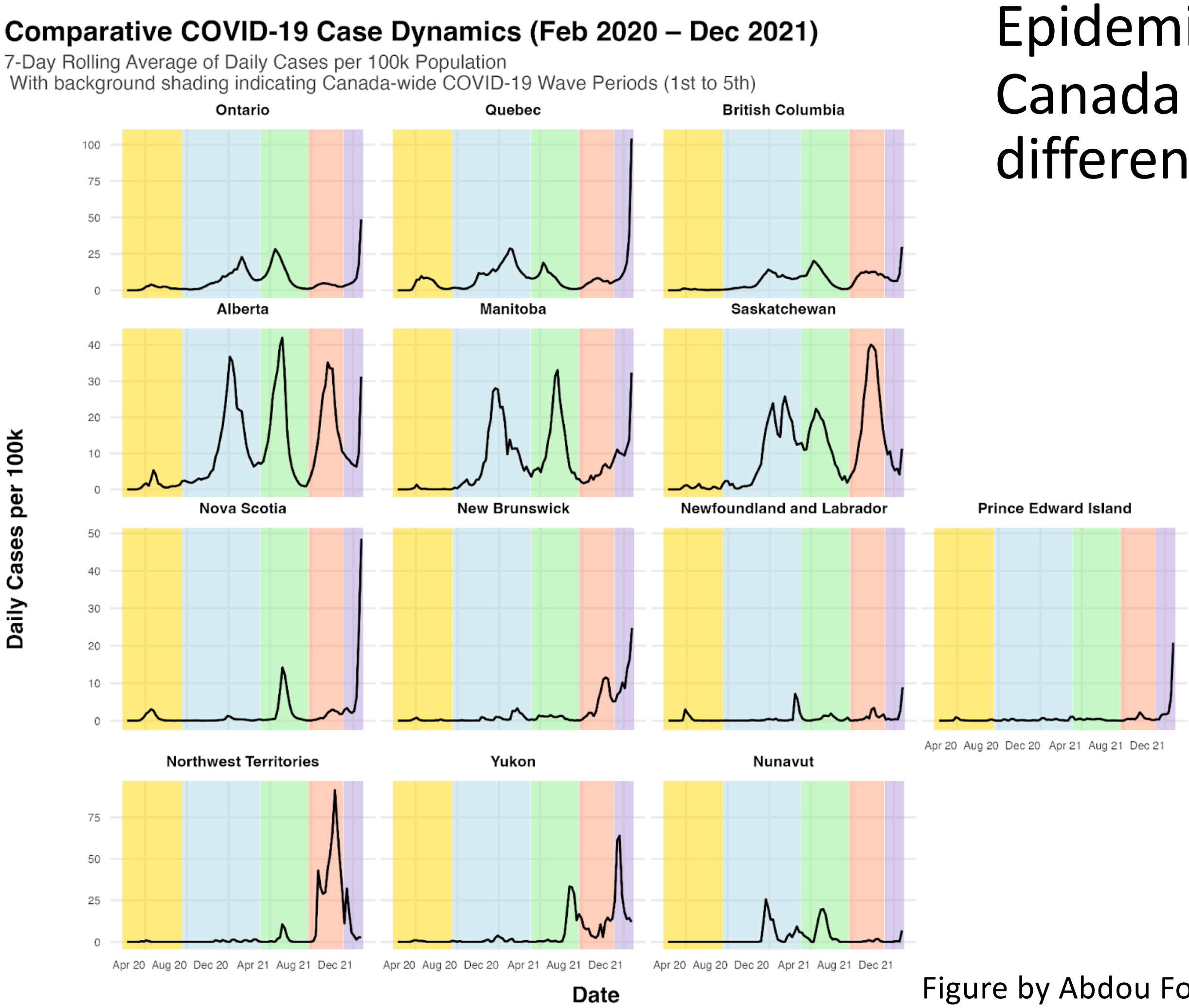

Figure by Abdou Fofana

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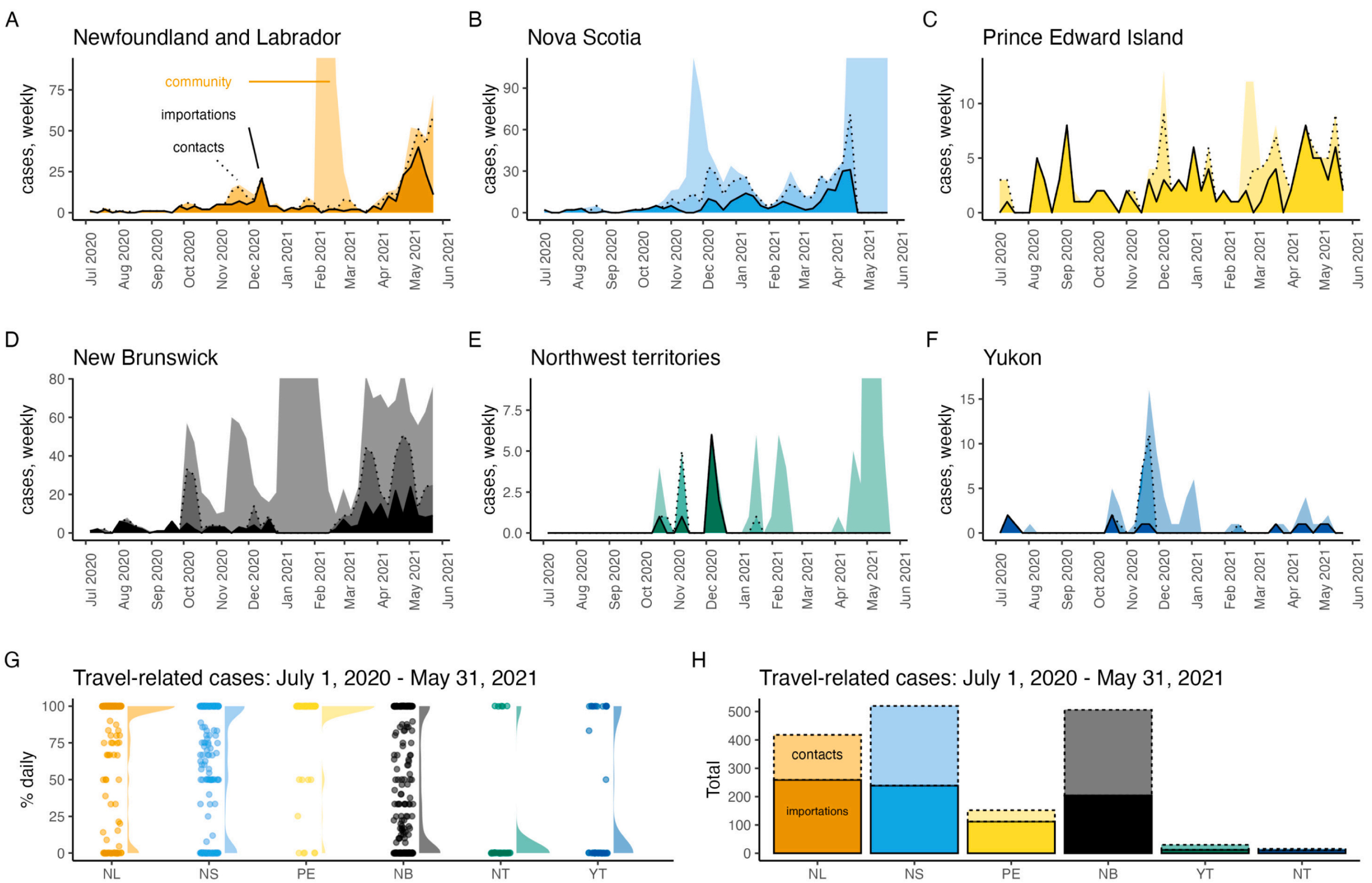

Epidemiology in Atlantic Canada and the territories was different

Hurford et al. 2023. Pandemic modelling for regions implementing an elimination strategy. J Theor Biol.

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The gap in pandemic preparedness

- It is well-known that Atlantic Canada and the territories had different epidemiology during the COVID-19 pandemic
- What has been insufficiently discussed is that this implied different:
  - Data needs, models, analysis, and visualizations
  - Key indicators/parameter that describe the epidemiology
  - Recommended control strategies

Modelling needs for Canadian pandemic preparedness

(1) Counterfactual simulation framework for jurisdictions that are not experiencing community spread

(2) Appropriate key indicators that inform situational awareness and decision-making for all Canadian jurisdictions;

(3) Theory that describes when travel measures and elimination strategies are appropriate (to inform decisions and strategy)

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Counterfactual modelling for jurisdictions that are not experiencing community spread

1. Extended importation modelling*
2. Community spread models

*Extended importation modelling: extending an importation model by adding a spillover model to predict the probability of a major community outbreak beginning on any day

Minor and major outbreaks

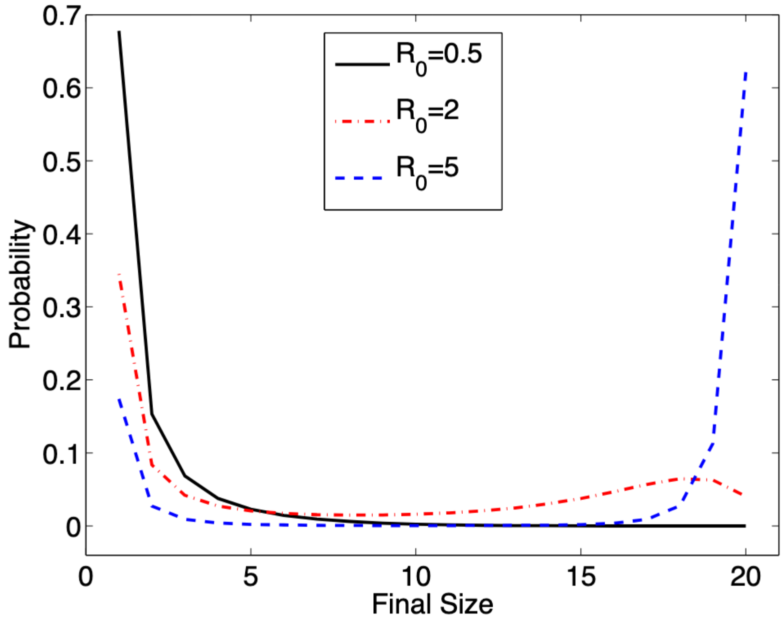
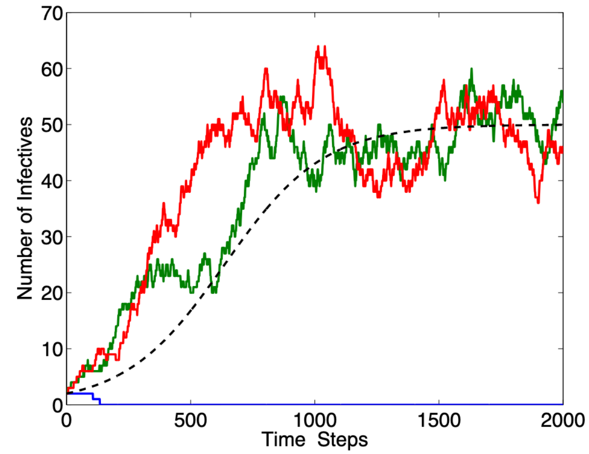


Fig. 13. Distribution for the final size of an epidemic for three different values of $\mathcal{R}_0$ when $\gamma = 1$, $N = 20$, and $\text{Prob}\{\mathcal{I}(0) = 1\} = 1$.



$$\text{Probability of an Outbreak} \approx \begin{cases} 0, & \text{if } \mathcal{R}_0 \le 1 \\ 1 - \left(\dfrac{1}{\mathcal{R}_0}\right)^{i_0}, & \text{if } \mathcal{R}_0 > 1 \end{cases}.$$

Linda Allen. 2008. An introduction to stochastic epidemic models.

