COVID Model Projections

May 18, 2022

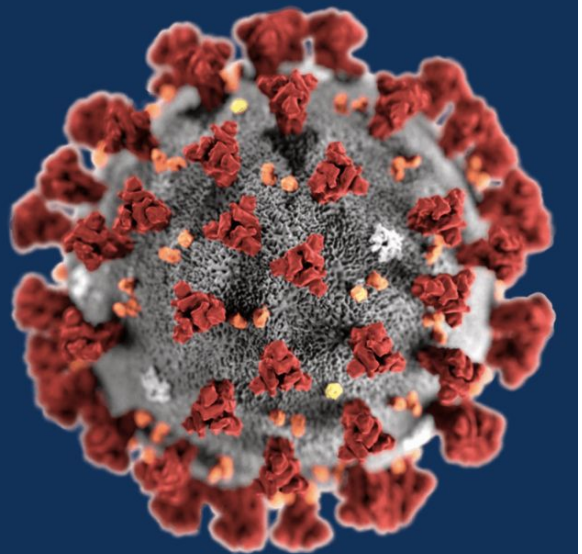
BC COVID-19 Modelling Group

@bcCOVID19group

About BC COVID-19 Modelling Group

The BC COVID-19 Modelling Group works on rapid response modelling of the COVID-19 pandemic, with a special focus on British Columbia and Canada.

The interdisciplinary group, working independently from Government, includes experts in epidemiology, mathematics, and data analysis from UBC, SFU, UVic, and the private sector, with support from the Pacific Institute for the Mathematical Sciences.



https://bccovid-19group.ca

Contributors to report

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Daniel Coombs (UBC)
Elisha Are (SFU)
Bryn Wiley (UBC)

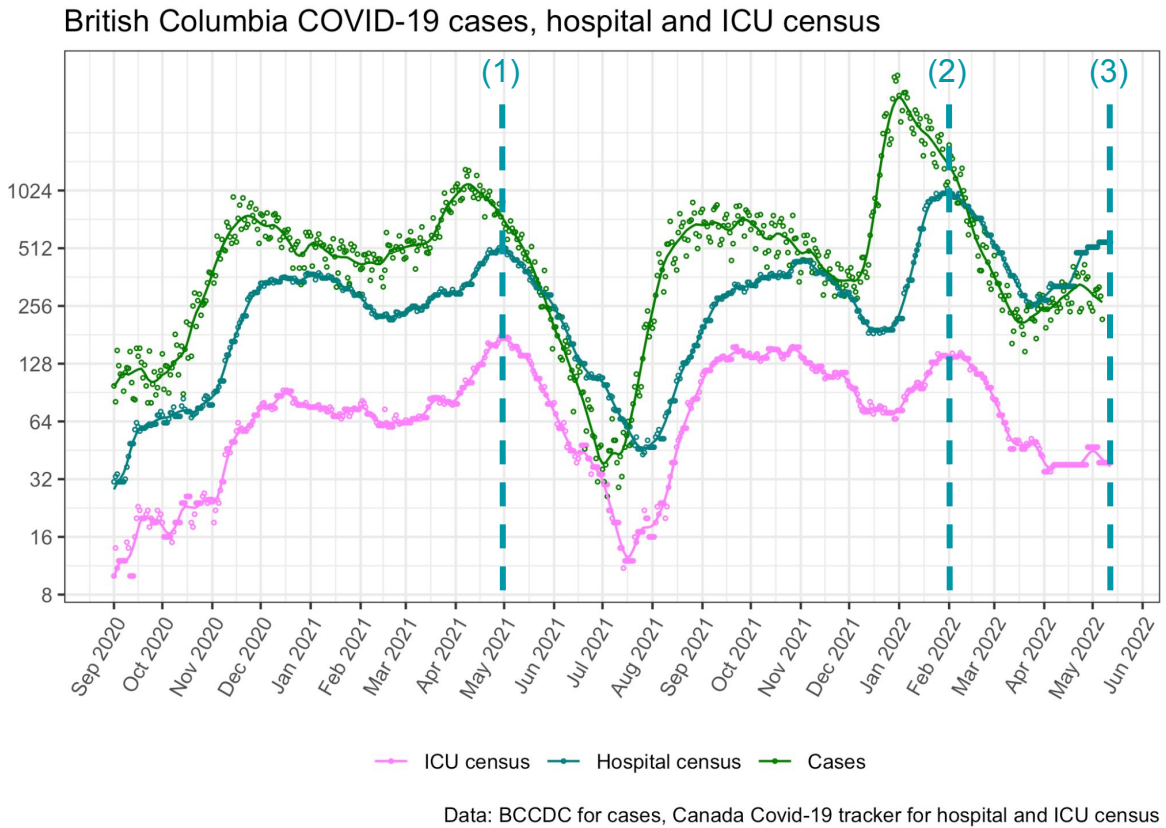
Independent and freely offered advice, using a diversity of modelling approaches.

Overview

Second Omicron wave (BA.2) is showing signs of having peaked in BC

- Reported cases, cases among those aged 70+, hospitalization data, and most wastewater sites together suggest COVID-19 infections are declining in BC (but not Facebook/UMD survey data).
- Omicron sub-variant BA.2 comprises >98% of recent sequences in Canada.
- While the second Omicron wave (BA.2 driven) appears to be peaking at a lower level than the first Omicron wave (BA.1 driven), hospital occupancy and cases (using an age-based correction for underreporting) are still higher than any previous time in the pandemic, prior to Omicron.
- The turnarounds are driven by growing population immunity (unlike previous behaviour-driven turnarounds) and uncertainty in projections comes from uncertainty in modeling that immunity.
    - Our previous reports (April 6 and 27) predicted the turnarounds well in advance. Models of population immunity therefore have predictive power despite the many sources of uncertainty.

Hospital trends in BC



The numbers of reported cases and people in hospital and ICU are stabilizing in BC.

Number in hospital with COVID-19:

Pre-Omicron

(1) Highest = 515 (28 April 2021)

Omicron wave:

(2) Highest = 1038 (31 January 2022)

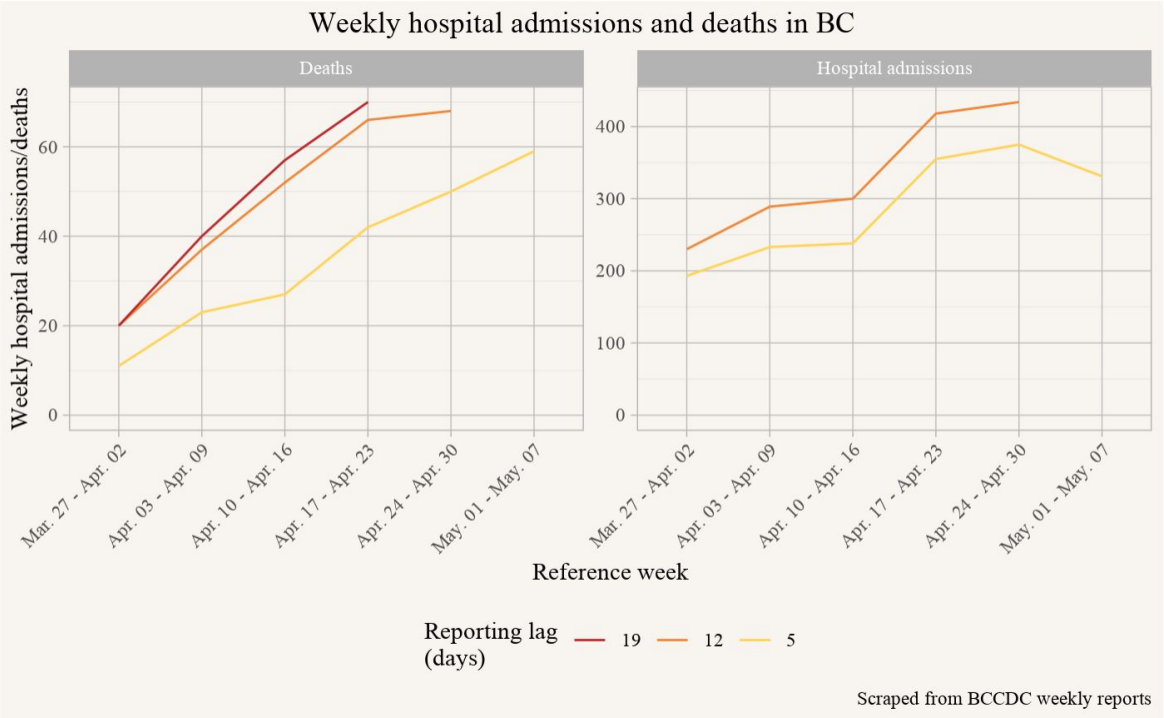
(3) Current = 596

Source (J. von Bergmann) Case data from BC COVID-19 Database (http://www.bccdc.ca/health-info/diseases-conditions/covid-19/data). STL trend lines on log scale.

