AFTER THE PANDEMIC

WHAT'S NEXT?

- **BUILDING CAPACITY IN MECHANISTIC MODELLING**
- **SUPPORTING REGIONAL NEEDS**
- **ESTIMATING KEY QUANTITIES**
- **BUILDING RELATIONSHIPS**

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BUILDING CAPACITY IN MECHANISTIC MODELLING

Mechanistic model (epidemiology):

- A mathematical or computer simulation model that describes the ***processes*** of infectious disease spread. For example, transmission, recovery, and control measures.
- Types: mathematical compartmental models or agent-based models
- Distinct from statistical models in:
  - Emphasizing biological realism in describing processes (rather than variables and prediction)
  - That many parameters are independently estimated

INDEPENDENTLY ESTIMATED PARAMETERS

COVID-19 Epidemiological and Modelling Parameters Report - April 15th, 2020

Current to Daily Scan of April 13th, 2020 (citations added since report of April 8th marked in blue text; citations with updated values since report of April 8th marked in red text)

References within this report are taken from the Daily Scan of COVID-19 Scientific Publications (contact: lisa.waddell@canada.ca)
> Foci included in data extraction: Epidemiological; Clinical Data; and Modelling/Prediction
> Data extracted by Public Health Risk Sciences Division | NML | PHAC
>> Inquiries related to the enclosed tables are to be directed to ainsley.otten@canada.ca

Notes of Caution: N
19. These works, if
evolve beyond the
have been reviewe
This report is not a

Interpret With Caution (IWC) - noted in the table to indicate data is extracted and the researcher has assumed it is a reasonable proxy of the parameter at this time.

Parameter	Units	Description	Cau
Basic Reproduction Number, R_0 *	-	The basic reproduction number (R_0) is defined as the average number of secondary cases caused by a single infectious individual in a totally susceptible population.	
Case Number Doubling Time	days	Time it takes for the number of cases to double.	
Case Fatality Rate (CFR)	%	Number of deaths divided by the number of cases for a certain period of time.	Tra be The
Serial interval*	days	Serial interval describes the duration of time between the onset of symptoms in a primary case and the onset of symptoms in a secondary case infected by the primary case.	
Incubation period*	days	The incubation period represents the time period between the occurrence of infection (or transmission) and the onset of disease symptoms.	
Latent period*	days	The latent period is definied as the period of time between the occurrence of infection and the onset of infectiousness	
Infectious Period	days	The time during which an infected person can transmit an infectious agent to another person. May also be referred to	In n extr
Proportion asymptomatic but infective*	%	Proportion of cases in which the infected individual does not and will not exhibit symptoms, but are capable of infecting others.	Ma Val ass
Proportion Hospitalized	%	Proportion of cases admitted to hospital divided by total number of cases	Par

Definitions sourced/amended from:

* - Moghadas, S. and Milwid, R. Glossary of Terms for Infectious Disease Modelling. National Collaborating Centre for Infectious Diseases. 2016. Available at: https://nccid.ca/publications/glossary-terms-infectious-disease-moc

About | R_0 | Doubling Time | CFR | Serial Interval | Incubation Period | La | +

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INDEPENDENTLY ESTIMATED PARAMETERS

COVID-19 Epidemiological and Modelling Parameters Report - April 15th, 2020

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Incubation Period (days)

Author	Title	MLV	Plausible Range	N	Population	Location
Chen, L., Lou, J., Bai, Y., et al	COVID-19 Disease With Positive Fecal and N	6		1	Clinically Confirmed (fecal sample +)	Wuhan
Fan, C., Lei, D., Fang, C., et al	Perinatal Transmission of COVID-19 Associa	7		Case 1	Two confirmed cases during third trimester of pregnancy	Wuhan
Liang, J. & Yuan, H.	The impacts of diagnostic capability and pre	5.57	2.67 - 7.95 (95% CI)		confirmed cases	Wuhan
Sun, D., Li, H., Lu, X.X., et al	Clinical features of severe pediatric patients		5 - 10	4	Confirmed severe pediatric cases (family cluster and single nosocomial cas	Wuhan
Zhang, B., Zhou, X., Qiu, Y., et	Clinical characteristics of 82 death cases wit	7	5 - 10	7	Hospitalized confirmed cases	Wuhan
Zhang, l., wan, k., chen, j., et a	When will the battle against novel coronavir	3		(modelled)	confirmed cases	Wuhan
Lin, Y., Ji, C., Weng, W., et al	Epidemiological and Clinical Characteristics c	7	5 - 10	124	Confirmed and suspected elderly outpatient cases	Wuhan
Lin, Y., Ji, C., Weng, W., et al	Epidemiological and Clinical Characteristics c	7	5 - 10	60	Confirmed and suspected elderly outpatient cases, male	Wuhan
Lin, Y., Ji, C., Weng, W., et al	Epidemiological and Clinical Characteristics c	7	4.75 - 9	64	Confirmed and suspected elderly outpatient cases, female	Wuhan
Li,Q.;Guan,X.;Wu,P.;Wang,X.;	Early Transmission Dynamics in Wuhan, Chi	5.2	4.1 - 7.0 (95% CI)	10	first 425 confirmed cases in Wuhan	Wuhan
Xie, M., Tian, J., Hun, M., et a	Analysis of Epidemiological and Clinical Char	6.78		9	Confirmed children cases	Wuhan
Jiang, X., Rayner, S. & Luo, M	Does SARS-CoV-2 has a longer incubation p	4.9	4.4 - 5.5 (95%CI)	50	Confirmed cases	Wuhan
Bao, H., Fang, Y., Lai, Q., et al	Comprehensive Comparisons to Demonstra	5	4 - 7.75 (IQR)	101	Confirmed hospitalized cases, All patients	Wuhan
Bao, H., Fang, Y., Lai, Q., et al	Comprehensive Comparisons to Demonstra	4	3.25 5.25 (IQR)	12	Confirmed hospitalized cases, Severe cases	Wuhan
Bao, H., Fang, Y., Lai, Q., et al	Comprehensive Comparisons to Demonstra	5	4 7.75 (IQR)	89	Confirmed hospitalized cases, Mild cases	Wuhan
Lytras, T., Panagiotakopoulo:	Estimating the ascertainment rate of SARS-C	4.38	4.34 - 4.41 (95% CI)	49948	confirmed cases	Wuhan
Zhou, F., Yu, X., Tong, X., et al	Clinical features and outcomes of 197 adult	6.14	(SD±9.27)	283	confirmed hospitalized cases who were discharged from hospital	Hubei
Ai, J., Chen, J., Wang, Y., et al	The cross-sectional study of hospitalized co	8.09 (SD±4.99)	1 - 20	44	Hospitalized confirmed cases	Hubei
Linton, N.M., Kobayashi, T., \	Incubation Period and Other Epidemiologica	5	4.2 - 6.0 (95% CI)	52	Cases diagnosed outside of Wuhan excluding Wuhan residents	China (except Wuhan)
Linton, N.M., Kobayashi, T., \	Incubation Period and Other Epidemiologica	5.6	5 - 6.3 (95% CI)	158	Cases diagnosed outside of Wuhan including Wuhan residents	China (except Wuhan)
Han, H.	Estimate the incubation period of coronavir	5.84	(SD ± 2.93)	59	confirmed, chain-of-infection	China (except Hubei)
Han, H.	Estimate the incubation period of coronavir	6.73	(SD ± 3.20)	32	confirmed, chain-of-infection, >=40 years old	China (except Hubei)
Han, H.	Estimate the incubation period of coronavir	4.84	(SD ± 2.28)	25	confirmed, chain-of-infection, <40 years old	China (except Hubei)
Miao, C., Zhuang, J., Jin, M., e	A comparative multi-centre study on the clir	7	3 - 9	62	Confirmed and suspect cases (incubation period based on confirmed case	China (except Hubei)
Sanche, S., Lin, Y.T., Xu, C., et	High Contagiousness and Rapid Spread of S	4.2	3.5 - 5.1 (95% CI)	24 case reports	publicly available case reports, 140	China (except Hubei, r
Leung, C.	The difference in the incubation period of 2(	1.8	1 - 2.7	175	Confirmed case in travelers to Hubei	China (excluding Hub
Leung, C.	The difference in the incubation period of 2(	7.2	6.1 - 8.4	175	Confirmed case in non-travelers to Hubei	China (excluding Hub
Lauer,Stephen A.;Grantz,Kyra	The incubation period of 2019-nCoV from p	5.2	4.4 - 6.0 (95% CI)	101	Confirmed cases	China (except Hubei)
Li, M., Chen, P., Yuan, Q., et a	Transmission characteristics of the COVID-1	7.2	(SD ± 4.11)	(modelled)	Confirmed cases	China (except Hubei)
Sanche,Steven;Lin,Yen Ting;X	The Novel Coronavirus, 2019-nCoV, is Highl	4.2	3.5 - 5.1	140	first case reports in Chinese provinces other than Hubei	China
Leung, C.	Estimating the distribution of the incubatior	1.8	1 - 2.7	152	Travelers to Hubei and non-travellers	China
Leung, C.	Estimating the distribution of the incubatior	6.9	5.5 - 8.3	152	Non-travellers to Hubei	China
Backer,Jantien A.;Klinkenberg	The incubation period of 2019-nCoV infecti	6.4	5.6 - 7.9 (95% CI)	88	Travellers from Wuhan with confirmed COVID-19	China
Guan, W., Liang, W., Zhao, Y.,	Comorbidity and its impact on 1,590 patien	3.6	0 - 7.8	1590	Hospitalized confirmed cases	China
Guan, W., Liang, W., Zhao, Y.,	Comorbidity and its impact on 1,590 patien	3.7	0 - 8	1191	Hospitalized confirmed cases, patients without comorbities	China
Guan, W., Liang, W., Zhao, Y.,	Comorbidity and its impact on 1,590 patien	3.5	0 - 7.4	399	Hospitalized confirmed cases, patients with comorbidities	China
Liu,Tao;Hu,Jianxiong;Kang,M	Transmission dynamics of 2019 novel coror	4.8 (±2.2)	2 - 11		confirmed cases	China
Guan,Wei-jie;Ni,Zheng-yi;Hu,	Clinical characteristics of 2019 novel corona	3	0 - 24	1099	patients with laboratory-confirmed cases from 552 hospitals	China