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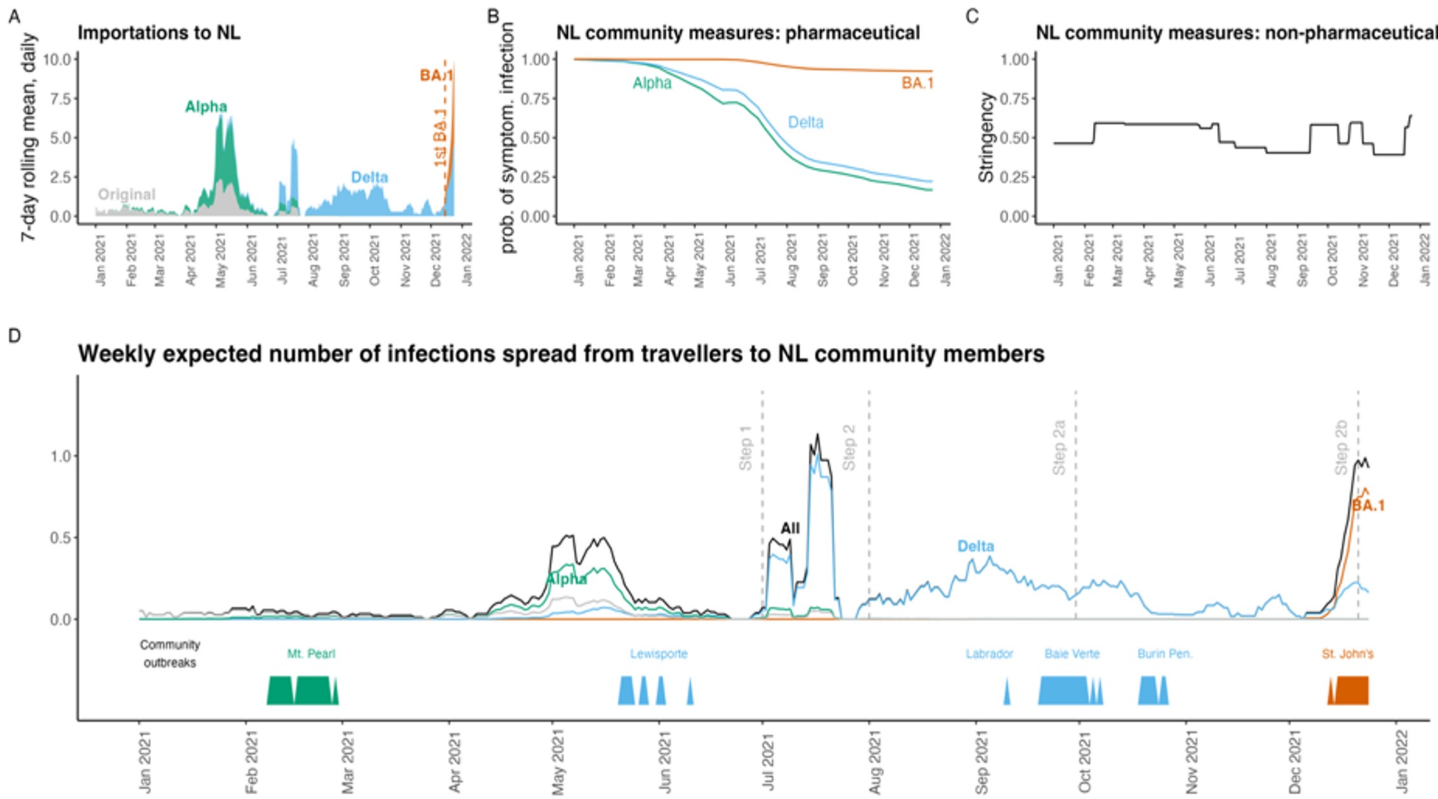
Extended importation modelling (to predict a major outbreak)



Hurford et al. 2023. Pandemic modelling for regions implementing an elimination strategy. Journal of Theoretical Biology

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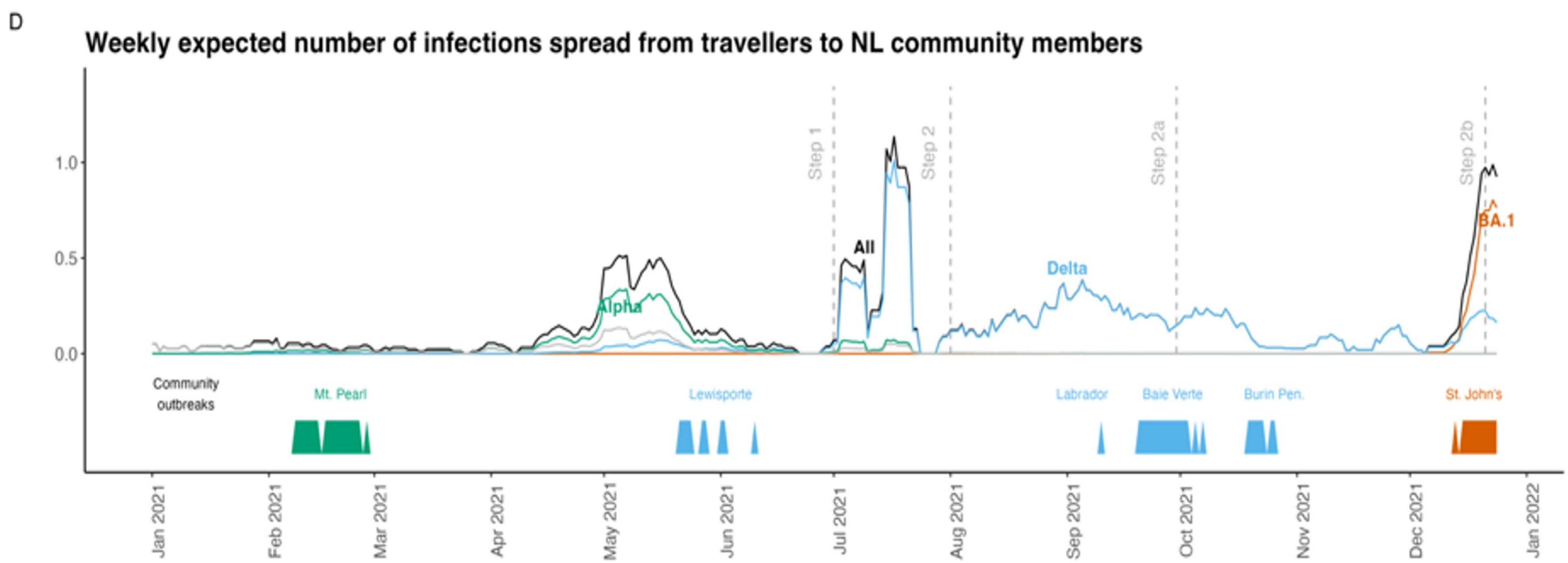
Analogous to R_t vs. time graph for jurisdictions with no community spread



Hurford et al. 2023. Pandemic modelling for regions implementing an elimination strategy. Journal of Theoretical Biology