Hospital admissions and deaths

Hospital admissions data and deaths are now reported weekly in BC but still suffer major data lags

- When first reported, only data up to 5 days prior are included
- Data are substantially underreported when first reported (revised in the following weeks)



Updated the next week (and the week after)

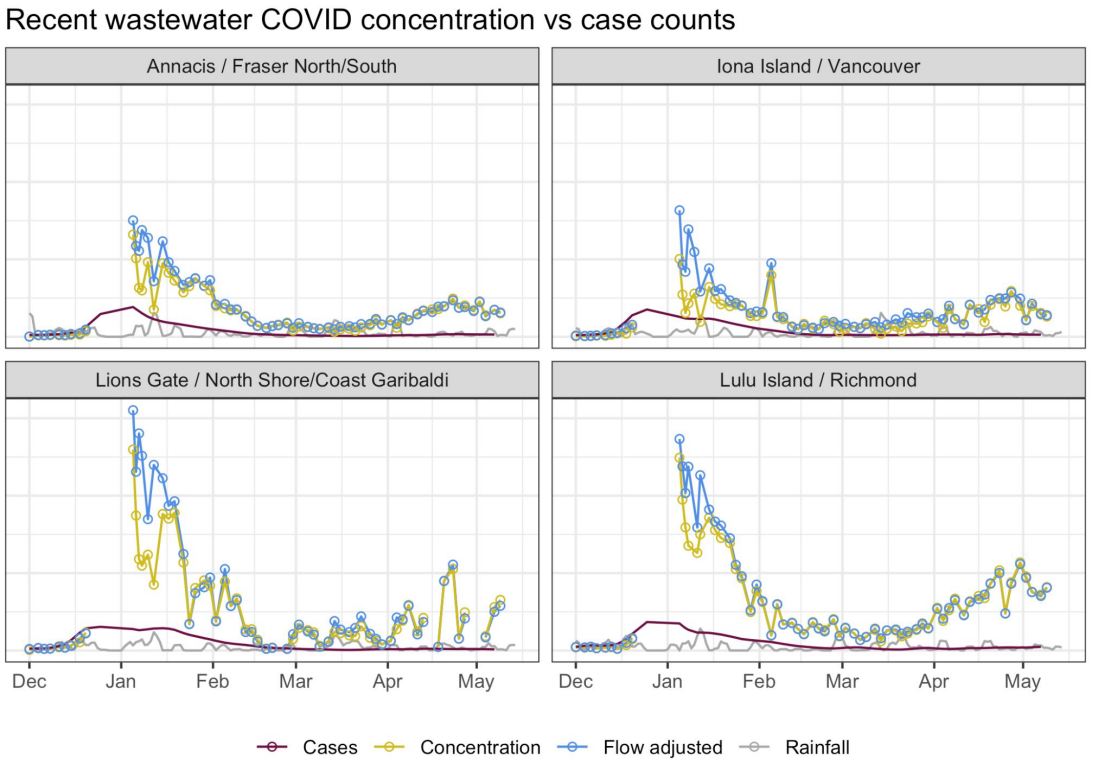
Value initially reported

BC hospital admissions are revised upwards by ~20% and deaths by ~80% when updated.

Wastewater trends in Metro Vancouver

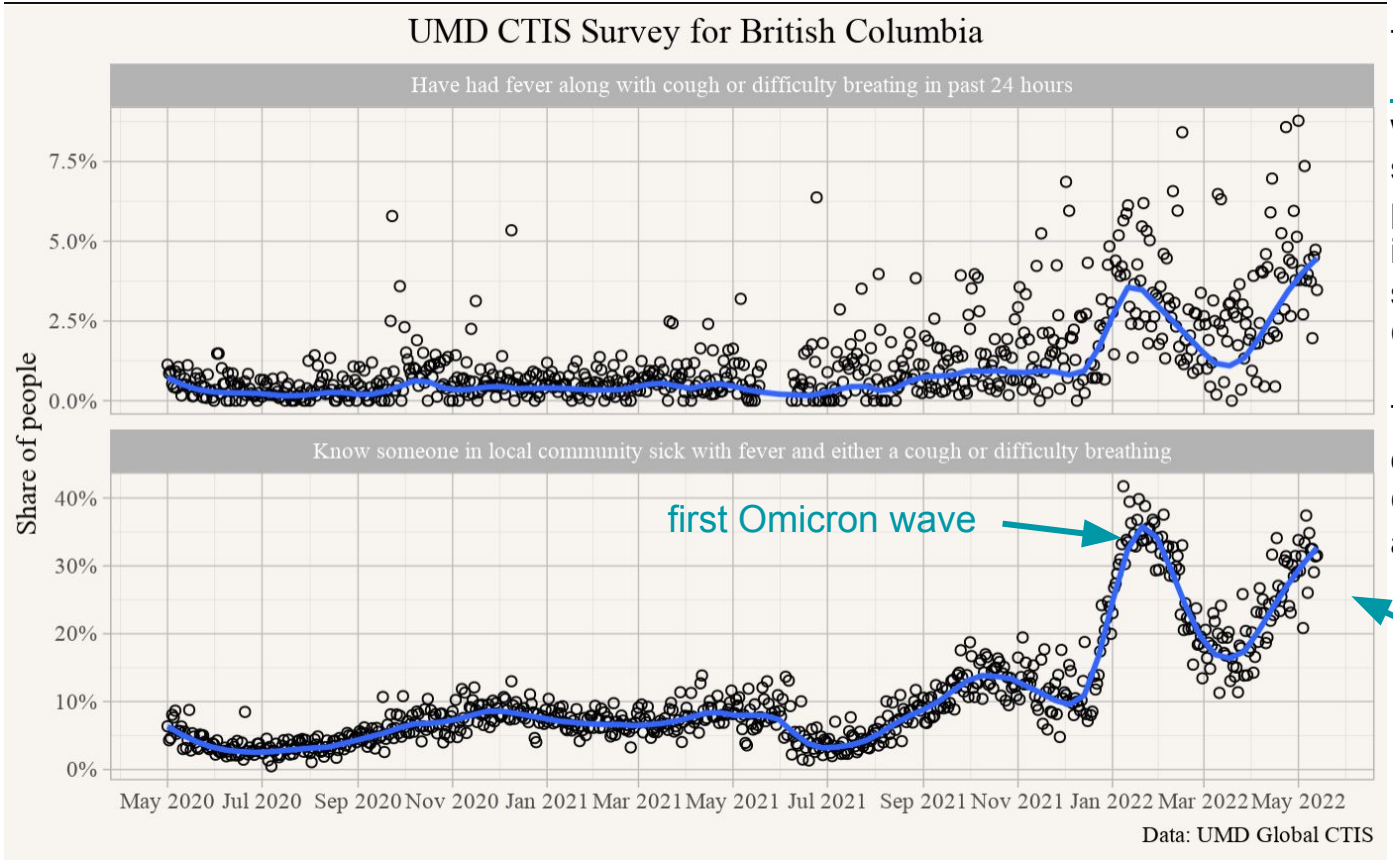
Clear trends in wastewater signals are difficult to discern, the data are consistent with several explanations, including that the second Omicron wave may have peaked.

Increasing collection frequency, expanding coverage, reducing data lag, and adding covariates to help with modelling are important steps toward an alternative surveillance program based on wastewater.