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MECHANISTIC MODELLING FOR PANDEMIC PREPAREDNESS

- Support decisions on resource needs for "hypothetical-yet-plausible" future pandemics
- Ready-to-go methods that can be adapted and used for long-range forecasting and to explore scenarios to support public health decisions on the use of interventions

Ogden NH et al. ***Mathematical modelling for pandemic preparedness in Canada: Learning from COVID-19***. Can Commun Dis Rep 2024;50(10):345–56.
https://doi.org/10.14745/ccdr.v50i10a03

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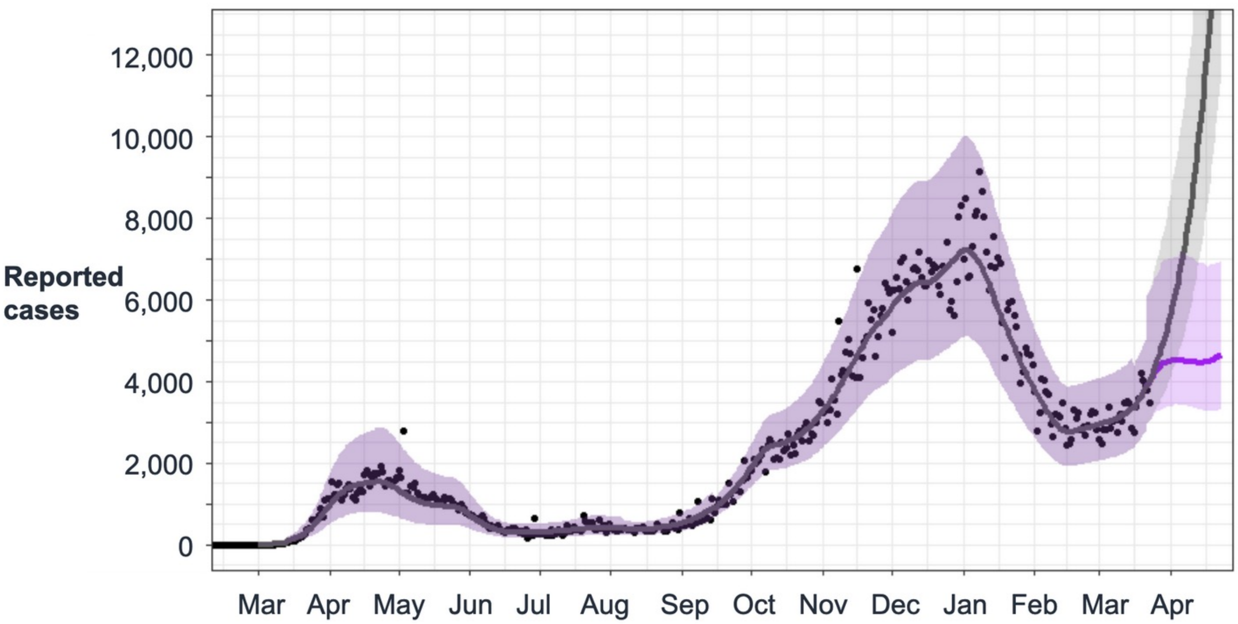
MECHANISTIC MODELS

PHAC report involving `McMasterPandemic`

Longer-range forecast shows stronger public health measures will be required to counter more transmissible variants of concern



With **spread** of VOCs **and** we **maintain or increase** the current number of people we contact each day

If VOCs are controlled by **reducing** the current number of people we contact each day

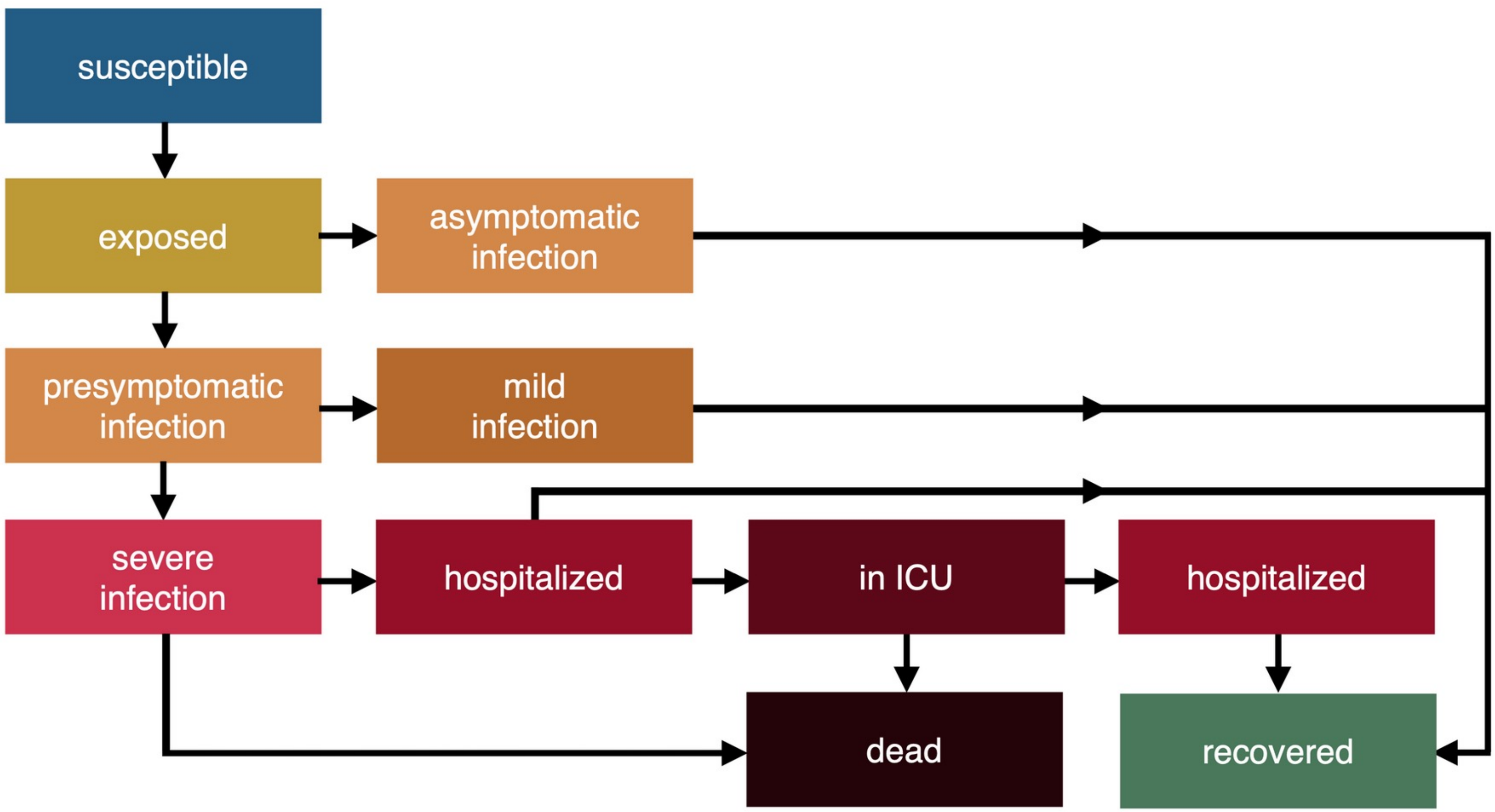
Data as of March 24, 2021
Note: *Ensemble of output from PHAC-McMaster and Simon Fraser University models*