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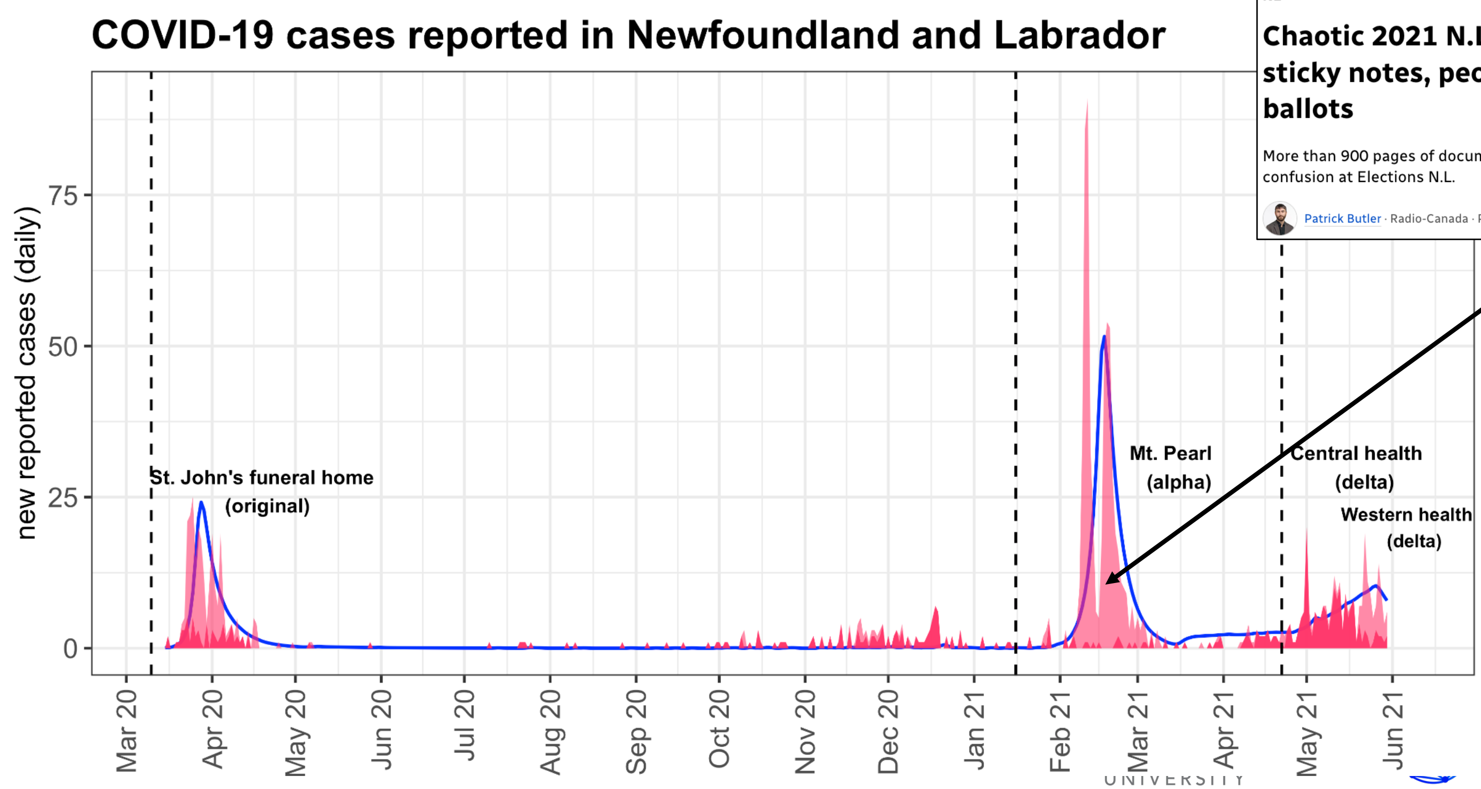
Extended importation models can support decisions about when to have events



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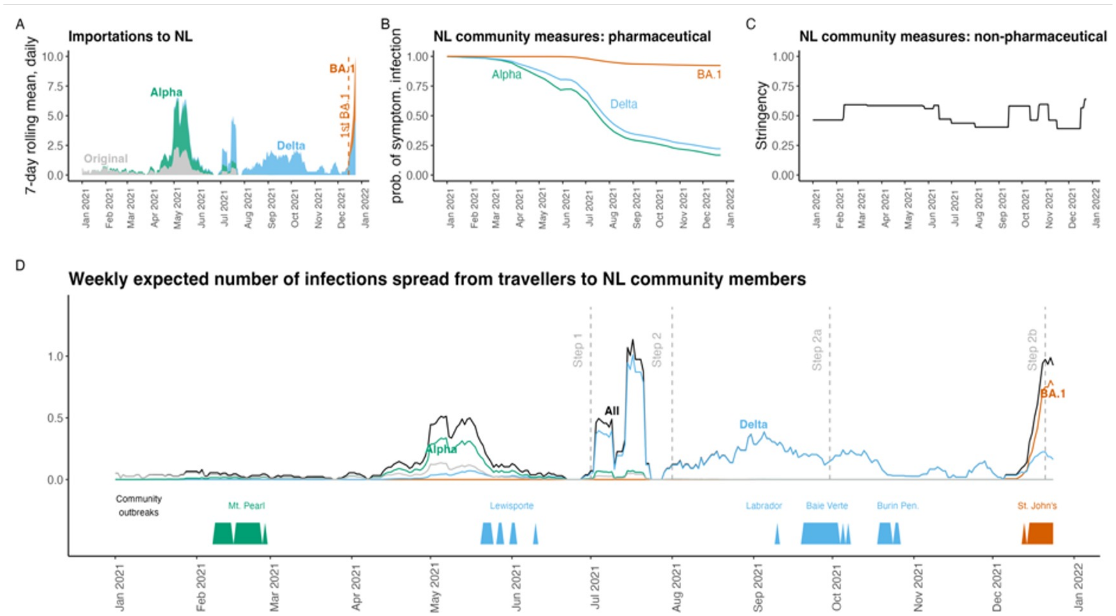
How to model the importations

The figure on the right just uses travel-related cases (no model)

If these data are unavailable*
or for forecasting:

- Statistical model
- Importation model
- Metapopulation model
- Agent-based model



*but we should advocate to have these data be available

Data gaps for modelling importations: requires real-time access to travel volume data

Block-Fitness Modeling of the Global Air Mobility Network

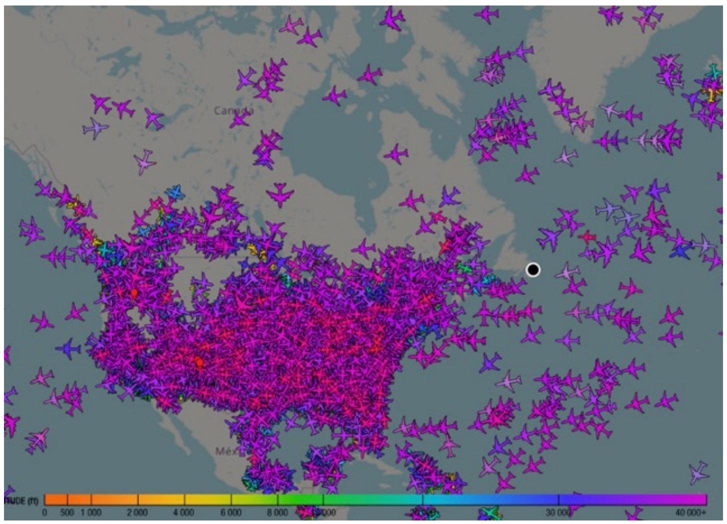
Giulia Fischetti[1,+], Anna Mancini[2,3,+], Giulio Cimini[2,3,4,*], Jessica T. Davis[5], Abby Leung[5], Alessandro Vespignani[5], and Guido Caldarelli[1,4,6]

ABSTRACT

Accurate representations of the World Air Transportation Network (WAN) are fundamental inputs to models of global mobility, epidemic risk, and infrastructure planning. However, high-resolution, real-time data on the WAN are largely commercial and proprietary, therefore often inaccessible to the research community. Here we introduce a generative model of the WAN that treats air travel as a stochastic process within a maximum-entropy framework. The model uses airport-level passenger flows to probabilistically generate connections while preserving traffic volumes across geographic regions. The resulting reconstructed networks reproduce key structural properties of the WAN and enable simulations of dynamic spreading that closely match those obtained using the real network. Our approach provides a scalable, interpretable, and computationally efficient framework for forecasting and policy design in global mobility systems.

Preprint on arxiv

Data gaps for modelling importations: requires real-time access to travel volume data



For details see: Ciupeanu, A.-S., Wickramasinghe, A., Muthukumarana, S. & Arino, J. *Investigating air travel network changes in Canada, USA and Europe during COVID-19 using open source data*. Preprint at https://doi.org/10.21203/rs.3.rs-2426208/v1 (2023)

Figure 1. The OpenSky network provides freely available real time data describing aircraft type and location to contributors hosting an antennae in the network. Data such as these are necessary to inform analysis that considers the appropriateness of travel measures. The map is from August 26, 2025 at 4.24pm. St. John's is shown with a black dot.

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Data gaps for modelling importations: travel-related cases

During a pandemic, when reporting cases to the Public Health Agency of Canada (PHAC), provinces and territories should also report:

- if cases have a travel history, and if so,
- the province, territory and country of origin

- These data were already made public so there is no anonymity issues
- Without travel-related case data, and without province/territory/country of origin information, importation models are substantially less accurate

Mohammadi et al. 2025. Importation models for travel-related SARS-CoV-2 cases reported in Newfoundland and Labrador during the COVID-19 pandemic. J Roy Soc Open Sci

Extending the importation model

- Spillover model is a mechanistic model for:
  - travelers arriving and self-isolating;
  - infecting their close contacts;
  - contacting and infecting community members;
  - that leads to a major outbreak;

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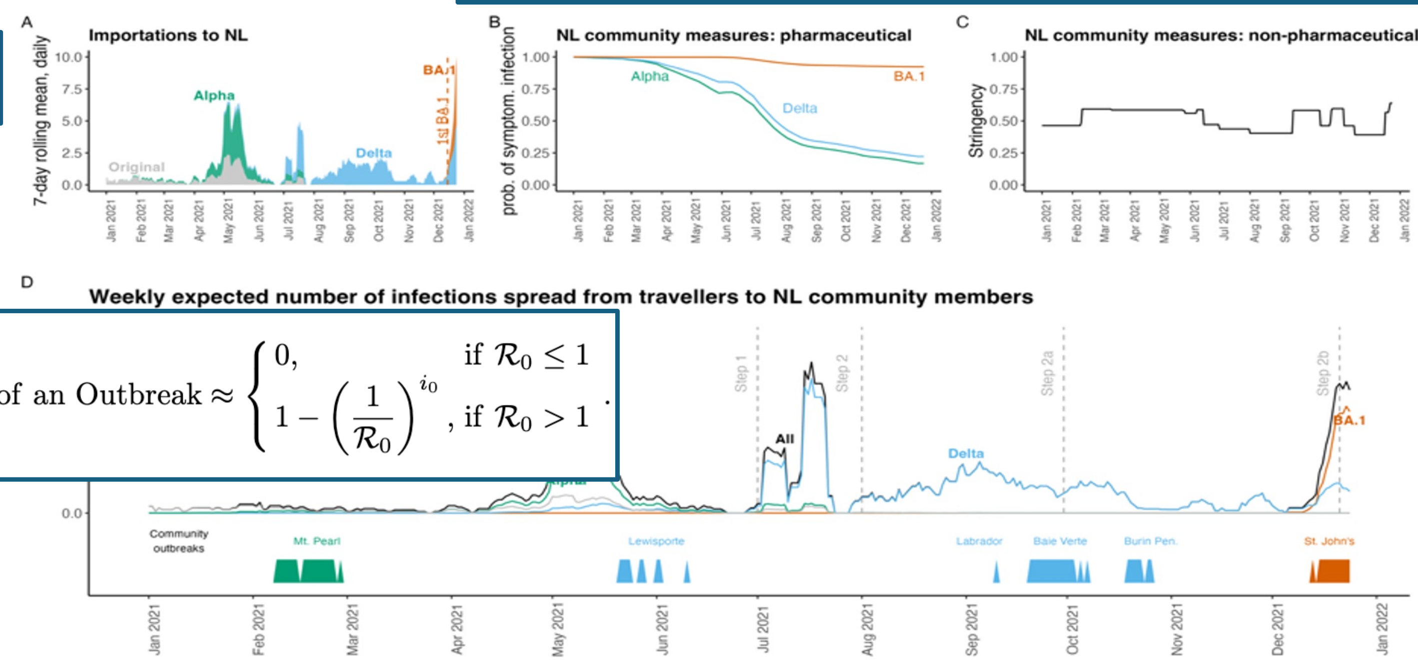
Hurford et al. 2023 is still not quite there…