Source (J. Bergmann) Data from Metro Vancouver's Testing for the COVID-19 VIrus in Wastewater

Survey of COVID-19 trends in Metro Vancouver

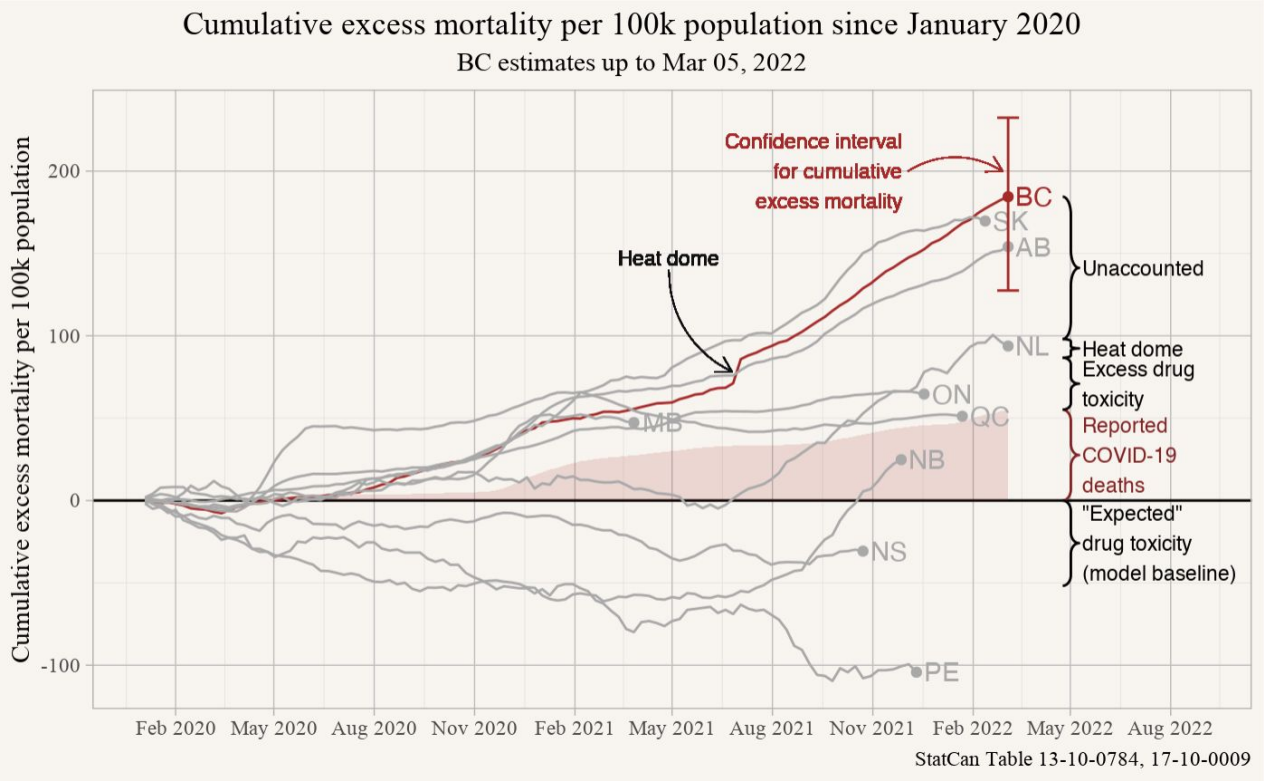


The [COVID-19 Trends and Impact survey], in collaboration with Facebook, shows signatures of high numbers of people who are currently infected (top) or know of someone infected (bottom) with COVID-19*.

The survey data is not consistent with the second Omicron wave having peaked already

Source (J. Bergmann) Data from [COVID-19 Trends and Impact survey].

Excess mortality



As official COVID-19 data in BC becomes less available we consider alternative data sources to measure the impact of the pandemic in BC. Excess mortality is one such metric.

It accounts for all causes of mortality in excess of expected deaths.

Half of BC's excess mortality since the start of the pandemic is accounted for in official statistics.

The model baseline consists of "expected" deaths based on the previous four years, including drug toxicity and other causes.

Excess mortality background information

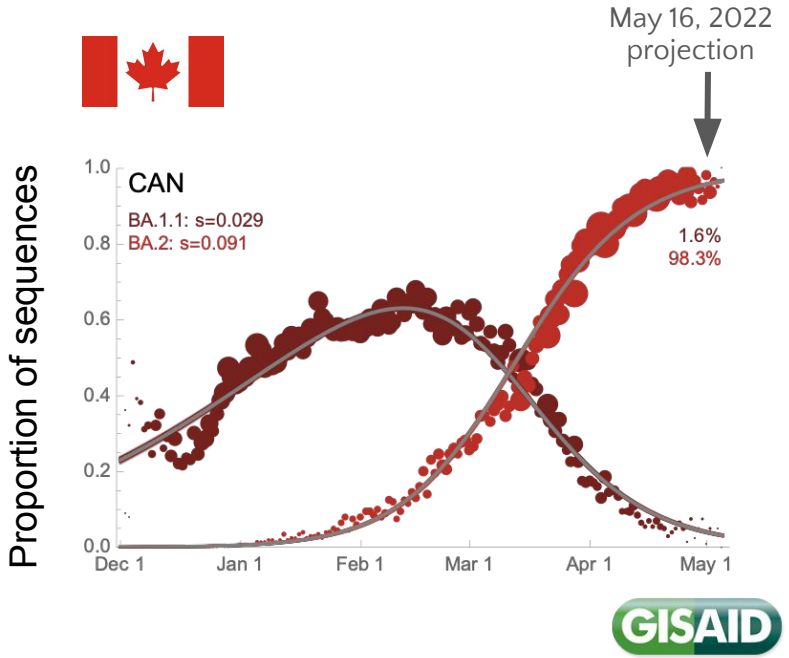
- Excess mortality compares observed deaths to a baseline “expected” deaths derived from a model based on the prior 4 years deaths by age and time in the year in each province.
- The “expected” COVID-19 and heat dome deaths are zero since those events did not occur in the previous years, the “expected” drug toxicity deaths reflect the rate in the 4 previous years and are also shown. Excess mortality would have been reduced by the indicated amount if those deaths had been avoided.
- There can be significant year-to-year variation independent of impacts of particular health emergencies, but this is very unlikely to explain all of BC’s excess mortality beyond the deaths that are officially accounted for.
- Pandemic measures have likely lead to lower than expected death due to flu and other respiratory diseases, as evidenced by some of the provinces experiencing negative excess mortality. This may mask some increases in mortality related to COVID.
- “Unaccounted” reasons refer to excess deaths not included in official statistics relating to the three recent health emergencies: COVID-19, drug toxicity, and the heat dome. These include under-reported COVID-19 and heat-dome deaths, other COVID-related deaths or deaths of other unknown causes, and statistical noise that could shrink or enlarge excess mortality.

Spread of Omicron sub-lineages in Canada

Data shared by Public Health labs across Canada allow us to track the spread of Omicron sub-lineages over time.

→ BA.1.1 spread slightly faster than BA.1 at a rate of s=3% per day (dark red).

→ BA.2 is spreading much faster than BA.1 at a rate of s=9% per day (this is similar to selective spread of Alpha). Proportion of BA.2 cases estimated this week at **98%.**



How does this vary across Canada?

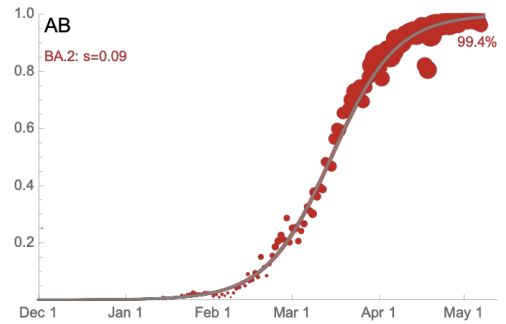
What does this imply for case numbers?

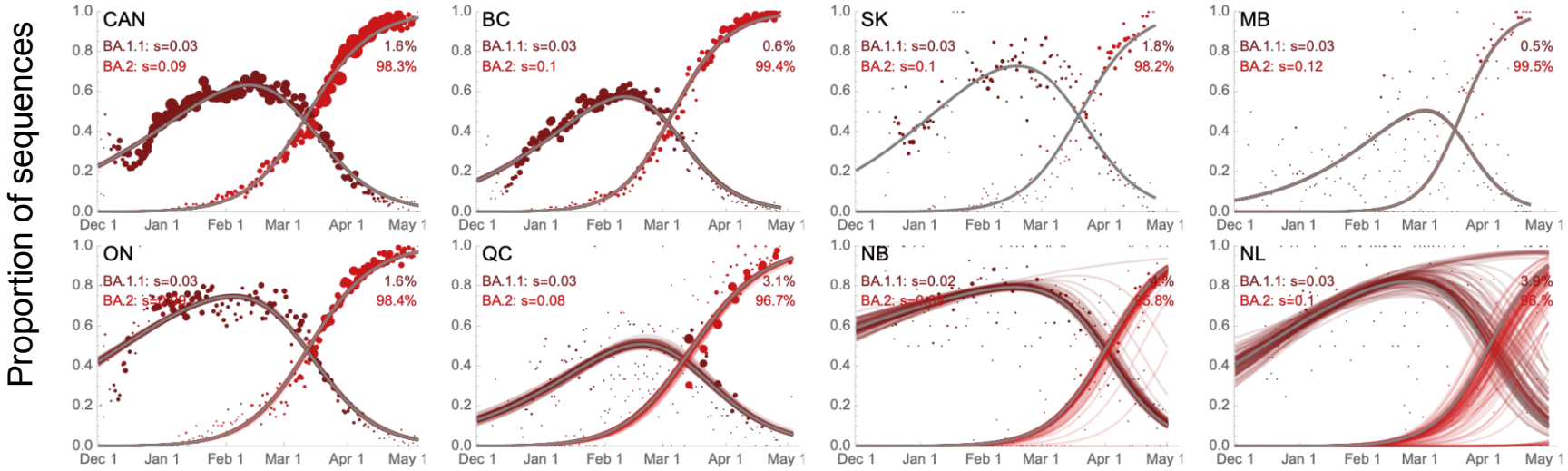
Source (S. Otto) Canadian sequences for Omicron (GRA clade) were downloaded from GISAID on 16 May 2022 (Alberta sequences were removed as AB first identifies variants and preferentially sequences BA.2). A model of selection was fit to the numbers of each type using maximum likelihood based on a trinomial distribution given the expected frequencies on each day. Hessian matrix used to show plausible trajectories, accounting for uncertainty in the parameters.