The PHAC McMaster forecast is based on current estimates transmission rates fitted to reported cases. It assumes VOCs are introduced in mid-Dec (~1 week prior to first detected case in Canada) at very low prevalence; VOCs (all VOCs known to date) are 50% more transmissible than wild-type; growth rate AND replacement rate are negatively correlated with the strength of public health measures. Proportion of VOC is obtained by a combination of calibrating to surveillance data as well as information on proportions of cases that are VOC. Recent changes in testing rates are not taken into account in this forecast. SFU methods are at https://www.sfu.ca/magpie/blog/variant-simple-proactive.html

Slide by Steve Walker (https://canmod.github.io/macpan2/)

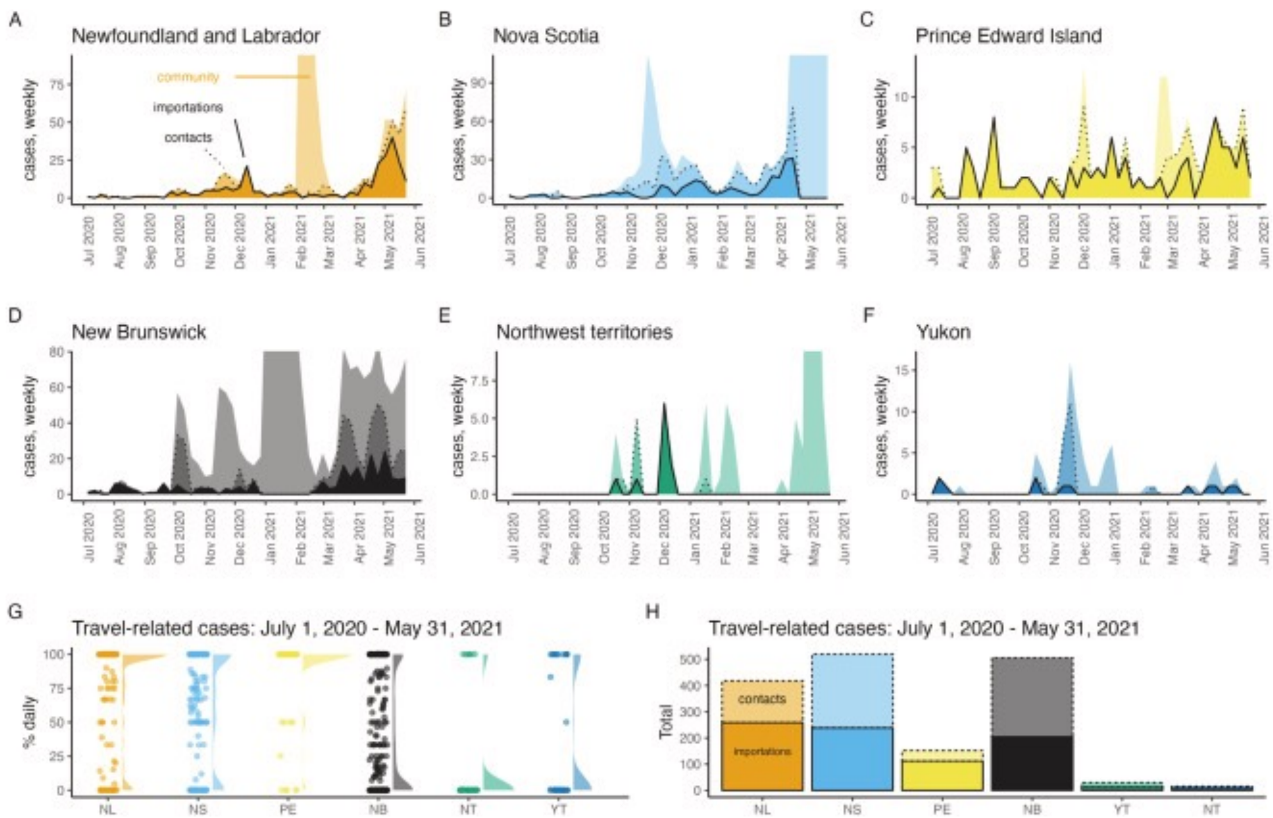
MECHANISTIC MODELS

McMasterPandemic COVID-19 (Mechanistic) Model



Slide by Irena Papst/Steve Walker (https://canmod.github.io/macpan2/)

SUPPORTING REGIONAL NEEDS



Daily % travel-related (median)	
NL	100
NS	80
PE	100
NB	13
NT	0
YT	0

"Small jurisdictions problems are **different**, harder and under-served"

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

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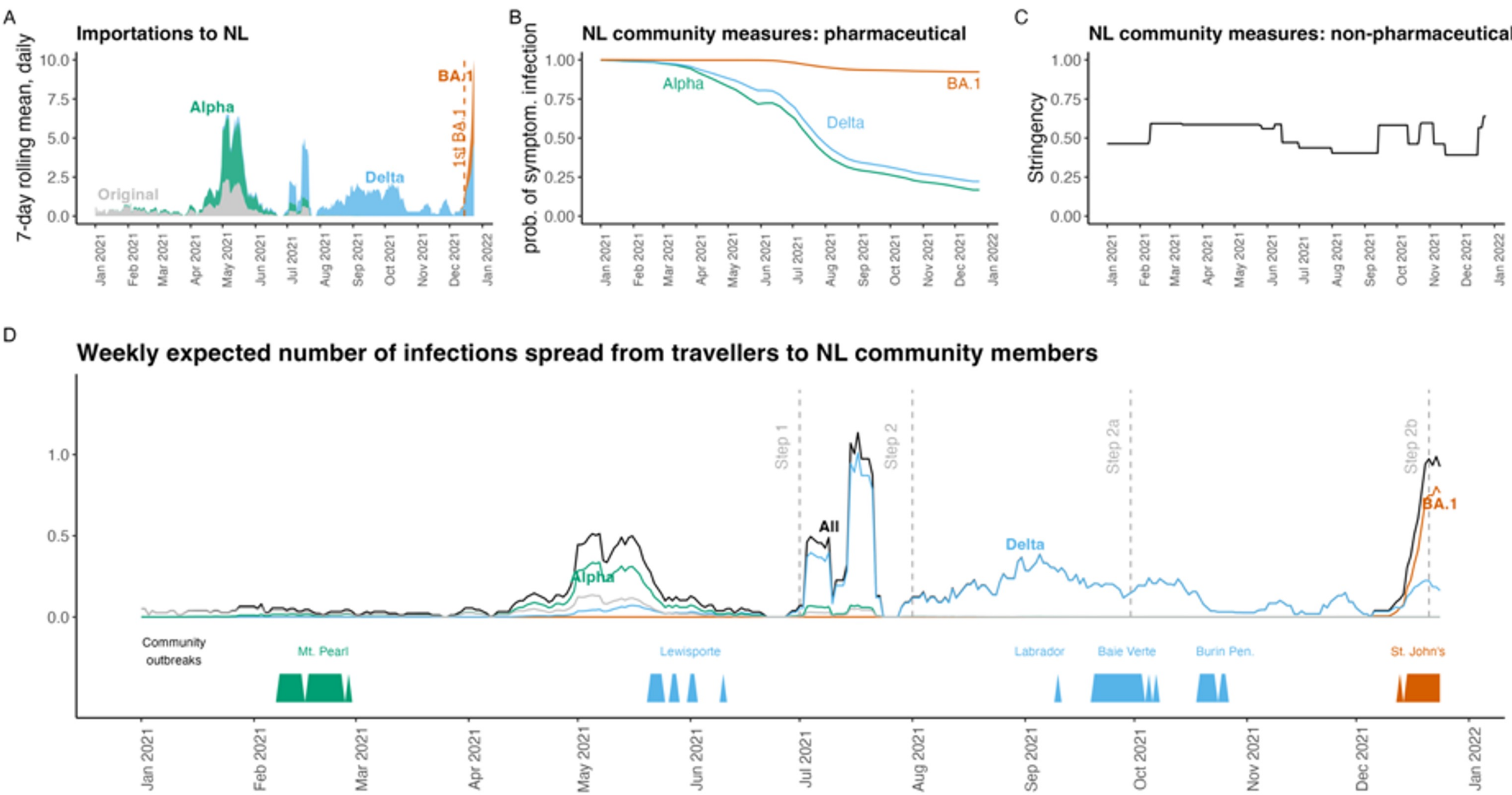
SUPPORTING REGIONAL NEEDS