R_t from an average traveller to NL community member

i_0



$$\text{Probability of an Outbreak} \approx \begin{cases} 0, & \text{if } \mathcal{R}_0 \leq 1 \\ 1 - \left(\dfrac{1}{\mathcal{R}_0}\right)^{i_0}, & \text{if } \mathcal{R}_0 > 1 \end{cases}.$$

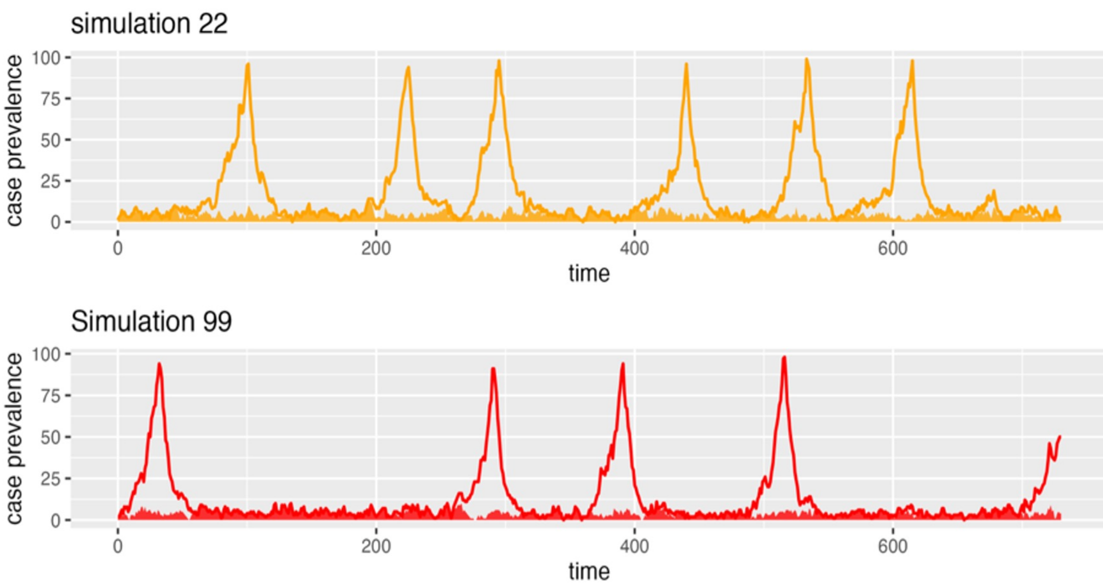
Hurford et al. 2023. Pandemic modelling for regions implementing an elimination strategy. Journal of Theoretical Biology

Counterfactual modelling for jurisdictions that are not experiencing community spread

1. Extended importation modelling*
2. **Community spread models**

*Extended importation modelling: extending an importation model to predict the probability of a community outbreak beginning on any day

Counterfactual simulation framework



Reporting for multiple realizations
DO: ● Av. outbreak frequency ● Av. size of community outbreak ● Av. days without community cases ● i.e., key indicators DO NOT: ● Av. prevalence at a given time ● Consider the date meaningful

- Community outbreak dates affected by extended importation model
- $R_t > 1$ except from when community cases ≥ 100 until elimination

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Can't we just use Vicky's ABM model? Sure! But…

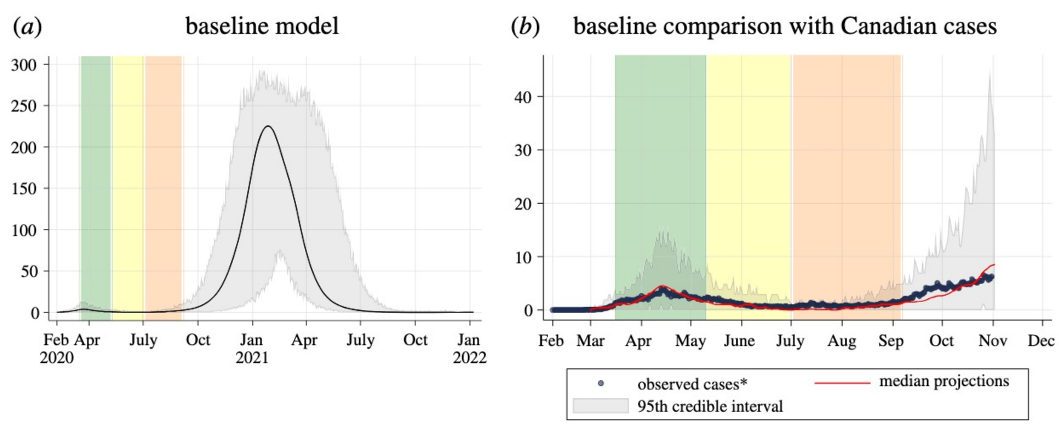

Figure 1. Baseline scenario. (*a*) Projected epidemic curve showing daily clinical incident cases per 100 000 people for the baseline model. The black line represents the median value across 50 model realizations. The grey area represents the 95% credible interval across 50 model realizations. The green bar represents 16 March to 10 May (initial shutdown), the yellow bar represents 11 May to 30 June (easing of shutdown) and the orange bar represents 1 July to 7 September (changes in summer). (*b*) Comparison between locally acquired Canadian cases by onset date (blue dots) and the median modelled clinical cases from the baseline model from 50 model realizations (red line). The grey area represents the 95% credible interval across 50 model realizations. Note that the baseline model was fitted to Canadian levels of interventions up until 8 September (the end of the orange bar) and does not consider additional interventions occurring across the country beyond 8 September.

Ng V, Fazil A, Waddell LA, Turgeon P, Otten A, Ogden NH. 2021 Modelling the impact of shutdowns on resurging SARS-CoV-2 transmission in Canada. R. Soc. Open Sci. 8: 210233. https://doi.org/10.1098/rsos.210233

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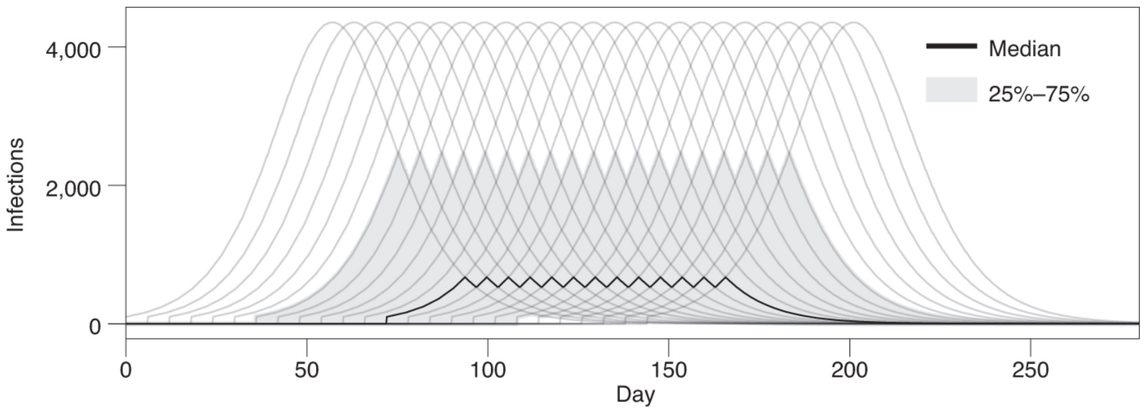
… it is less about the model that generates the importations, more about how the results are presented/interpreted



Simulations of the outbreak on the island Transmithaca (created using a deterministic compartmental model). Grey curves show individual simulations. Median and confidence intervals calculated using fixed-time statistics are defined in the legend. Simulations are identical except for the date on which the outbreak starts. The fixed-time descriptive statistics do not capture peak numbers of infections.

Juul et al. 2021. Fixed-time descriptive statistics underestimate extremes of epidemic curve ensembles

Reporting for multiple realizations

DO:

- Av. outbreak frequency
- Av. size of community outbreak
- Av. days without community cases
- i.e., key indicators

DO NOT:

- Av. prevalence at a given time
- Consider the date meaningful

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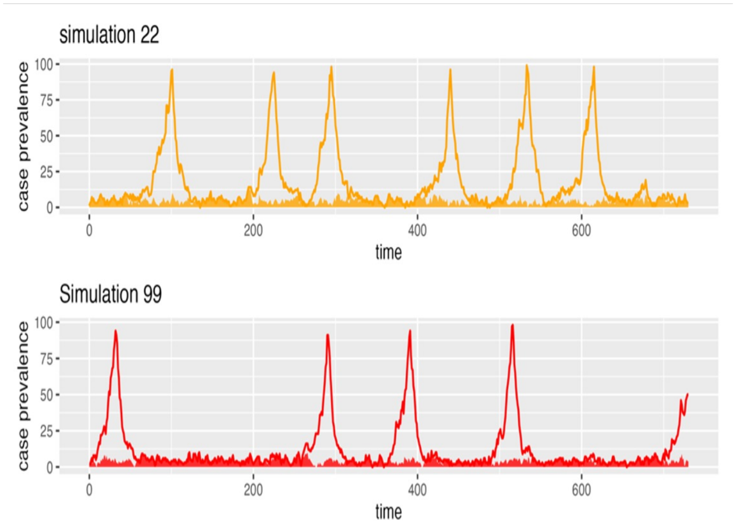
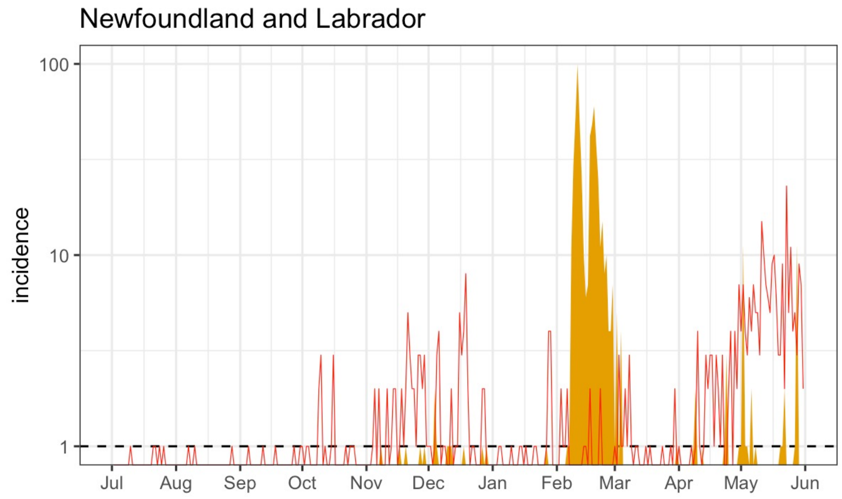
Counterfactual simulation framework