Spread of Omicron sub-lineages in Canada

BA.2 is expected to have reached a frequency of >95% today, showing a similar selective advantage, in all provinces analysed.

Alberta analysed separately (based on PCR typing)





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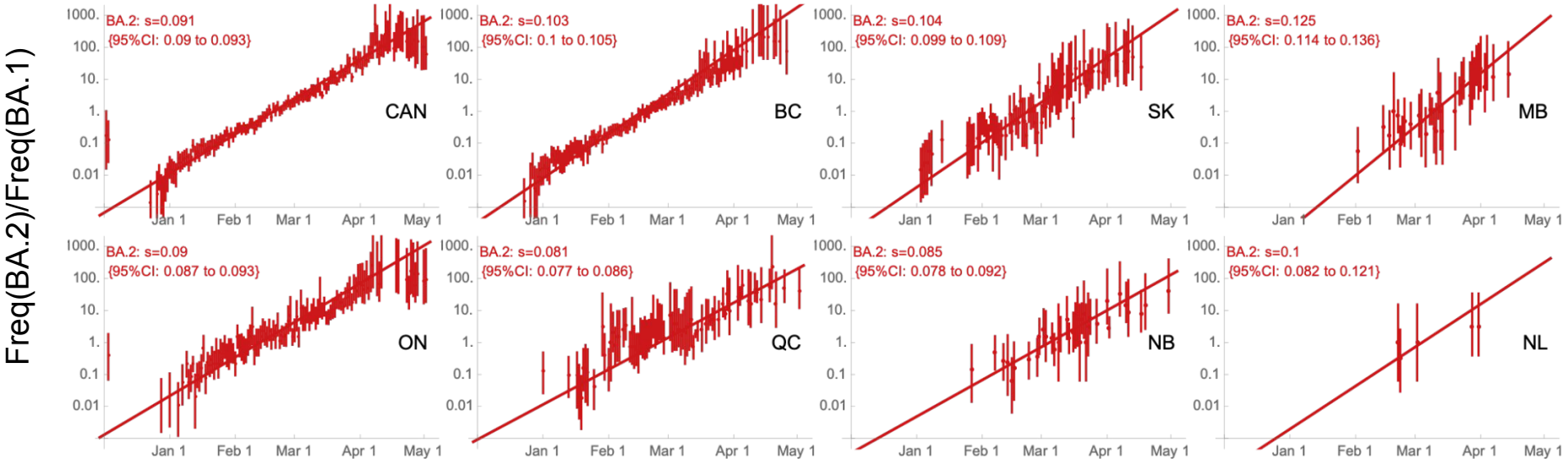
Spread of Omicron sub-lineages in Canada

The same data, plotted on a log-scale as the frequency of BA.2 versus BA.1, shows a linear rise with a slope equal to the strength of selection. **The strength of selection favoring BA.2 has remained approximately constant** (no large change in slope).



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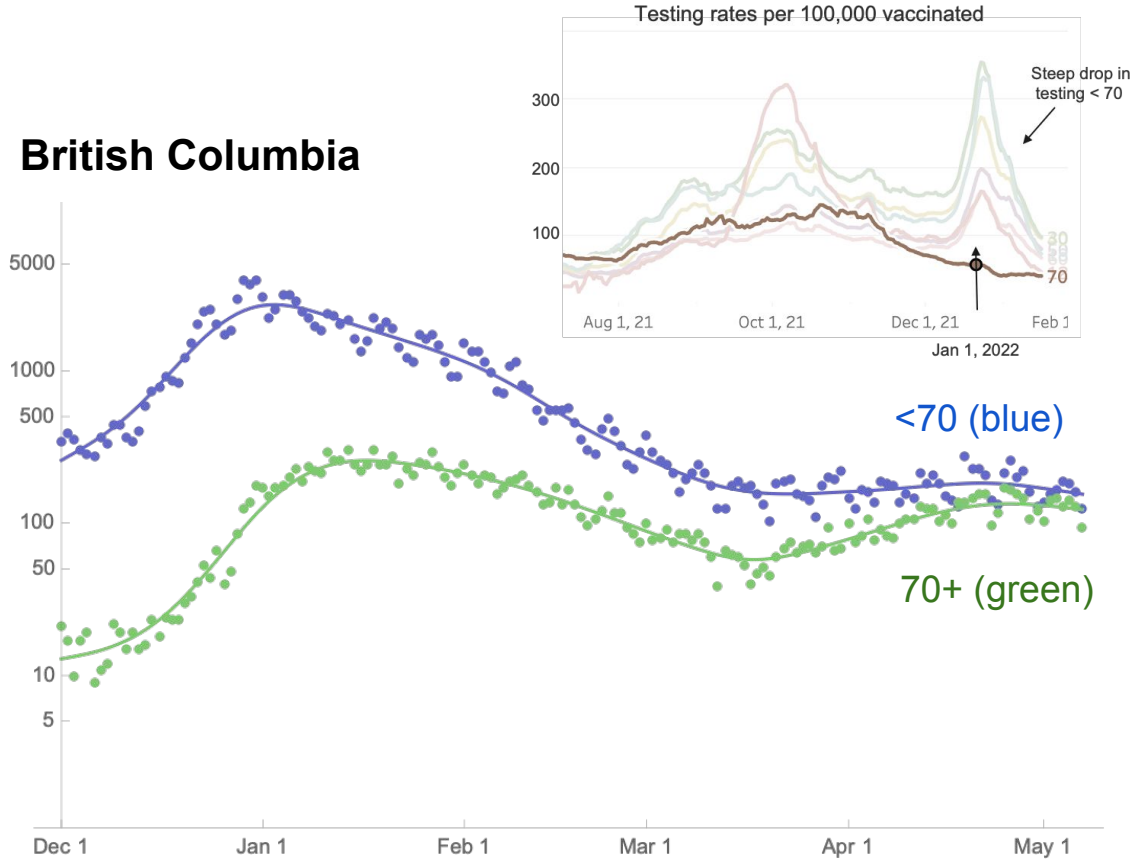
What does this imply for case numbers?

We'll use case numbers observed in individuals aged 70+, who have been more consistently tested.

Cases among the 70+ age group are now declining, but not **significantly***
(see Health Authority data later in report).