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

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SUPPORTING REGIONAL NEEDS

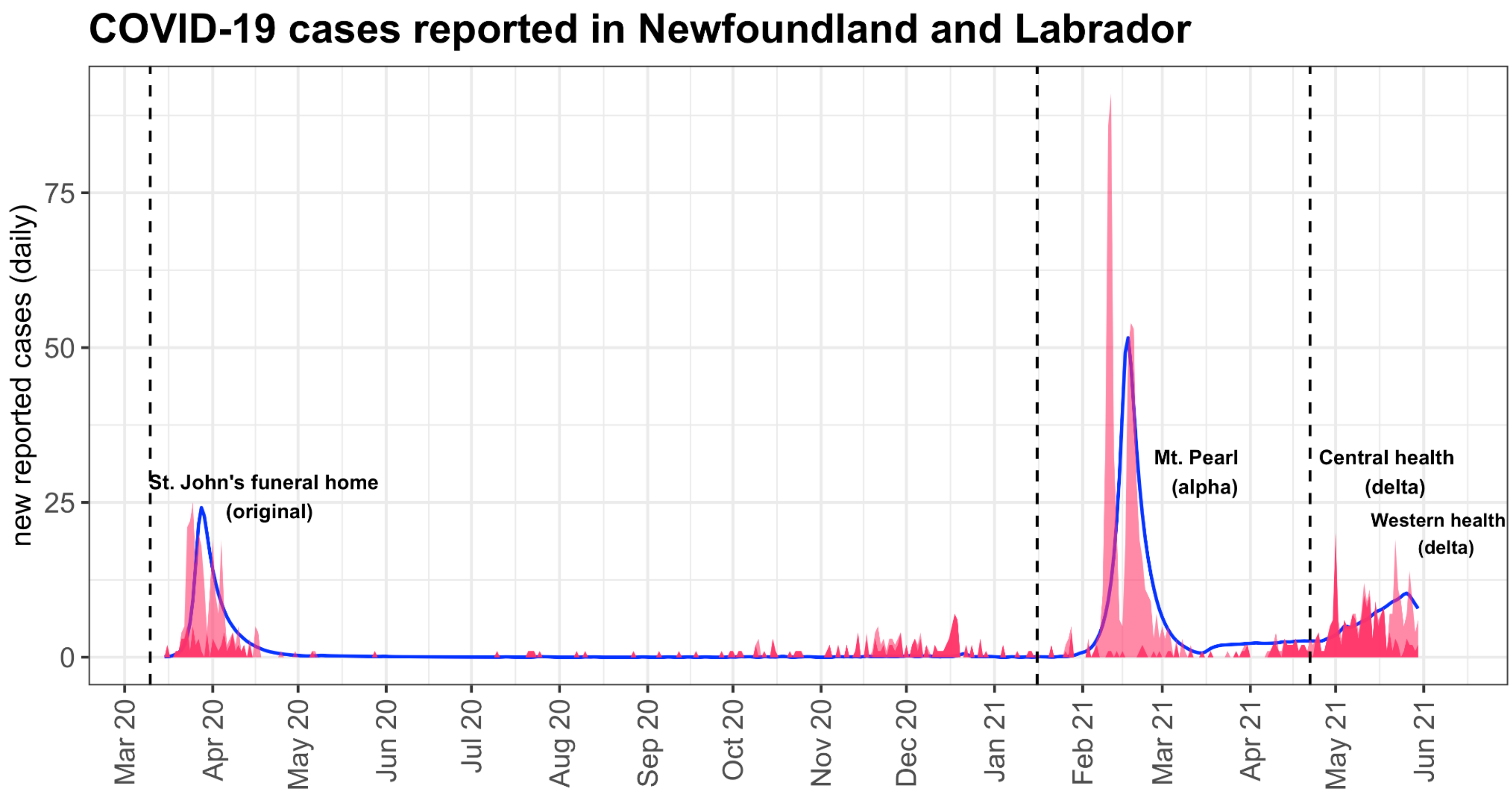

Figure by Zahra Cook (Mohammadi) with Steve Walker

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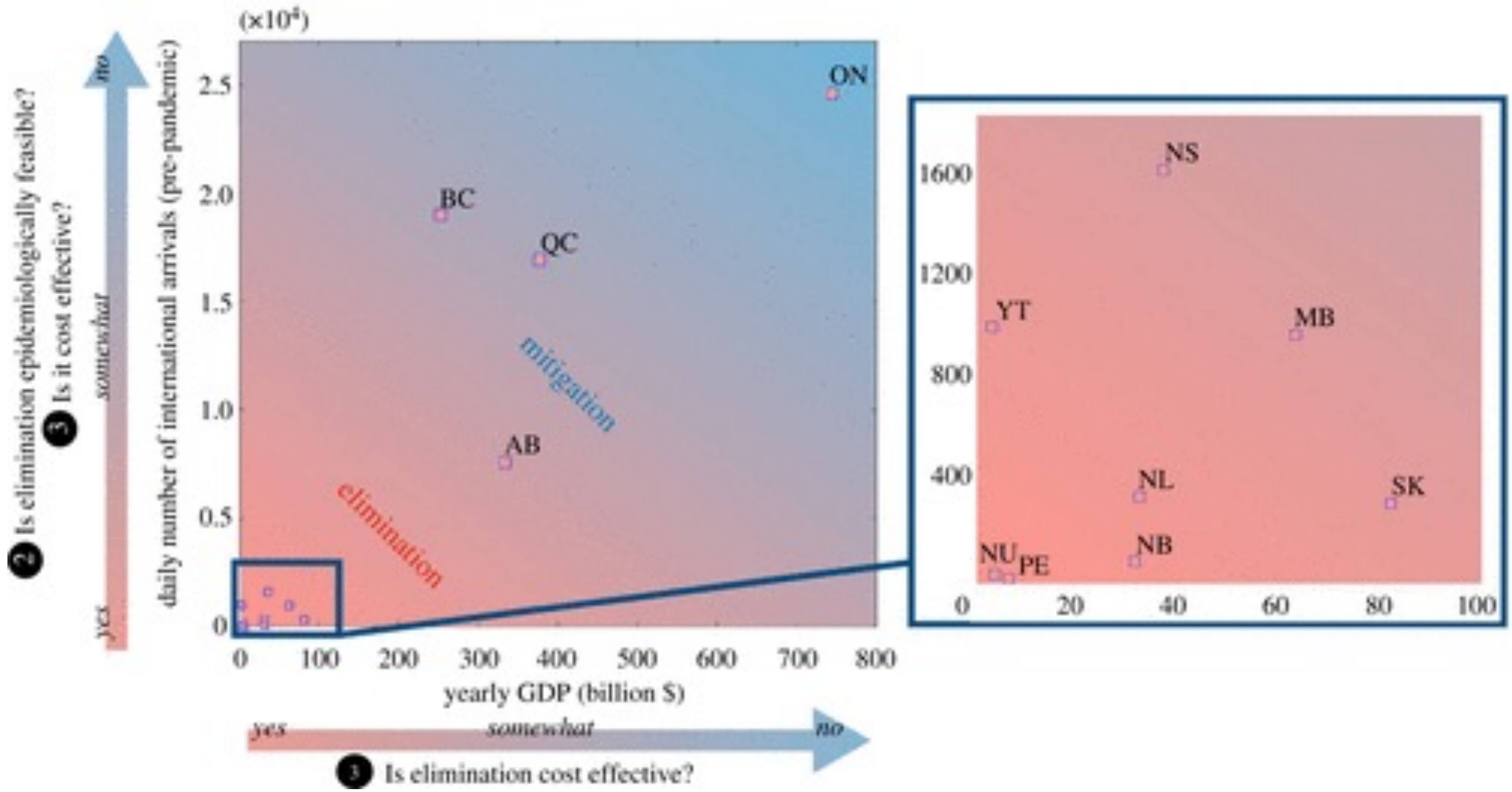
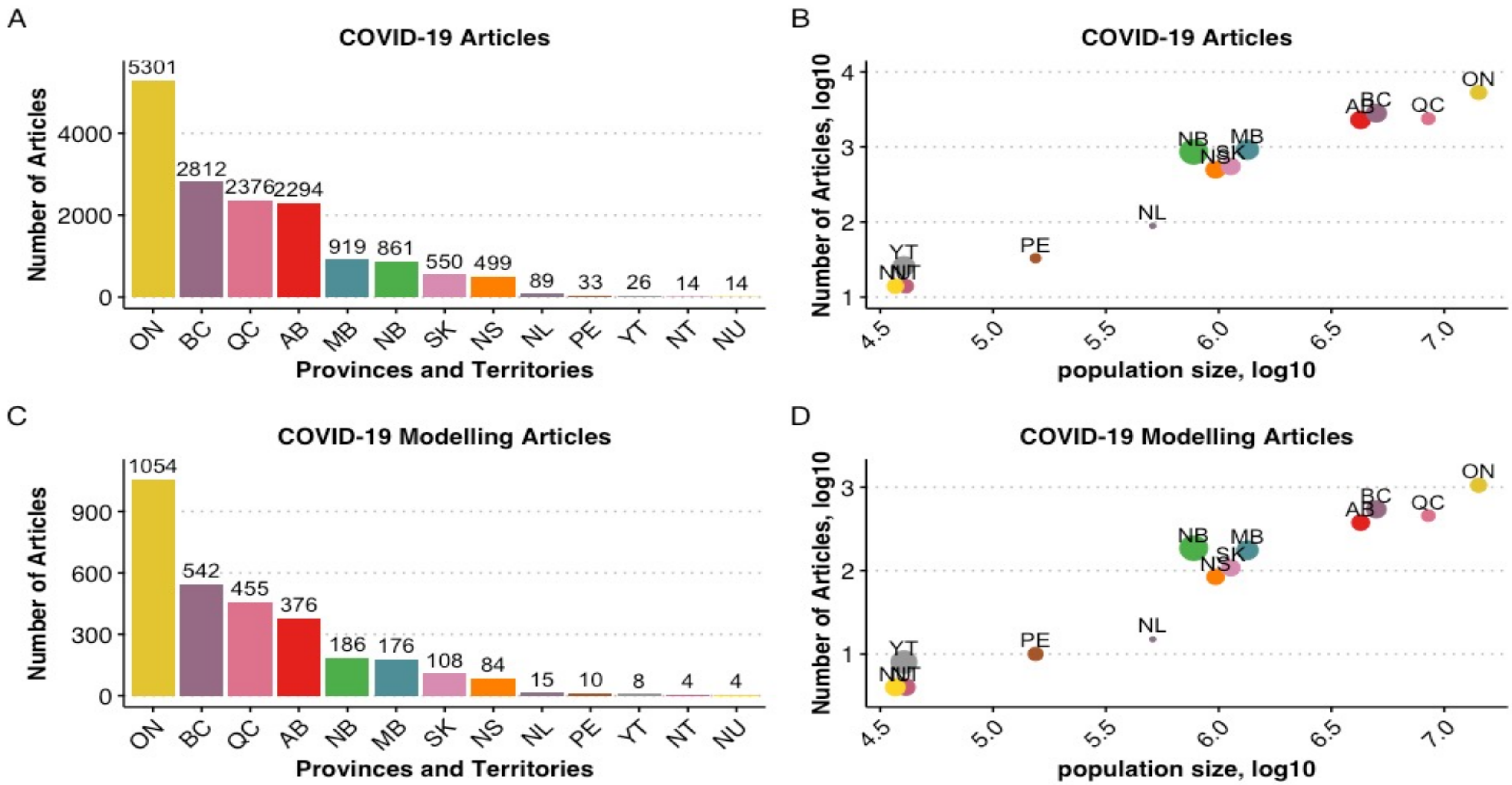
SUPPORTING REGIONAL NEEDS