- Community outbreak dates affected by extended importation model
- $R_t > 1$ except from when community cases ≥ 100 until elimination

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Parameters and model needs for counterfactual simulation framework

Parameter estimation: outbreak frequency
community spread R_t (no NPIs)
community spread R_t (with NPIs)
time to outbreak detection

Models: Importation model
Spillover model
Community spread model

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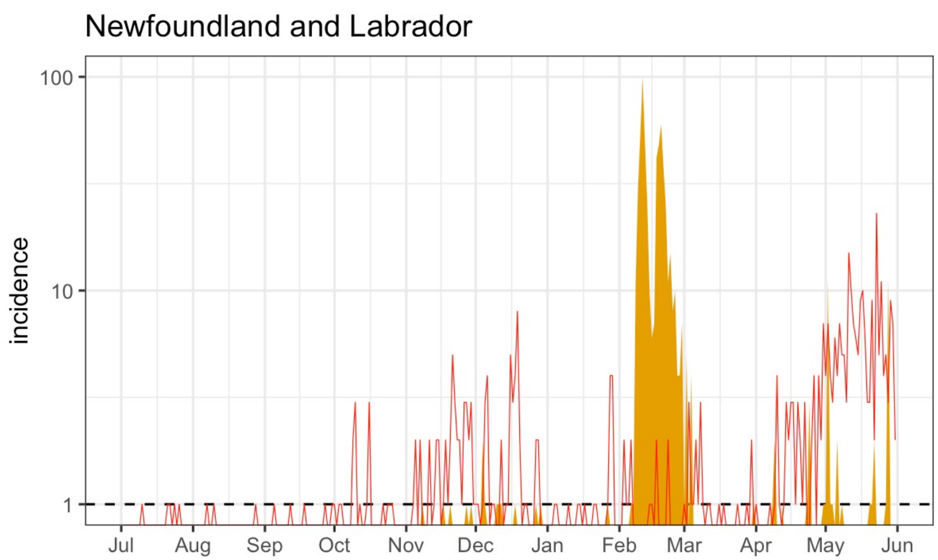
Parameter estimation



Time series summary:

- 1 major outbreak + 3(?) minor outbreaks

Parameter estimation:

- outbreak frequency: 1/334 days
- community spread R_t (no NPIs): several possible estimation methods*
- community spread R_t (with NPIs): 0.33**
- time to outbreak detection: 10 days (assume)

*Multiple outbreaks of same variant – randomly choose R_t during counterfacutal?

** 5 days after NPIs implemented based on Hurford et al. 2023. J Theor Biol

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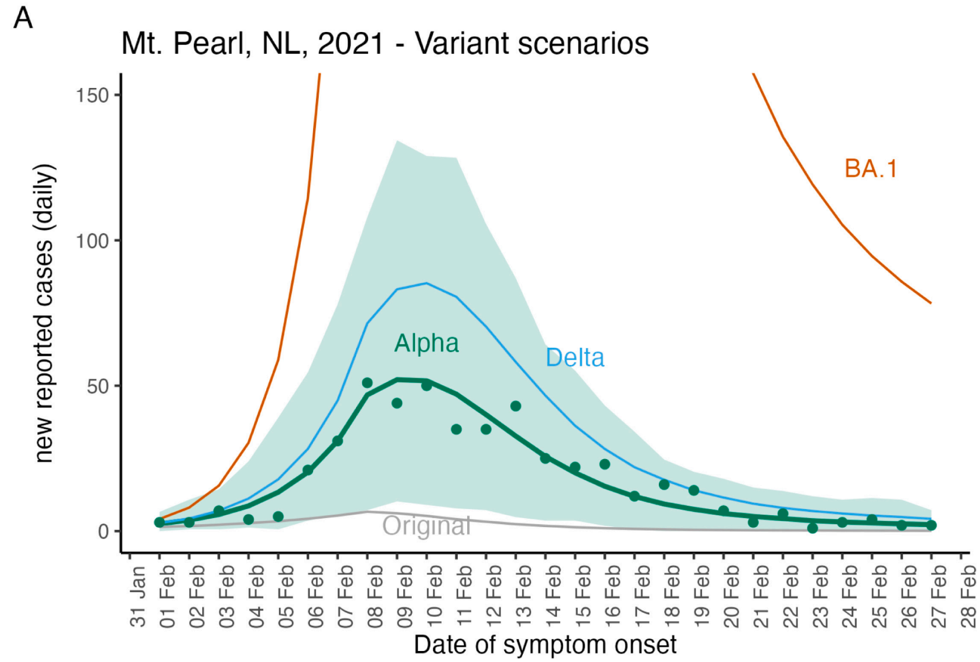
Estimating: R_t no NPIs

<u>Method 1.</u> Fit data on reported cases

- R_t (no NPIs) = 0.887/(0.1+0.5)
  = 1.48 (n=10)



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Estimating: R_t no NPIs

Method 2. Contact tracing data

- R_t (no NPIs) = 1.11 (95% CI: [1.02, 1.21]; n = 474)

	Poisson		Negative Binomial		
Alert Level	$\widehat{R_t}$	AIC	$\widehat{R_t}$	$\hat{k}$	AIC
2	1.11	1148	1.11	194.0	1151
3	1.19	298	1.19	58.7	301
4	0.95	680	0.95	107.0	684
5	1.33	825	1.33	46.8	826
Overall	1.13	2964	1.13	121	2970

Doig et al. *Changing contact patterns in Newfoundland and Labrador, Canada in response to public health measures during the COVID-19 pandemic*. Preprint. MedRxiv

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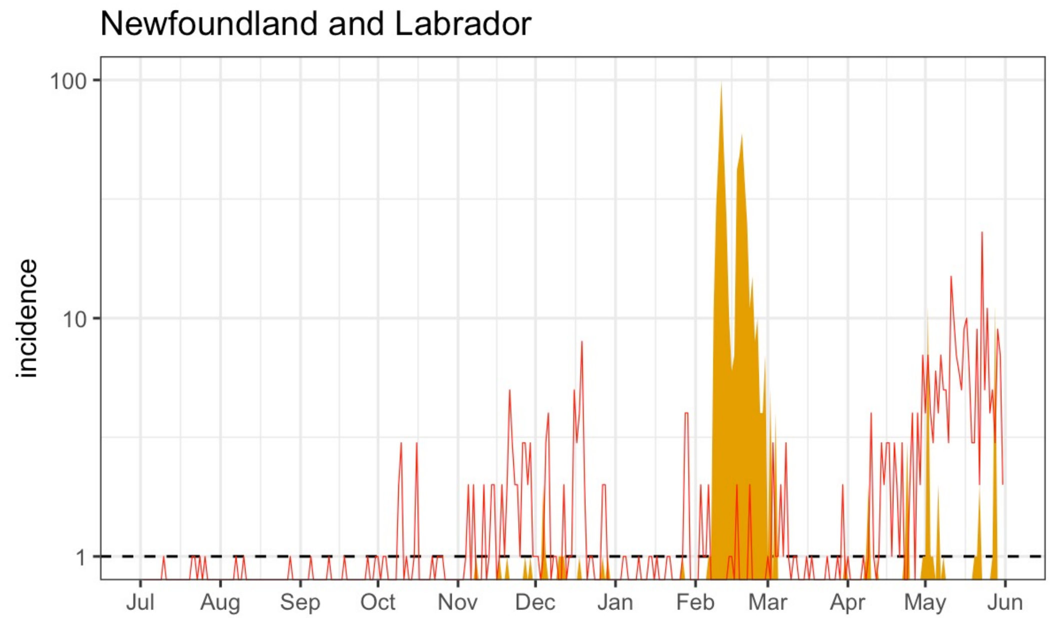
Estimating: R_t no NPIs

Method 3. Probability of a major outbreak

- R_t (no NPIs) = 1.33 (n = 4)

$$P = 1 - \frac{1}{R_0} = \frac{1}{4}$$

$$R_0 = \frac{1}{1-P} = \frac{1}{1-0.25} = 1.33$$



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Summary of R_t estimation example

Method	R_t	n
1. Time series	1.48	10
2. Contact tracing	1.11	474
3. Probability of outbreak	1.33	4

Modelling needs

(1) Counterfactual simulation framework for jurisdictions that are not experiencing community spread;

(2) Appropriate key indicators that inform situational awareness and decision-making for all Canadian jurisdictions;

(3) Theory that describes when travel measures and elimination strategies are appropriate (to inform decisions)

Key indicators example from Ontario Science Table

Current Status in Ontario

Key Indicators	
Effective Reproduction Number R(t), on 28-Nov-2021	1.16
Estimated Number of COVID-19 Cases per Day, on 01-Dec-2021	876
Change per week	+147
Doubling Time (Days)	25
Estimated Percentage Caused by Delta	99.9%
COVID-19 Hospital Occupancy, on 01-Dec-2021	312
Change per week	+4
COVID-19 ICU Occupancy, on 01-Dec-2021	155
Change per week	+18
COVID-19 Deaths per Day, on 28-Nov-2021	3
Change per week	-1
COVID-19 Cases per 1 Million per Day, on 01-Dec-2021	51.6
Among Unvaccinated	212.1
Among Fully Vaccinated	39.1
Reduction Associated with Full Vaccination	-81.5%
COVID-19 Hospital Occupancy per 1 Million, on 01-Dec-2021	21.2
Among Unvaccinated	122.7
Among Fully Vaccinated	7.9
Reduction Associated with Full Vaccination	-93.6%
COVID-19 ICU Occupancy per 1 Million, on 01-Dec-2021	10.5
Among Unvaccinated	77.2
Among Fully Vaccinated	2.7
Reduction Associated with Full Vaccination	-96.5%

COVID-19 Vaccination, on 29-Nov-2021	
Number of People With at Least 1 Dose	11,718,308
Change per week	+113,432
Number of Fully Vaccinated People	11,259,729
Change per week	+44,154
Percent of Population Aged 12+ Fully Vaccinated	86.4%
Change per week	+0.3%

SCIENCE TABLE
COVID-19 ADVISORY FOR ONTARIO

https://wayback.archive-it.org/all/20211201183127/https://covid19-sciencetable.ca/ontario-dashboard/

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Key indicators for all Canadian jurisdictions

- What does this dashboard look like if it includes all Canadian provinces and territories?