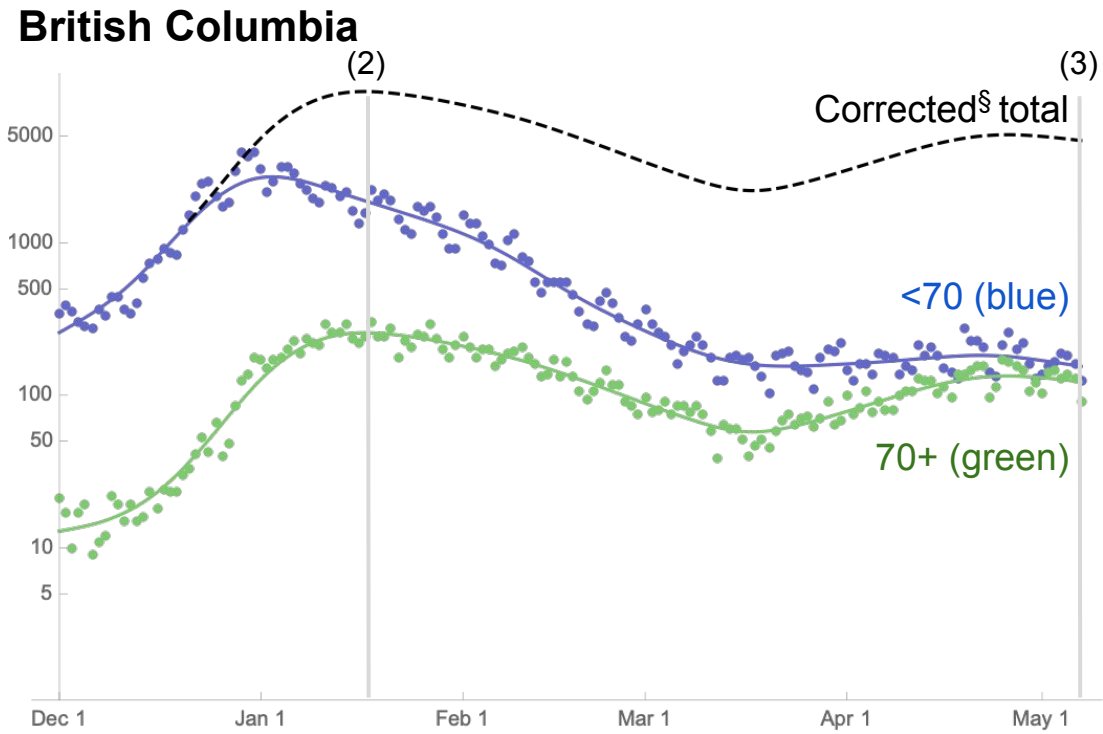
Source (S. Otto) New cases per day in 10-year age groups were downloaded from the [BCCDC COVID-19 data portal](). Cubic spline fits to log-case data were obtained (curves) for those 70+ (green) or <70 (blue). *Linear regression through log case counts among 70+ from last 14 days of data.

What does this imply for case numbers?

The black curve estimates the **total** number of cases we would have seen had testing continued at previous rates[§]
.

Number of reportable COVID-19 cases:
Pre-Omicron
(1) Highest = 1293 (8 April 2021)
Omicron wave **[inferred from correction[§]]**:
(2) Highest = 9800 (31 January 2022)
(3) Current = 4700

[§] Correction assumes testing is consistent in 70+ and % of infections in this age class has been stable.



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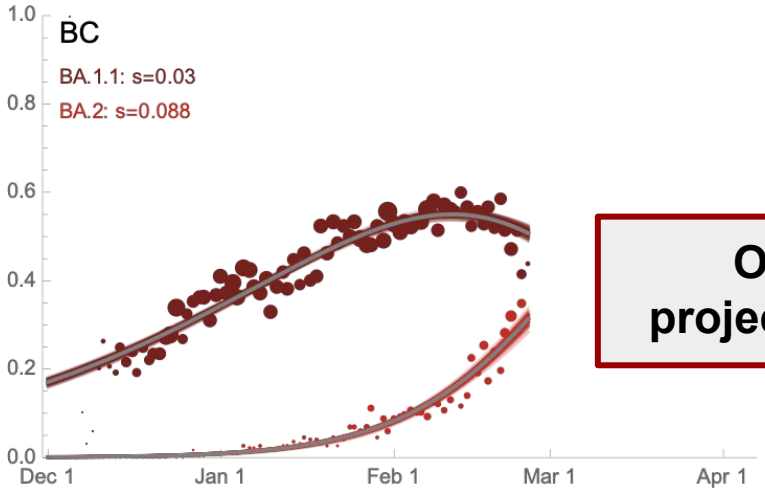
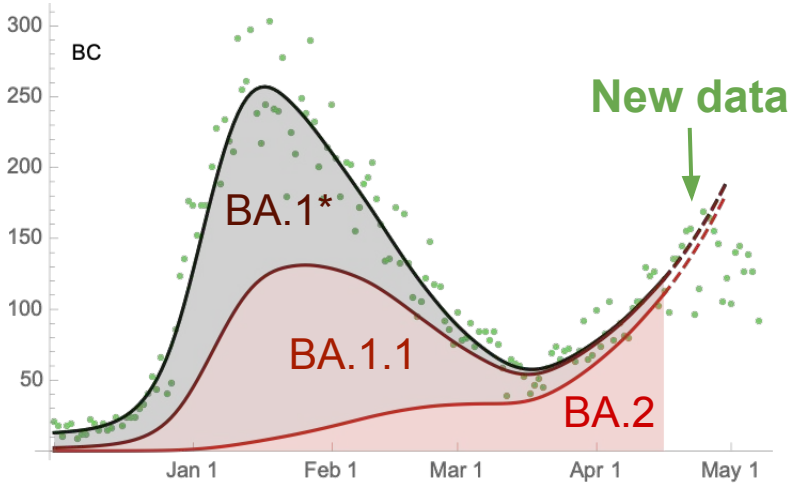
What does this imply for case numbers?

Fitting models of selection allows us to estimate rate of spread of BA.1.1 and BA.2, relative to BA1 in BC.



Old projections

Multiplying by the # of cases in those over 70 allows us to **estimate** growth in numbers of each Omicron sublineage.



→ Here we add the last three weeks of data to previous projections, showing excellent fit to the projected rise in case numbers among 70+ due to spread of BA.2

Source (S. Otto) Canadian sequences were downloaded from GISAID for BA.1, BA.1.1, and BA.2. A model of selection was fit to the numbers of each type using maximum likelihood based on a trinomial distribution given the expected frequencies on each day. Hessian matrix used to obtain confidence regions. *Grey includes other variants.

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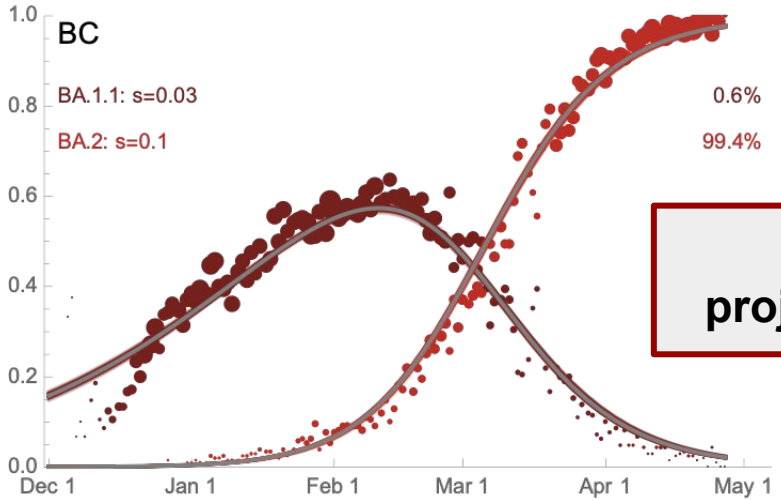