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

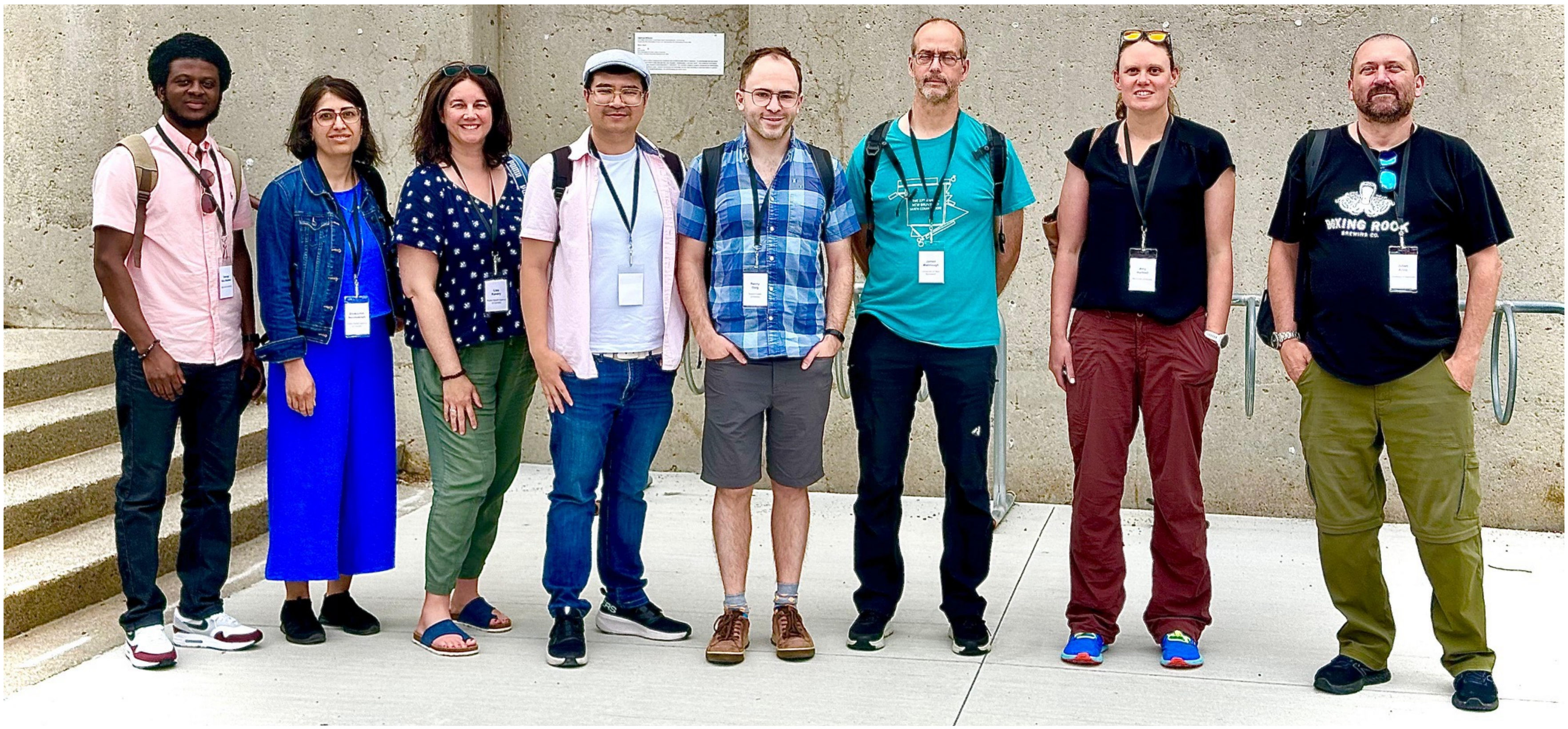
SUPPORTING REGIONAL NEEDS



"Small jurisdictions problems are different, harder and **under-served**"

Figure by Francis Anokye

CANADIAN SMALL JURISDICTIONS GROUP



With both large and small jurisdictions Canada can be a leader in describing the role of regional heterogeneity in pandemic preparedness

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SUPPORTING REGIONAL NEEDS

Call to Action 55. All levels of government provide reports and data to the National Council for Reconciliation:

iii. The income and educational attainments of Aboriginal peoples in Canada compared to non-Aboriginal peoples.