For jurisdictions where no community spread is occurring:

- R_t for community spread (and doubling time etc) cannot be estimated using the standard methods
- R_t for community spread is also not the most useful way to summarize the epidemiology

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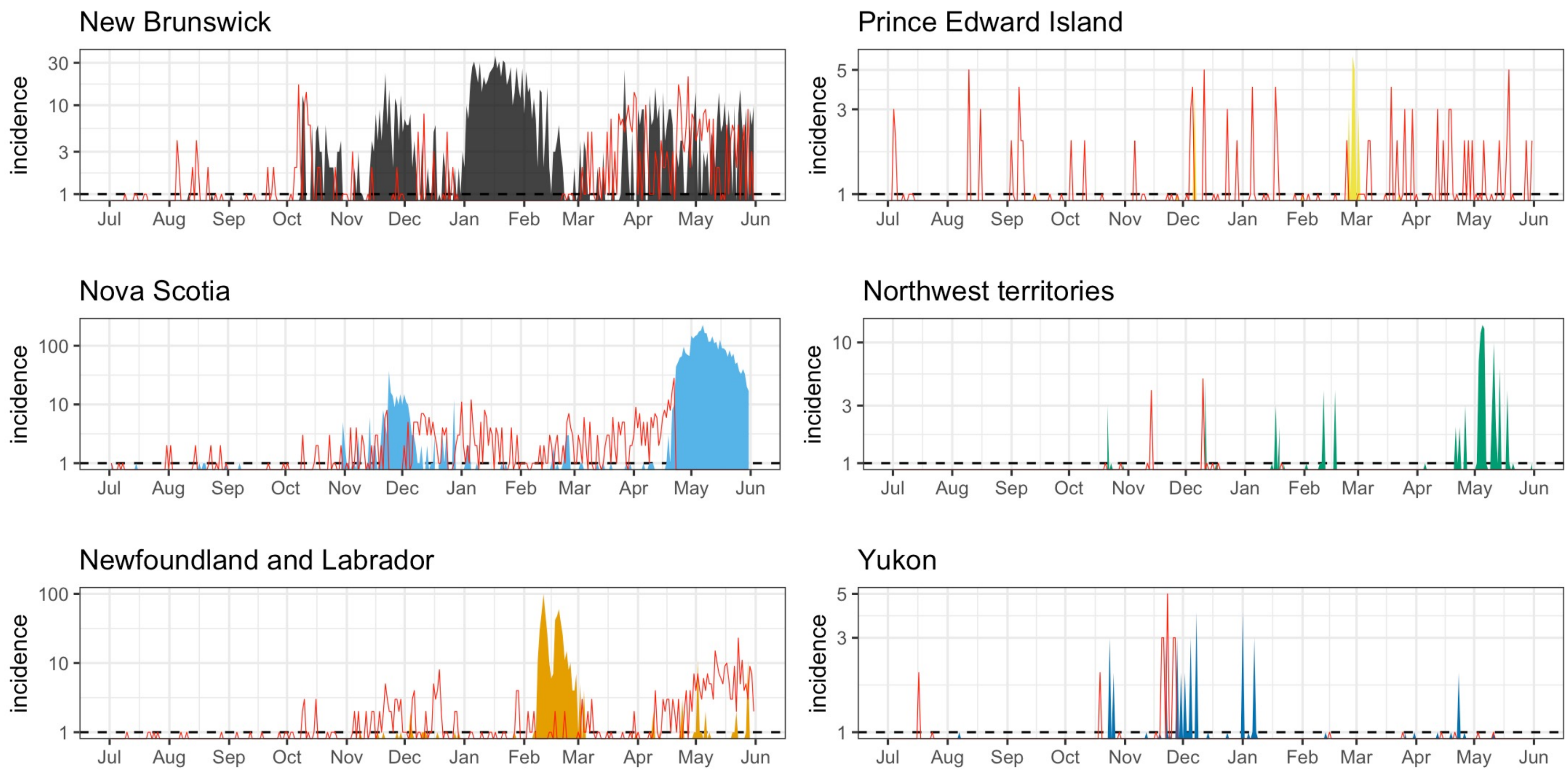
Travel-related and community cases (2020-21)



All other provinces and territories: no reporting of travel history during this period. Travel-related includes out-of-province.

Why should travel-related and community cases be separated?

- In NL, travelers arriving from outside the province were required to self-isolate for 14 days (with the exception of the Atlantic bubble, July 3-Nov 26, 2020)
- The data suggests infection spread from traveler to community members was rare
- Mechanisms of community spread versus travel-related cases are different

WHO transmission classification

Reporting Country/Territory/Area[i]	New cases in last 7 days	Cumulative cases	Cumulative cases per 1 million population	New deaths in last 7 days	Cumulative deaths	Cumulative deaths per 1 million population	Transmission classification[ii]
Lesotho	135	2 285	1 067	0	44	21	Community transmission
Côte d'Ivoire	133	21 772	825	0	133	5	Community transmission
Chad	128	1 867	114	0	102	6	Community transmission
Guinea	112	13 532	1 030	1	80	6	Community transmission
Liberia	103	1 779	352	0	83	16	Community transmission
Eritrea	98	754	213	0	0	0	Sporadic cases
Malawi	87	6 153	322	1	187	10	Community transmission
Gabon	70	9 400	4 223	1	64	29	Community transmission
Benin	62	3 152	260	0	44	4	Community transmission
Sierra Leone	51	2 486	312	0	75	9	Community transmission
South Sudan	47	3 228	288	0	62	6	Community transmission
Burundi	32	761	64	1	2	0	Community transmission
Equatorial Guinea	29	5 214	3 716	0	85	61	Community transmission
Comoros	19	643	739	0	7	8	Community transmission
Seychelles	17	202	2 054	0	0	0	Sporadic cases
Mauritius	10	524	412	0	10	8	Clusters of cases
Gambia	6	3 788	1 567	0	123	51	Community transmission
Guinea-Bissau	3	2 447	1 243	0	44	22	Community transmission
Sao Tome and Principe	3	1 012	4 618	0	17	78	Community transmission
Central African Republic	0	4 936	1 022	0	63	13	Community transmission
Madagascar	0	17 587	635	0	259	9	Community transmission
United Republic of Tanzania	0	509	9	0	21	0	Community transmission

[ii] Transmission classification is based on a process of country/territory/area self-reporting. Classifications are reviewed on a weekly basis and may be revised as new information becomes available. Differing degrees of transmission may be present within countries/territories/areas. For further information, please see: Considerations for implementing and adjusting public health and social measures in the context of COVID-19:

- No (active) cases: No new cases detected for at least 28 days (two times the maximum incubation period), in the presence of a robust surveillance system. This implies a near-zero risk of infection for the general population.
- Imported / Sporadic cases: Cases detected in the past 14 days are all imported, sporadic (e.g. laboratory acquired or zoonotic) or are all linked to imported/sporadic cases, and there are no clear signals of further locally acquired transmission. This implies minimal risk of infection for the general population.
- Clusters of cases: Cases detected in the past 14 days are predominantly limited to well-defined clusters that are not directly linked to imported cases, but which are all linked by time, geographic location and common exposures. It is assumed that there are a number of unidentified cases in the area. This implies a low risk of infection to others in the wider community if exposure to these clusters is avoided.
- Community transmission: Which encompasses a range of levels from low to very high incidence, as described below and informed by a series of indicators described in the aforementioned guidance. As these subcategorizations are not currently collated at the global level, but rather intended for use by national and sub-national public health authorities for local decision-making, community transmission has not been disaggregated in this information product.
  - CT1: Low incidence of locally acquired, widely dispersed cases detected in the past 14 days, with many of the cases not linked to specific clusters; transmission may be focused in certain population sub-groups. Low risk of infection for the general population.
  - CT2: Moderate incidence of locally acquired, widely dispersed cases detected in the past 14 days; transmission less focused in certain population sub-groups. Moderate risk of infection for the general population.
  - CT3: High incidence of locally acquired, widely dispersed cases in the past 14 days; transmission widespread and not focused in population sub-groups. High risk of infection for the general population.
  - CT4: Very high incidence of locally acquired, widely dispersed cases in the past 14 days. Very high risk of infection for the general population.
- Pending: transmission classification has not been reported to WHO.

https://www.who.int/publications/m/item/weekly-epidemiological-update---22-december-2020

Province/territory	Transmission classification	Modelling type	Key indicators
Ontario (Nov 29, 2021)	Community spread	SEIR (importations likely negligible, but can be included)	Community outbreak Cases per day = 876 R_t = 1.16 Doubling time = 25 days Hospital occupancy = 312 % Delta variant = 99.9
New Brunswick (7-day rolling average ending May 31, 2021)	Suppression	SEIR with importations	Community outbreak Travel-related cases per day = 3.1 Community cases per day = 6.3 (+ other statistics for Ontario)
Nova Scotia (7-day rolling average ending May 31, 2021)	Elimination/ containment	Distinct SEIR and extended importation modelling (switch model)	Current status: community outbreak Outbreak frequency = 2/334 days Current community outbreak (began April 2021) Cases per day = 33 + other statistics for Ontario; and R_t (before NPIs), R_t (with NPIs), time to elimination Last period with no community outbreak (Jan-April 2021) (all key indicators listed for NL)
Newfoundland and Labrador (7-day rolling average ending May 31, 2021)	Elimination/ containment	Distinct SEIR and extended importation modelling (switch model)	Current status: no community outbreak Outbreak frequency = 1/334 days Current period with no community outbreak (April 2021-): Community cases per day = 1.7 Travel-related cases per day = 5.9 % Delta variant in travel-related = ? Last community outbreak (ended March 2021) (key indicators as for NS)

Province/territory	Transmission classification	Modelling type	Key indicators
PEI (28-day rolling average ending May 31, 2021)	sporadic cases/ cluster of cases	Extended importation modelling	Community cases per day = 0 Travel-related cases per day = 0.8 % Delta variant in cases = ?
Yukon (28-day rolling average ending May 31, 2021)	sporadic cases/ clusters of cases	Extended importation modelling	Community cases per day = 0.04 Travel-related cases per day = 0.04 % Delta variant in cases = ?
Northwest territories (28-day rolling average ending May 31, 2021)	sporadic cases/ clusters of cases	Extended importation modelling	Community cases per day = 2.5 Travel-related cases per day = 0 % Delta variant in cases = ?