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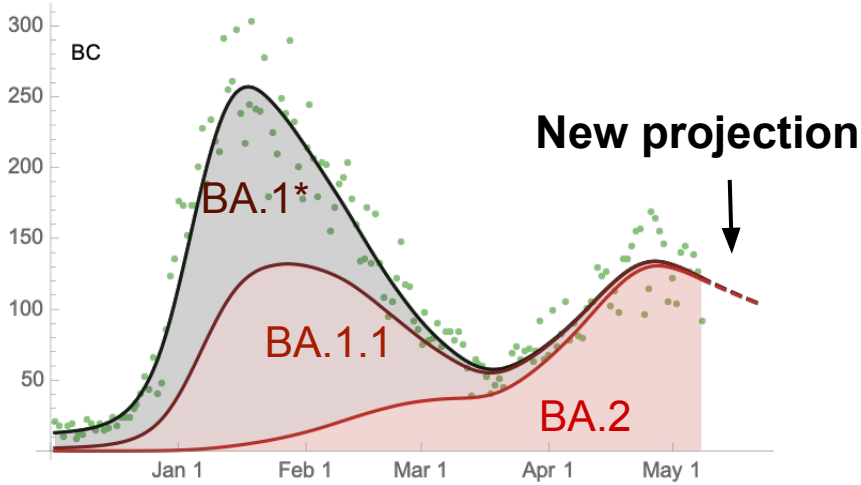
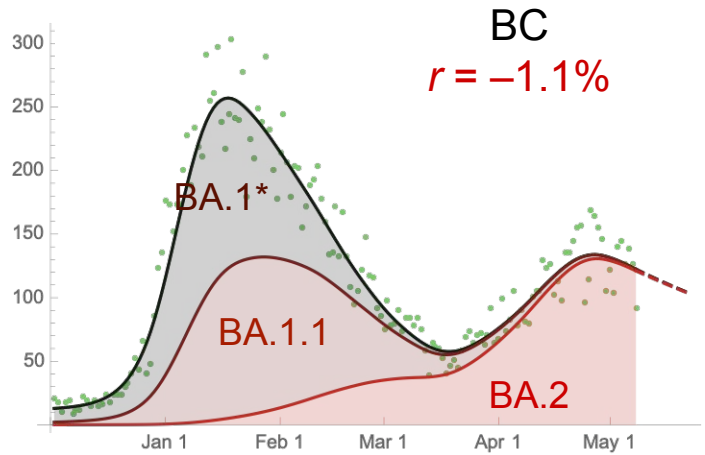
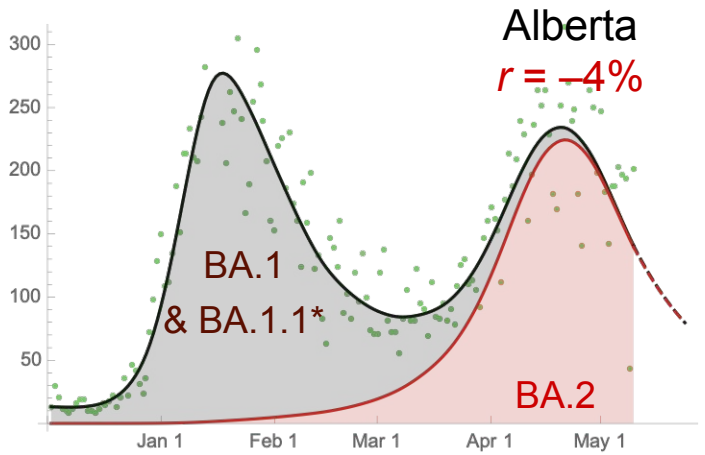


→ Updating the projections, we predict a downward trend in reported cases among 70+
(not yet significant**).

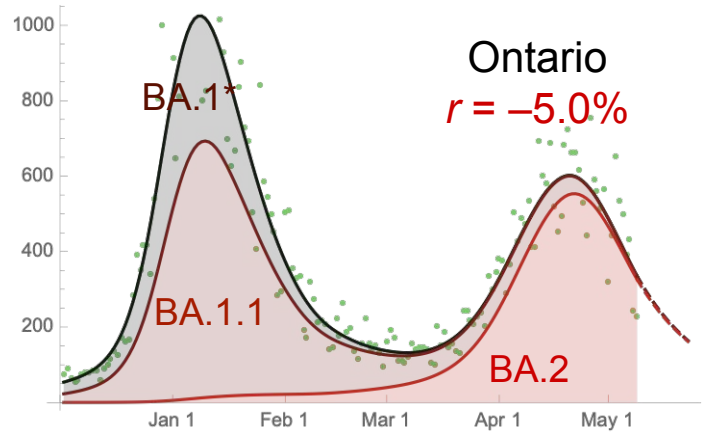
Source (S. Otto) Canadian sequences were downloaded from GISAID for BA.1, BA.1.1, and BA.2. A model of selection was fit to the numbers of each type using maximum likelihood based on a trinomial distribution given the expected frequencies on each day. Hessian matrix used to obtain confidence regions. *Grey includes other variants. **Linear regression through log case counts among 70+ from last 14 days of data.

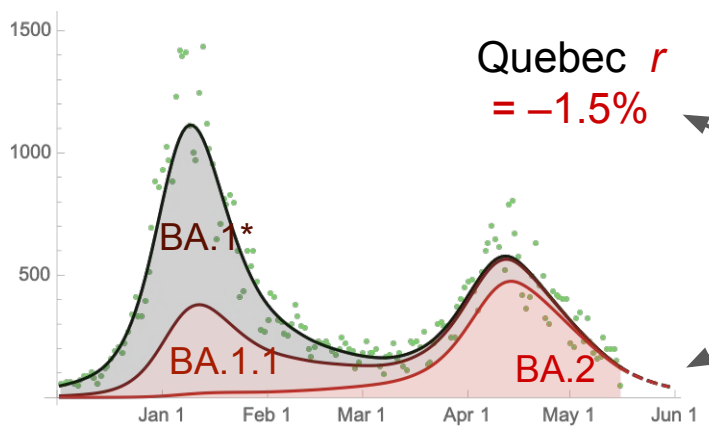
Daily growth rates





BA.2 wave appears to have peaked in provinces examined, based on cases among those >70 in age.





Daily growth rates estimated on latest date of data (projected forward)

*Grey includes other variants.

BC: Age-corrected case counts

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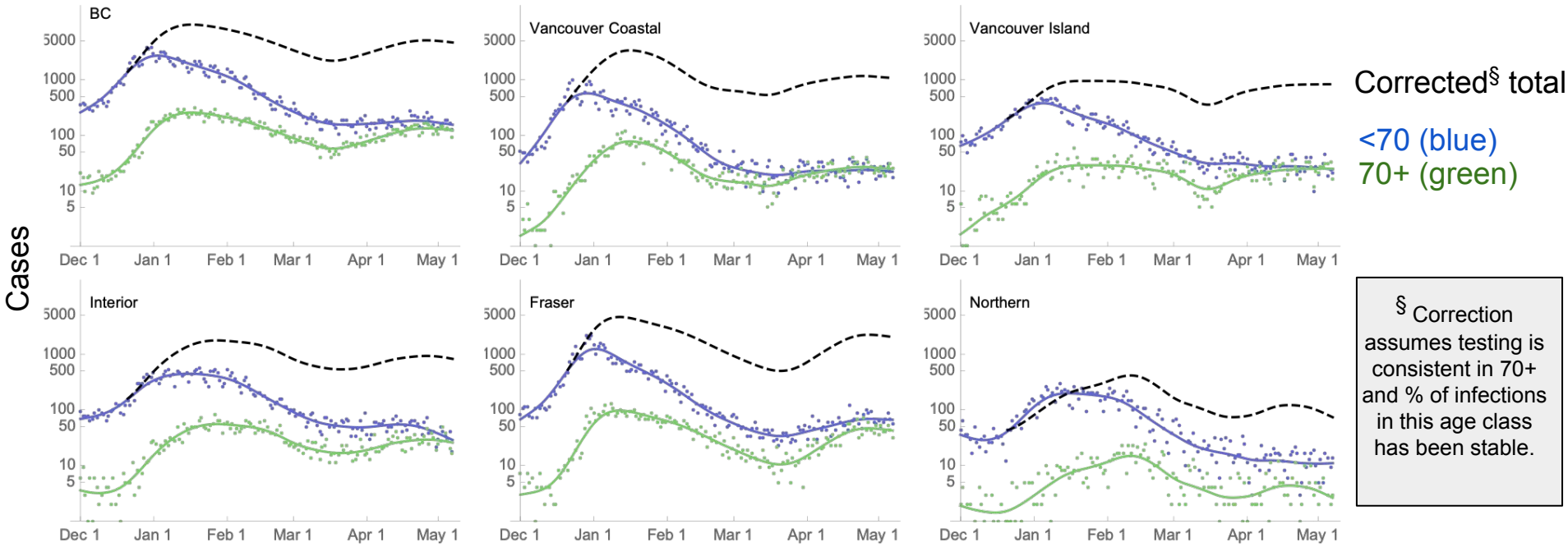