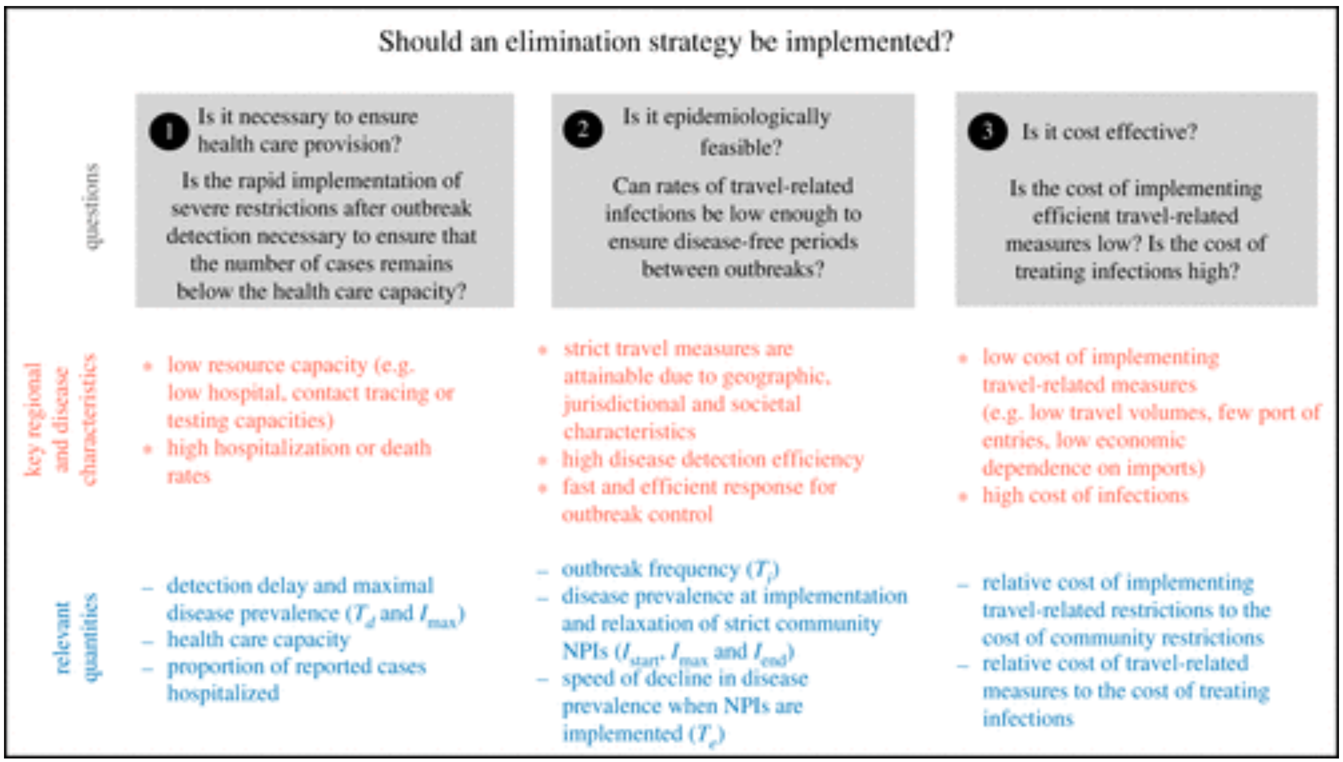
iv. Progress on closing the gaps between Aboriginal and non-Aboriginal communities in a number of health indicators such as: infant mortality, maternal health, suicide, mental health, addictions, life expectancy, birth rates, infant and child health issues, chronic diseases, illness injury and incidence, and the availability of appropriate health services

"Small jurisdictions problems are different[2], harder and under-served"
(different from large jurisdictions and different from each other)

Final report of the Truth and Reconciliation Commission of Canada. Volume One: Summary. 2015

SUPPORTING REGIONAL NEEDS

Our modelling to understand the role of regional heterogeneity aims to support sovereignty in decision-making



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

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SUPPORTING REGIONAL NEEDS

Memorial University: Maria Martignoni, Proton Rahman, J.C. Loredo-Osti, Zahra Mohammadi (Cook), Francis Anokye, George Adu-Boahen

PHAC: Michael Li, Lisa Kanary

McMaster University: Steve Walker

University of Manitoba: Julien Arino

University of New Brunswick: James Watmough

Others: Brian Gaas (Govt. of Yukon), Bilal Saleh Husain (UNB), Renny Doig (SFU), Amin Afshari (Memorial U), Shokoofeh Nourbakhsh (PHAC), Rania Wasfi (PHAC), Ashleigh Tuite (NACI), Steve Guillouzic (DND), Erin Rees (PHAC), Valerie Honogh (PHAC)

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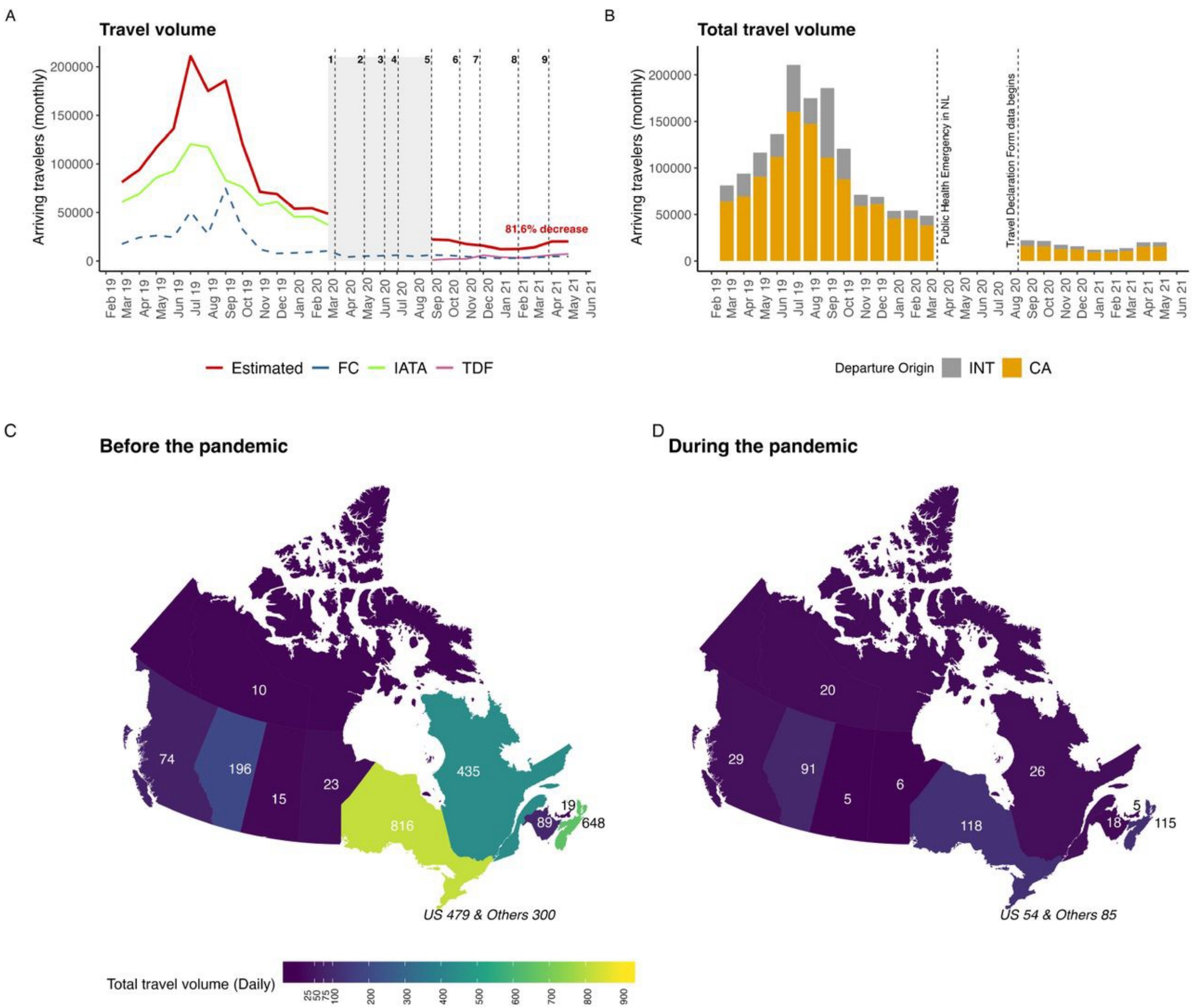
ESTIMATING KEY QUANTITIES

Analysis of pandemic data:

- Travel measures
- Contact tracing
- Non-pharmaceutical interventions

ESTIMATING KEY QUANTITIES



Travel to NL during the pandemic decreased by 82%

Mohammadi et al. Importation models for SARS-CoV-2 cases reported in Newfoundland and Labrador during the COVID-19 pandemic. Under review