Vaccination data would also be reported for all provinces and territories

Key indicators table for all Canadian jurisdictions

- It is unsatisfying that the key indicators (and modelling frameworks) are not the same for all jurisdictions, but maybe this is the reality…
- In the same Public Health Emergency, different Canadian jurisdictions potentially need to be supported with different key indicators, data and modelling
- This is a gap in future pandemic preparedness that needs more attention

Modelling needs

(1) Appropriate key indicators that inform situational awareness and decision-making for all Canadian jurisdictions;

(2) Counterfactual simulation framework for jurisdictions that are not experiencing community spread

(3) Theory that describes when travel measures and elimination strategies are appropriate (to inform decisions)

WHO recommendations on international travel from 2020

Recommendations for international traffic

WHO continues to advise against the application of travel or trade restrictions to countries experiencing COVID-19 outbreaks.

In general, evidence shows that restricting the movement of people and goods during public health emergencies is ineffective in most situations and may divert resources from other interventions. Furthermore, restrictions may interrupt needed aid and technical support, may disrupt businesses, and may have negative social and economic effects on the affected countries. However, in certain circumstances, measures that restrict the movement of people may prove temporarily useful, such as in settings with few international connections and limited response capacities.

Travel measures that significantly interfere with international traffic may only be justified at the beginning of an outbreak, as they may allow countries to gain time, even if only a few days, to rapidly implement effective preparedness measures. Such restrictions must be based on a careful risk assessment, be proportionate to the public health risk, be short in duration, and be reconsidered regularly as the situation evolves.

Updated WHO recommendations for international traffic in relation to COVID-19 outbreak. Feb 29 2020

Risk-assessment approach to the implementation of risk mitigation measures for international travel

National authorities should conduct thorough, systematic and regular risk assessments as new information emerges to inform the introduction, adjustment and discontinuation of risk mitigation measures in the context of international travel.

For international inbound travel, the following factors should be considered:

- the local epidemiology (8) in departure and destination countries
- the volume of travellers between countries and existing bilateral and multilateral agreements between countries to facilitate free movement
- public health and health services performance and capacity (7) to detect and care for cases and their contacts in the destination country, including among vulnerable travellers, such as refugees, migrants and temporary or seasonal workers whose livelihoods largely depend on cross-border activities
- public health and social measures implemented to control the spread of COVID-19 in departure and destination countries and available evidence on adherence and effectiveness of such measures in reducing transmission
- contextual factors, including economic impact, human rights and feasibility of applying measures.

Technical considerations for implementing a risk-based approach to international travel in the context of COVID-19 2 July 2021

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Province-level importation models are needed to support decisions to implement travel measures

Travel Ban for Those Entering Province Comes Into Effect Today

May 4, 2020 3:33 PM

The travel ban on all people arriving in Newfoundland and Labrador from outside the province comes into effect today.

The provincial government says as of today, the only people allowed in the province are:

– Residents of Newfoundland and Labrador;

– Asymptomatic workers and individuals who are subject to the updated exemption order that came into effect on April 22nd;

– People who have been permitted entry to the province in extenuating circumstances, as approved in advance by Chief Medical Officer of Health, Dr. Janice Fitzgerald.

She was denied entry for her mother's funeral. Now she's taking the N.L. government to court

Lawyer Rosellen Sullivan says government has left no choice but to go to court

CBC News · Posted: May 15, 2020 6:00 PM NT | Last Updated: May 15

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IN THE SUPREME COURT OF NEWFOUNDLAND AND LABRADOR
GENERAL DIVISION

Citation: *Taylor v. Newfoundland and Labrador*, 2020 NLSC 125
Date: September 17, 2020
Docket: 202001G2342

BETWEEN:
KIMBERLEY TAYLOR
FIRST APPLICANT
AND:
CANADIAN CIVIL LIBERTIES ASSOCIATION
SECOND APPLICANT
AND:
HER MAJESTY IN RIGHT OF NEWFOUNDLAND AND LABRADOR
FIRST RESPONDENT
AND:
JANICE FITZGERALD
SECOND RESPONDENT

[451] Based on the evidentiary record, and the uncontradicted evidence of Dr. Rahman, in particular, it is beyond argument that travel restriction is an effective means for reducing the spread of COVID-19 in Newfoundland and Labrador. The travel restriction is rationally connected to its objective.

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Intra-country COVID-19 control strategies

Research has also examined intra-country strategies. Canadian studies reported that “the Atlantic provinces (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador) and Northern Canada (Nunavut, Yukon and Northwest Territories) generally implemented a containment strategy” consistent with an “elimination” or “zero-COVID strategy” [16]. This approach demonstrated some success, with these regions reporting “long periods with no community cases” [17]. Martignoni et al. concluded that “While elimination may be a preferable strategy for regions with limited healthcare capacity, low travel volumes, and few ports of entry, mitigation may be more feasible in large urban areas with dense infrastructure, strong economies, and with high connectivity to other regions.”

Boyd et al. 2025. *Impact of Covid-19 control strategies on health and GDP growth outcomes in 193 sovereign jurisdictions*. PLOS Global Health.

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Strategies, definitions, and travel measures

Overview of Newfoundland and Labrador's Pandemic Response

The goal of Newfoundland and Labrador's pandemic response is in alignment with Canada's goal for responding to the COVID-19 pandemic,[17] which is to minimize severe illness and death due to COVID-19 while minimizing societal disruption.

Newfoundland and Labrador has an aging population as well as a high prevalence of chronic diseases; in fact, Newfoundland and Labrador's median age is the highest in Canada. As mentioned above, older adults and those with underlying medical conditions have an elevated risk of severe outcomes due to COVID-19. The provincial health care system had limited capacity to respond to a widespread COVID-19 outbreak resulting in high numbers of hospitalizations. Furthermore, the majority of communities in Newfoundland and Labrador are in rural/remote areas with limited access to health care infrastructure required to care for those severely ill with COVID-19. Therefore, in an effort to protect those in the province at increased risk and preserve health system capacity, Newfoundland and Labrador took a precautionary approach to implementing public health measures.

Prior to the Omicron wave, Newfoundland and Labrador adopted a containment approach to respond to COVID-19, which aims to minimize the risk of transmission from infected individuals to non-infected

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[17] Federal, Provincial, Territorial Public Health Response Plan for Ongoing Management of COVID-19

individuals in order to keep the number of cases as low as possible. In addition to broad sweeping public health measures at the population level, a containment approach also involves early detection of cases, tracing of close contacts, and quarantine for individuals at high risk of exposure (i.e., close contacts and travellers). The characteristics of the wild type, Alpha, Beta, Delta, and Gamma variants made a containment approach feasible for Newfoundland and Labrador.

Report to the House of Assembly on the COVID-19 pandemic. 2022. https://www.assembly.nl.ca/business/electronicdocuments/ReporttoHOACOVID-19PublicHealthEmergency2022.pdf

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Strategies, definitions, and travel measures

Public health strategy	**Description**
Elimination	Aims to reduce infection prevalence is reduced to zero locally, but not in all regions, such that there remains a risk of disease importation (Baker et al., 2020; Metcalf et al., 2021). Defined as $R_0^C < 1$. Our definition of elimination also requires that community isolation measures are sufficient to remain in place for T days, which is the condition that $U_{1[u_{1\max}]}(t) \leq U_{1\max}$ $\forall t \in [0, T]$.
Suppression	Aims to reverse epidemic growth (Ferguson et al., 2020) and bring the number of cases down to a low-level (Heywood and MacIntyre, 2020; James et al., 2020), noting that community transmission may still take place (Wu et al., 2021; Baker et al., 2020; Heywood and MacIntyre, 2020). Defined as $R_0^C < 1$ and $U_{1[u_{1\max}]}(t) \leq U_{1\max} \forall t \in [0, T]$. Note that given our deterministic model formulation, we cannot distinguish between elimination and suppression.
Mitigation	Aims to slow the spread of an infectious disease to avoid overwhelming healthcare capacities and to reduce overall morbidity and mortality (Baker et al., 2023; Wu et al., 2021). Defined as control measures do not reverse epidemic growth, $R_0^C \geq 1$. Our definition of mitigation also requires that community isolation measures are sufficient to remain in place for T days, which is the condition that $U_{1[u_{1\max}]}(t) \leq U_{1\max} \forall t \in [0, T]$.

Strategies, definitions, and travel measures

Local elimination does not guarantee that a pathogen is eradicated; the pathogen may be reintroduced from a range of sources [7], including importation from another location [8], recrudescence in a previous case [9], or zoonotic spillover [10, 11]. Furthermore, the feasibility of alternative strategies will be situation-dependent: elimination may not be feasible in jurisdictions that have large volumes of uncontrolled border traffic, extensive land borders, or under-resourced public health systems [12].