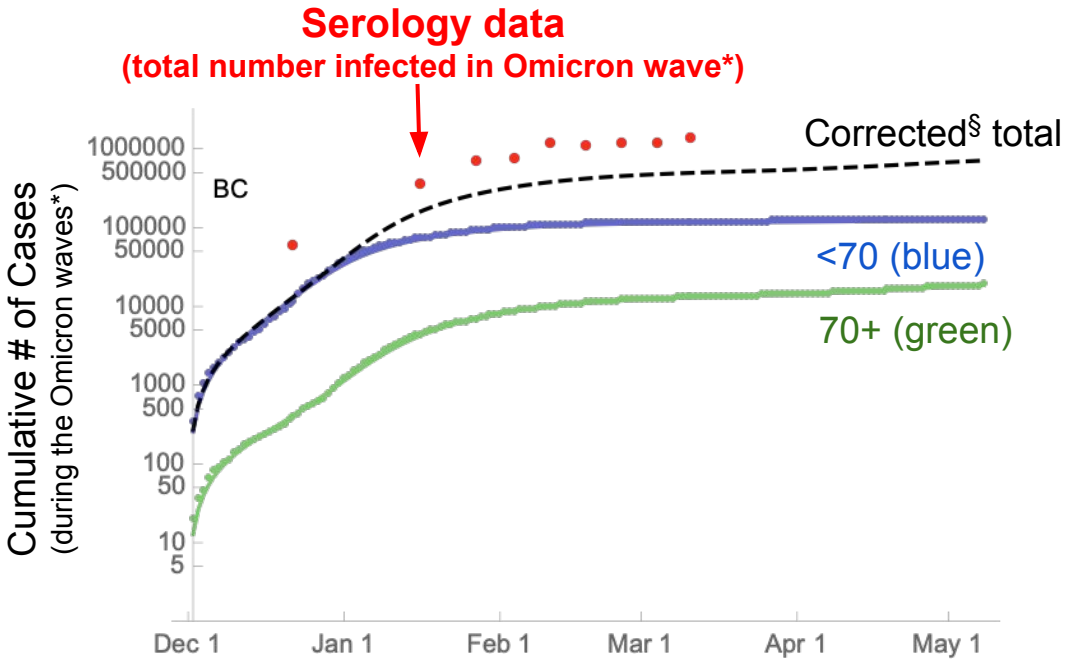
§ Correction assumes testing is consistent in 70+ and % of infections in this age class has been stable.

→ Cases among those aged 70+ (green) are stable or declining across the province. Black curves provide a rough guide of total cases, had testing continued in all age groups§.

Source (S. Otto) New cases per day in 10-year age groups were downloaded from the **BCCDC COVID-19 data portal**. Cubic spline fits to log-case data were obtained (curve) and estimates for those <70 obtained by applying the fits for those 70+, shifted up to match the projection for that age class on 21 December 2022 when testing limits were initially reached in many parts of the province.

BC: Serology

We can compare the cumulative number of cases to serology data, collected by the Canadian Blood Services & the COVID-19 Immunity Task Force during the Omicron wave. COVID-19 serology data look for signatures of the virus that are not encoded by the vaccine (here, antibodies to the nucleocapsid protein).



The serology data (red) tracks the age-based correction (black§) over time but suggests that there have been ~3-fold more infections than reported cases, even after correcting for lower testing rates in those <70.

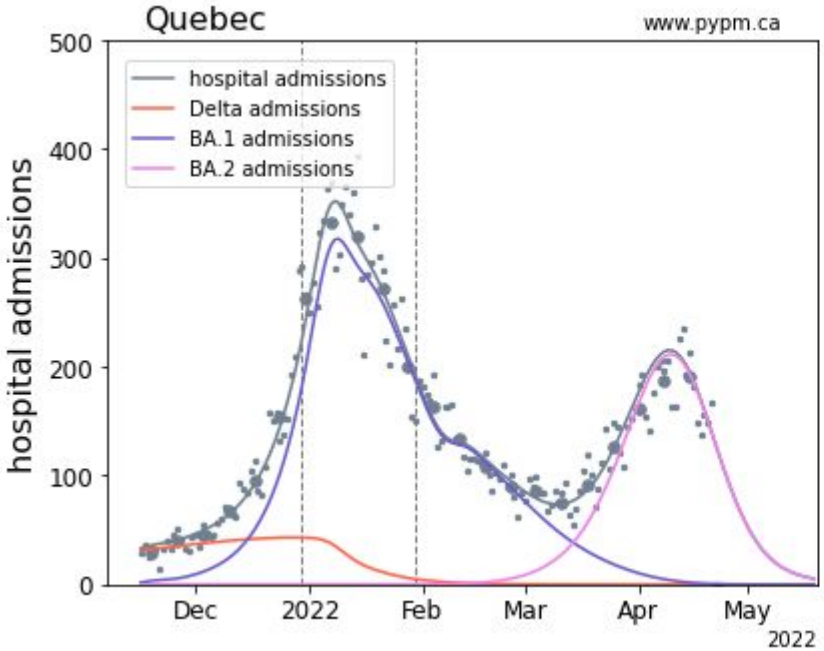
§ Correction assumes testing is consistent in 70+ and % of infections in this age class has been stable.

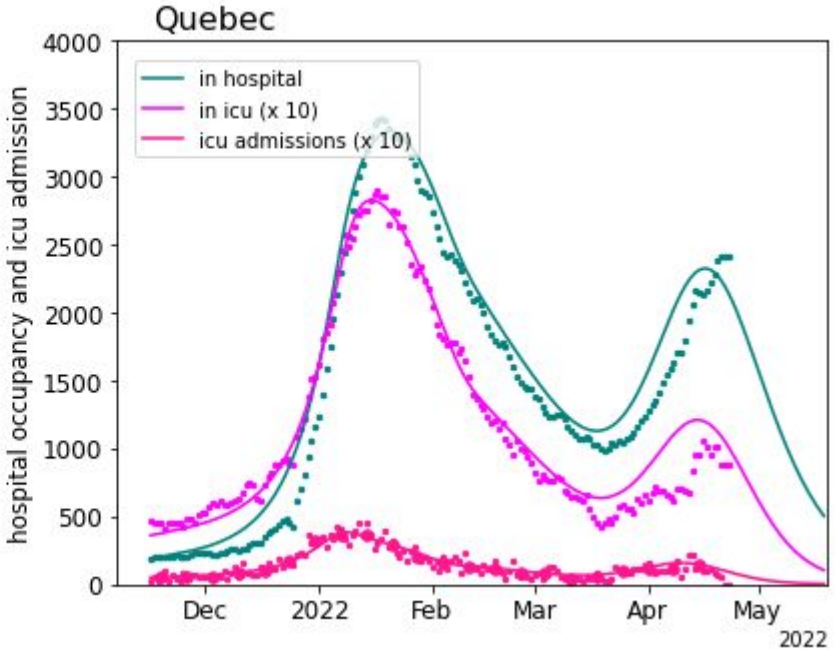
Note: Projecting these trends to today suggests that ~40% of BC has been infected with Omicron.

Source (S. Otto) New cases per day in 10-year age groups were downloaded from the **BCCDC COVID-19 data portal**. Cubic spline fits to log-case data were obtained (curve) and estimates for those <70 obtained by applying the fits for those 70+, shifted up to match the projection for that age class on 21 December 2022 when testing limits were initially reached in many parts of the province. *Serology data from CITF, subtracts off % positive for mid November, 2021 (i.e., excludes pre-Omicron infections).

April 27 hospital projection for Quebec (from our last report)

- In place of case data, hospital admission data are used to define the infection model.
- Immunity model predicted that peak hospital admissions had been reached.