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ESTIMATING KEY QUANTITIES

Table 1 Limitations of travel volume data sources. International Air Transport Authority (IATA, $s = 1$), Travel Declaration Forms (TDF, $s = 2$), and Frontier Counts (FC, $s = 3$) report an origin (either Canada or international), but report travel volumes that exclude some travelers that might spread infections to NL residents. When exclusions or exemptions apply to particular travel modes (air, sea, or land) or traveler types (i.e., crew or NL residents) the value of the exclusions indicator variable, $\mathbb{1}_{\text{MODES}}$ or $\mathbb{1}_{\text{TYPE}}$, is 1; and 0 if this exemption does not apply. These indicator variables appear in equation (A1), and the magnitude of the correction for the exclusion is given in Table A1 (see the Supplementary Information, Section A). The travel origin in TCAR reports ($s = 4$) was not reported, but the information in these reports was used to estimate the magnitude of the exclusions for the other data sources.

s	Data Source	Time frame, t	Pandemic	Travel modes excluded	$\mathbb{1}_{\text{MODES}} =$	Origin	Traveler type exclusions	$\mathbb{1}_{\text{TYPE}} =$
1	International Air Transport Authority (IATA)	Jan 2019 - March 2020 (monthly)	before	land, sea	1	Canada and International	Canadian crew	1 if Canada, 0 if International
2	Travel Declaration Forms (TDF)	Sep 2020 - May 2021 (daily)	during	none	0	Canada and International	NL residents, crew, and other exempt travelers	1
3	Frontier Counts (FC)	Jan 2019 - May 2021 (monthly)	before and during	none	0	International	None	0
4	Department of Tourism, Culture, Arts, and Recreation (TCAR)	Jan 2019 - Dec 2021 (monthly)	before and during	none	N/A	Unknown	NL residents	N/A

ESTIMATING KEY QUANTITIES

Table 2 Federal (Canada) and provincial (Newfoundland and Labrador) travel measures from September 2020 to May 2021 (Canadian Institute for Health Information, 2022). 'Line' corresponds to the numbering in Fig. 2A.

Line	Dates	Measure	Level
1	2020-03-13	Cruise ship season postponed	Fed
	2020-03-14	14-day self-isolation required for individuals returning from international travel	Prov
	2020-03-20	14-day self-isolation required for individuals returning from out-of-province travel	Prov
2	2020-05-04	Travel declaration forms and self-isolation plan required for non-NL resident entry to NL	Prov
3	2020-06-09	Relaxation of travel measures for foreign nationals with immediate family in Canada	Fed
4	2020-07-03	Atlantic bubble: No self-isolation requirement for residents of P.E.I., N.B. and N.S.	Prov
5	2020-08-31	Relaxation of travel measures for non-Atlantic Canada residents who own a second home or cabin in NL	Prov
6	2020-10-20	Relaxation of travel measures for international students attending institutions with a COVID-19 readiness plan	Fed
7	2020-11-26	Atlantic bubble suspended	Prov
8	2021-02-01	All international passenger flights must land either at the Vancouver, Calgary, Toronto or Montréal airports	Fed
9	2021-03-27	Passengers on provincial ferries limited to 50% of capacity	Prov

ESTIMATING KEY QUANTITIES

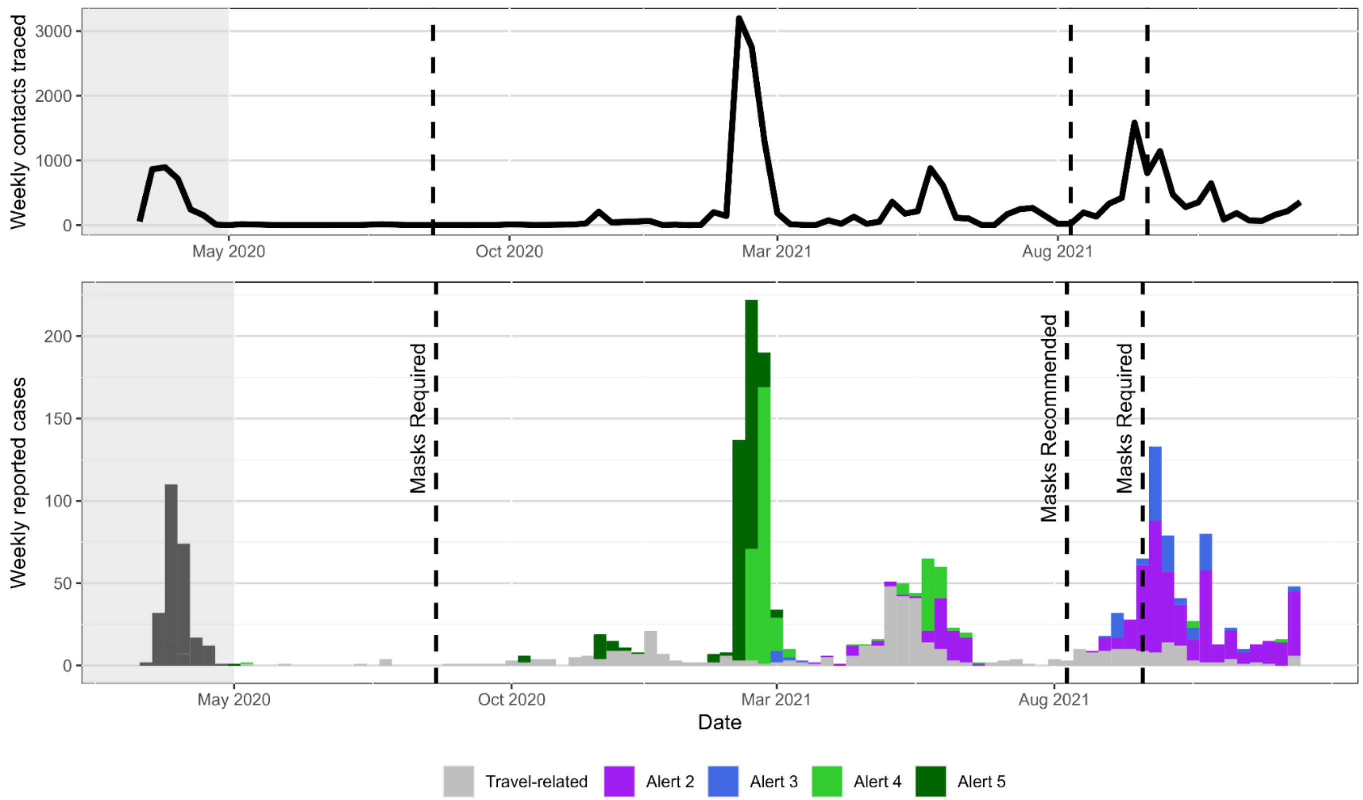

Table 1 Numerical summaries of contact tracing during focal period

	Overall	Alert 2	Alert 3	Alert 4	Alert 5
Contacts traced	19269	5740	1484	3199	6004
Cases reported	1522	484	137	349	342
Max. contacts traced in a week	4645	1217	406	996	4645
Mean contacts traced per person	12.5	11.9	10.8	9.17	17.6