Plank et al. 2025. Joint economic and epidemiological modelling of alternative pandemic response strategies. Preprint https://arxiv.org/pdf/2512.08355

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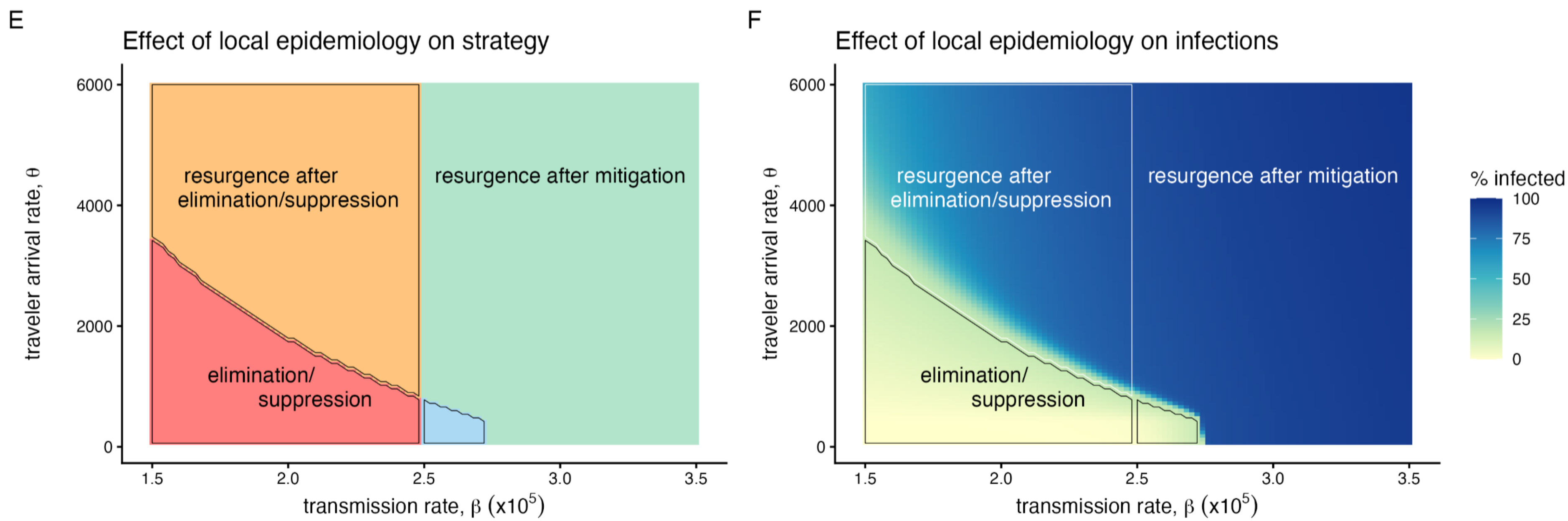
Martignoni et al. 2024. Is SARS-CoV-2 elimination or mitigation best? Regional and disease characteristics determine the best strategy. Royal Society Open Science

Should an elimination strategy be implemented?

	1	2	3
questions	**Is it necessary to ensure health care provision?** Is the rapid implementation of severe restrictions after outbreak detection necessary to ensure that the number of cases remains below the health care capacity?	**Is it epidemiologically feasible?** Can rates of travel-related infections be low enough to ensure disease-free periods between outbreaks?	**Is it cost effective?** Is the cost of implementing efficient travel-related measures low? Is the cost of treating infections high?
key regional and disease characteristics	* low resource capacity (e.g. low hospital, contact tracing or testing capacities) * high hospitalization or death rates	* strict travel measures are attainable due to geographic, jurisdictional and societal characteristics * high disease detection efficiency * fast and efficient response for outbreak control	* low cost of implementing travel-related measures (e.g. low travel volumes, few port of entries, low economic dependence on imports) * high cost of infections
relevant quantities	– detection delay and maximal disease prevalence (T_d and I_{max}) – health care capacity – proportion of reported cases hospitalized	– outbreak frequency (T_i) – disease prevalence at implementation and relaxation of strict community NPIs (I_{start}, I_{max} and I_{end}) – speed of decline in disease prevalence when NPIs are implemented (T_e)	– relative cost of implementing travel-related restrictions to the cost of community restrictions – relative cost of travel-related measures to the cost of treating infections

Adu-Boahen et al. *An optimal control model to show the effectiveness of pandemic response strategies should be interpreted within the regional context*. In prep.



Adu-Boahen et al. *An optimal control model to show the effectiveness of pandemic response strategies should be interpreted within the regional context*. In prep.

- In Peng et al. (2023), Canada and Australia are described as peer-countries due to similarity in 'income, culture and governance' but are noted to differ in that Australia implemented an elimination strategy, while Canada implemented a mitigation strategy.

- Peng et al. (2023) conclude that 'a comparison with Australia demonstrated that an elimination focus would have saved Canada tens of thousands of lives as well as substantial economic costs'.

- However, we know that elimination may not be possible (Martignoni et al., 2024) or optimal (Figure 2) in regions with a high importation rate and Canada differs substantially from Australia in this respect.

Peng A, Simmons A, Amoako A, Tuite A, Fisman D. Relative pandemic severity in Canada and four peer nations during the SARS-CoV-2 pandemic. Canada Communicable Disease Report. 2023;49(5):197.

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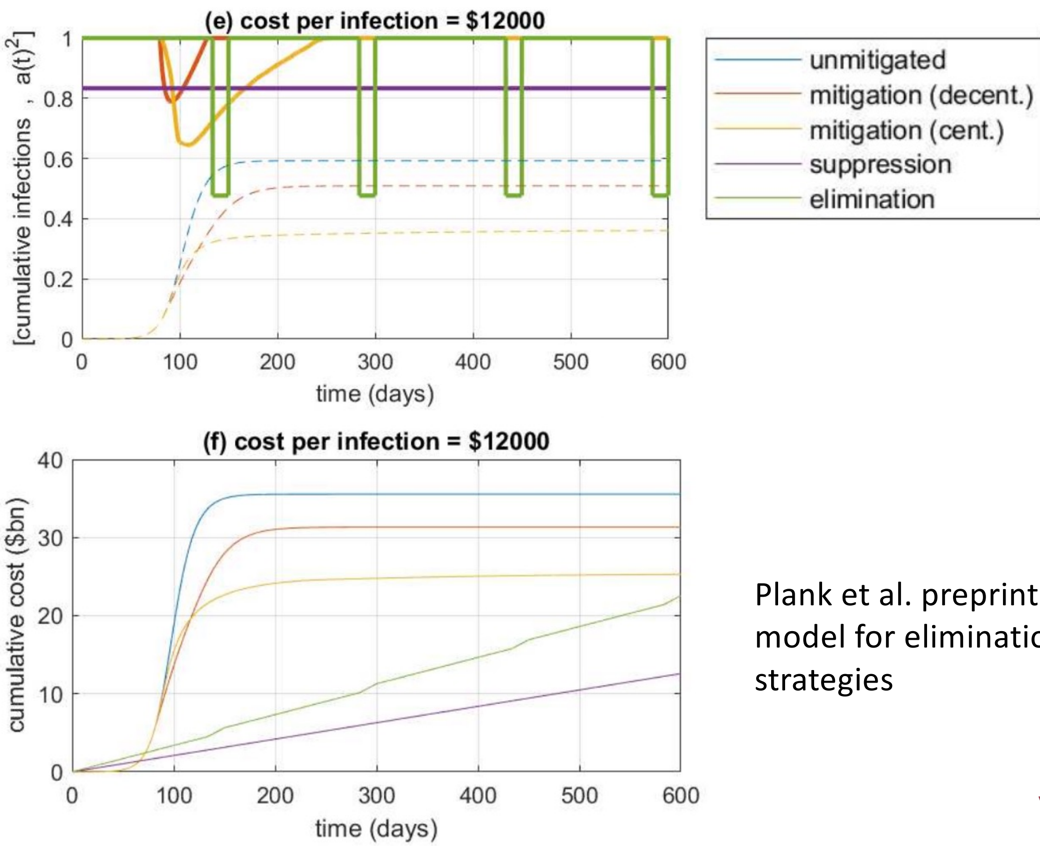
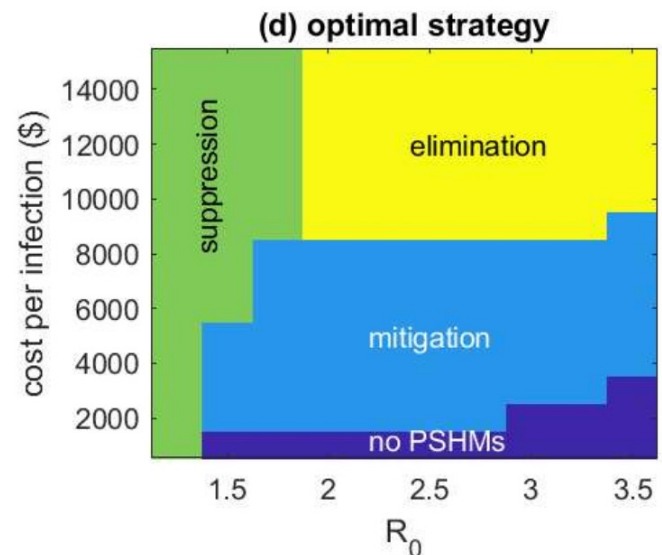
Plank et al. 2025. *Joint economic and epidemiological modelling of alternative pandemic response strategies*. https://arxiv.org/pdf/2512.08355





Plank et al. preprint uses a different model for elimination than for the other strategies

Parameter	Value
Transmission rate	$\beta = 0.25 - 0.7$ day^{-1}
Recovery rate	$\gamma = 1/5$ day^{-1}
Population size	$N = 5 \times 10^6$
Average cost per infection	$k = \$1000 - \$15000$
Contact reduction cost per person per unit time (linear)	$c_1 = \$46$ day^{-1}
Contact reduction cost per person per unit time (quadratic)	$c_2 = \$36$ day^{-1}
Border closure cost per unit time	$b = \$33.8$ million day^{-1}
Border-related outbreak frequency	$r = 1/150$ day $^{-1}$
Multiplicative effect of TTI measures on transmission	$\alpha = 0.8$
Time to detection of border-related outbreaks	$t_{\text{det}} = 14$ days
Proportion of economy restricted to control border-related outbreaks	$p_{\text{cont}} = 0.4$

Table 1: Parameter values. See Supplementary Material sec. 3 for further information. All costs are in New Zealand dollars (NZD).

Plank et al. 2025. Joint economic and epidemiological modelling of alternative pandemic response strategies. Preprint https://arxiv.org/pdf/2512.08355

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Conclusions

- Healthcare decision-making in Canada is decentralized so the majority of decisions during the pandemic occurred at the provincial- and territorial-level

- The provinces and territories are very different, and can have different data and modelling needs even concurrently during the same public health emergency

- This is Canada's area to lead in

Acknowledgements

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