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

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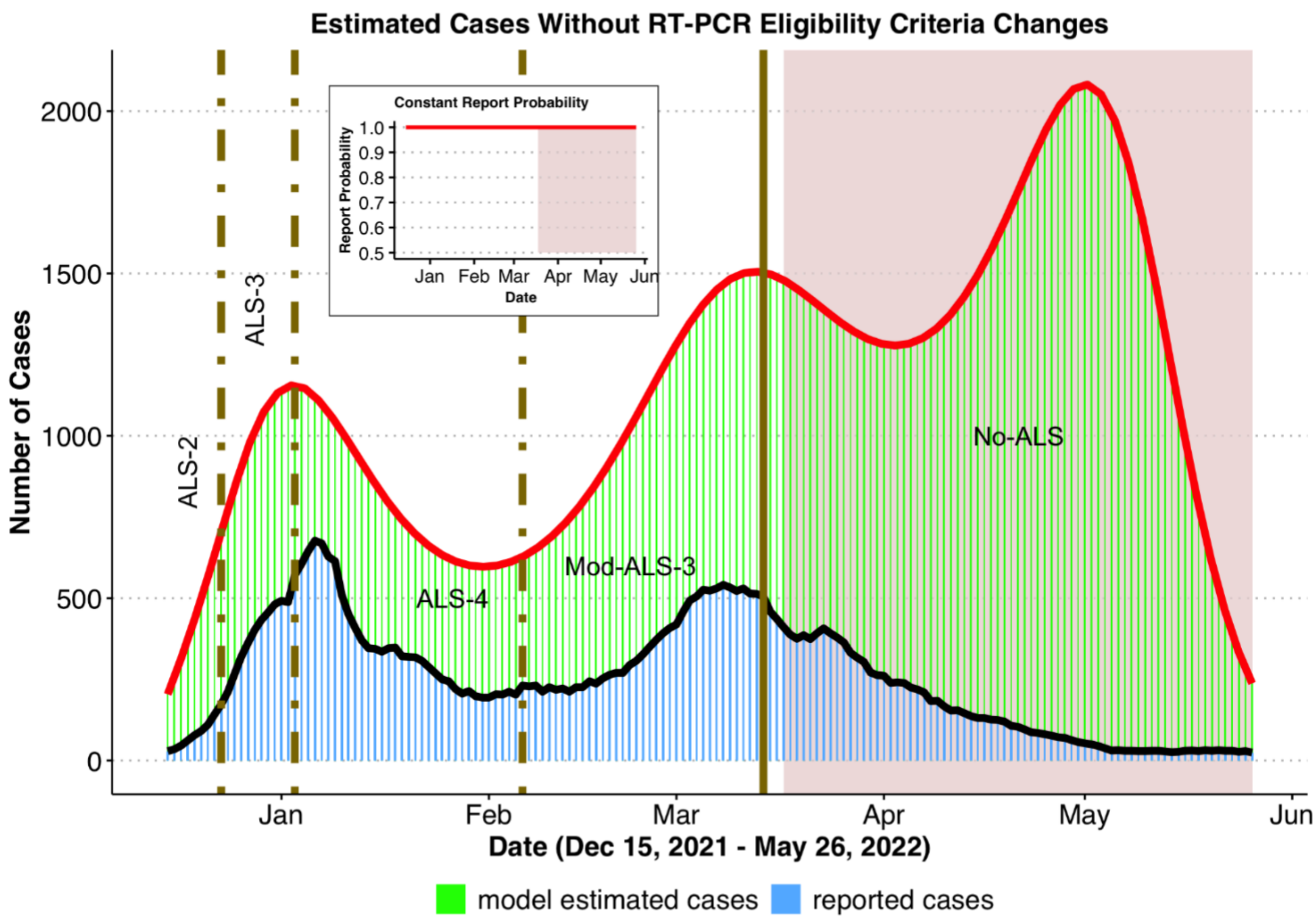
ESTIMATING KEY QUANTITIES



Anokye et al. Reconstruction of Omicron (B.1.1.529) transmission dynamics in Newfoundland and Labrador. In prep

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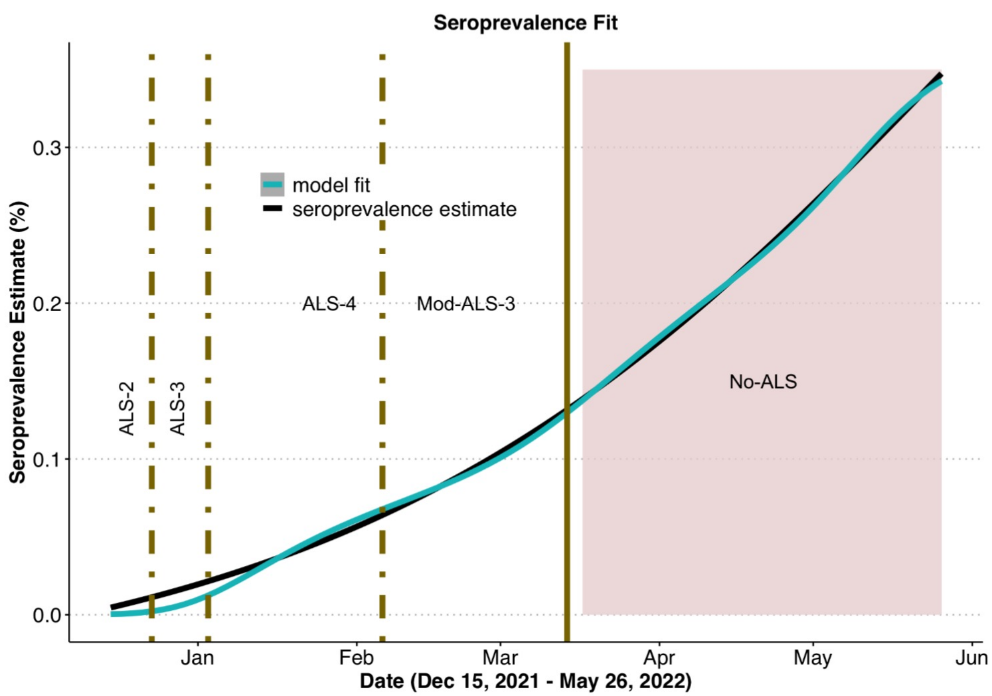
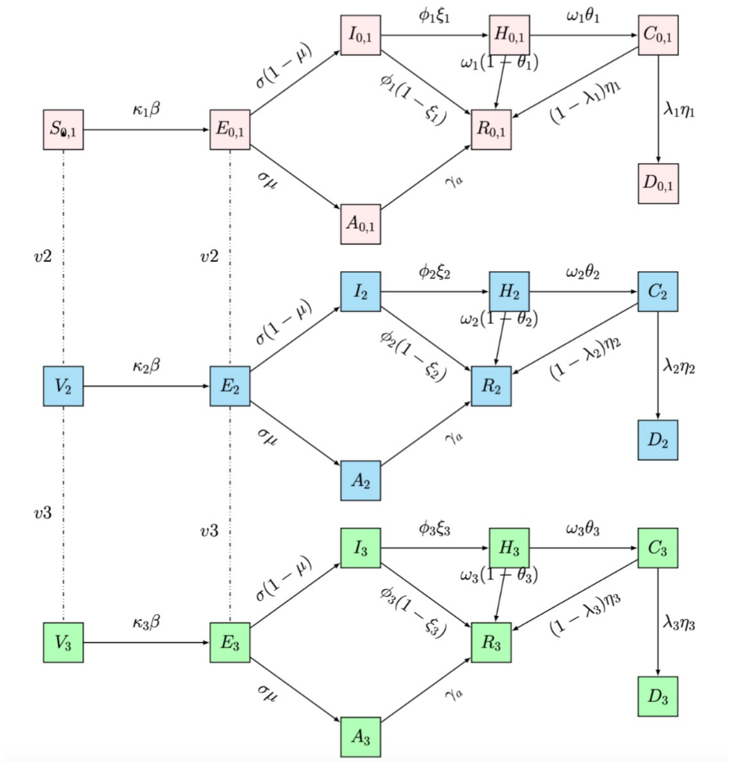
ESTIMATING KEY QUANTITIES





Anokye et al. Reconstruction of Omicron (B.1.1.529) transmission dynamics in Newfoundland and Labrador. In prep

ESTIMATING KEY QUANTITIES

Memorial U: Francis Anokye, Zahra Mohammadi (Cook)

PHAC: Michael Li

U of Manitoba: Julien Arino

U of Guelph: Zahra Mohammadi (Cook), Monica Cojocaru

Simon Fraser U: Renny Doig, Caroline Colijn, Liangliang Wang

NLHS: Suzette Spurrell, Andrea Morrissey

NLHS – Digital Health: Kendra Lester, Alicia Blackmore

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BUILDING RELATIONSHIPS

- Pandemic preparedness requires establishing relationships with modellers and decision-makers prior to a public health emergency

- This can be achieved by collaborative modelling non-pandemic infectious diseases of concern

BUILDING RELATIONSHIPS

- **Estimating the undiagnosed fraction of Hepatitis C in NL***

  Collaborators: Laura Bruce and Peter Daley (Memorial U)

- **Estimating human infections of avian influenza***

  Collaborators: Josh Mack, Joseph Baafi, Andrew Lang, Kathryn Hargan (Memorial U), Randy Green (Miauwpkek FN), ECCC, Govt of Nunatsiavut, Nunatukavut CC

- **Modeling *Culex* mosquito dynamics in Newfoundland**

  Collaborators: Joseph Baafi (Memorial U)

- **Building a general modelling framework for pandemic and non-pandemic SARS-CoV-2 and Avian influenza, malaria, Arctic rabies, and Lyme disease***

  Collaborators: Michael Li (PHAC) and Memorial U

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* in macpan2

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WHAT'S NEXT

- **Establishing collaborations that support mutual goals**

  My goals are to:

    build capacity in mechanistic modelling

    support regional needs

    estimate key quantities

- **Securing funding and advance capacity through training**

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