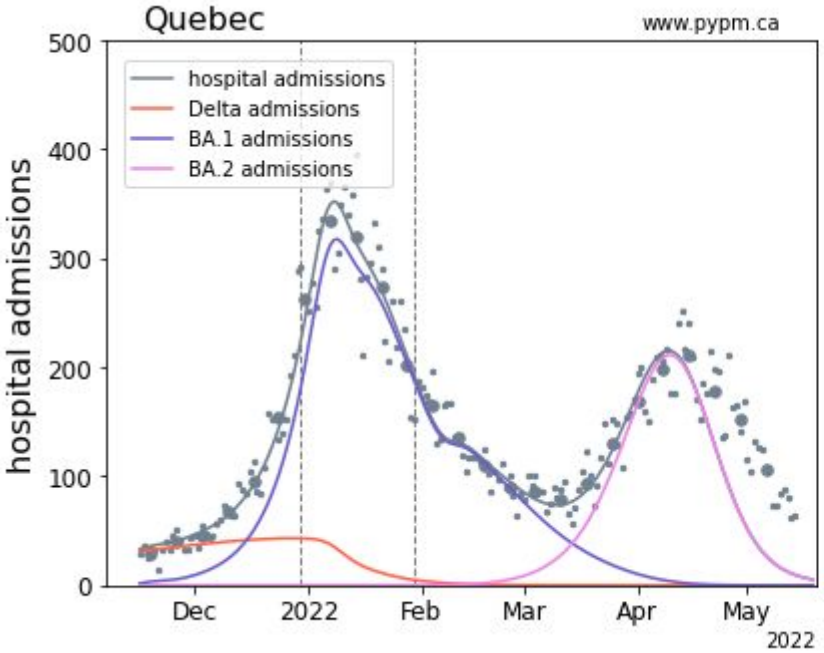


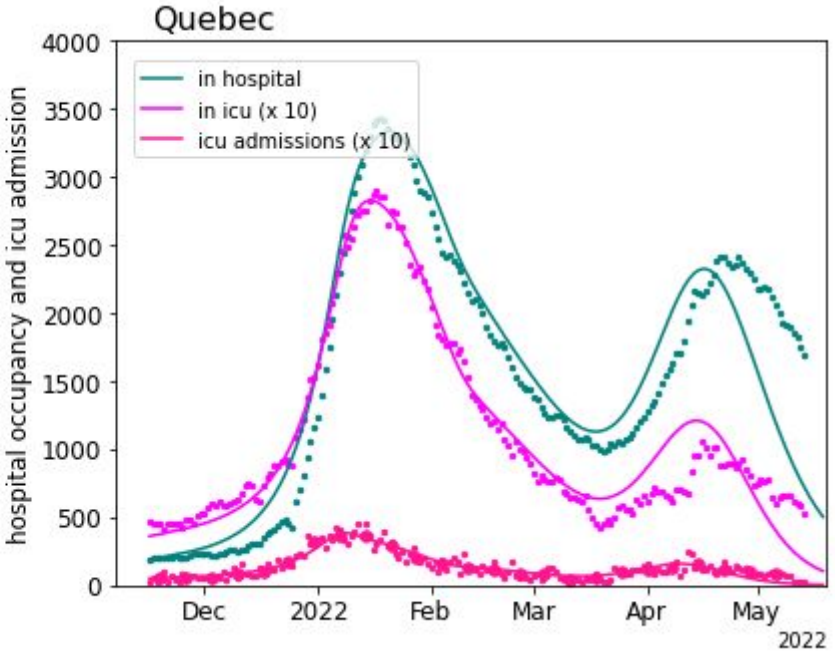


Source (D. Karlen) As in previous reports, the model has no age structure. Two Omicron strains are included (BA.1 includes BA.1.1) with both evading 80% of natural immunity from previous strains and 80% of 2 dose vaccinations. Booster doses are assumed to provide 80% effectiveness against infection. Omicron BA.1 (BA.2) infections were assumed to produce symptoms with a probability of 60% (50%) of that for previous strains. The probability that symptoms lead to hospitalization is 35% of that for previous strains. Vertical lines show fitted dates for transmission rate changes. The larger dots show weekly averages.

April 27 hospital projection for Quebec (with data update)

- Only minor revisions of previously reported data, so current data is likely reliable.
- Immunity model predicted faster decline than observed: Immunity growing too quickly in model.





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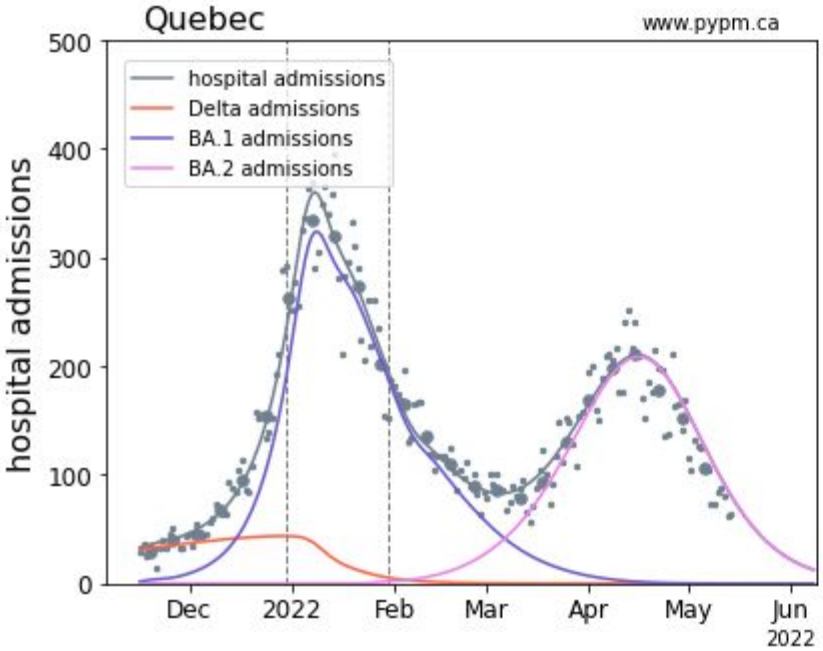
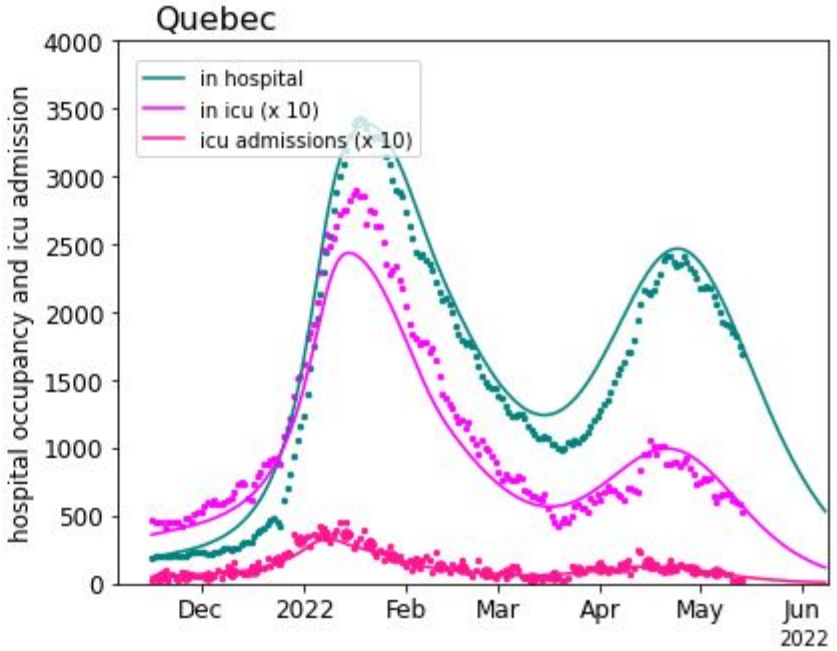
Updated hospital projection for Quebec

- Immunity model parameters were adjusted to better fit the data.





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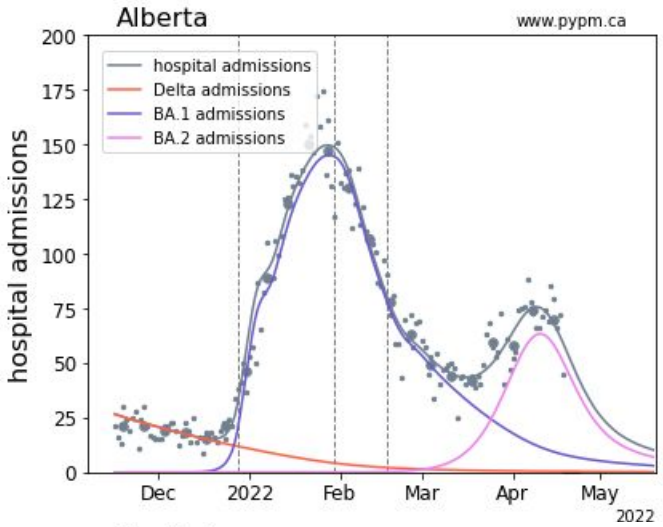
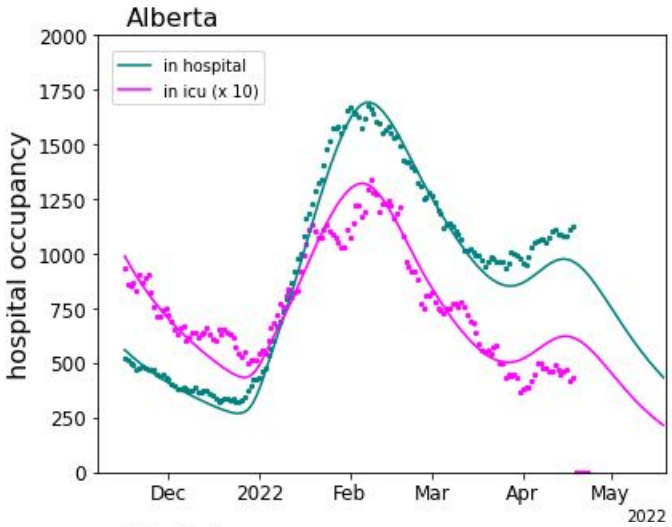
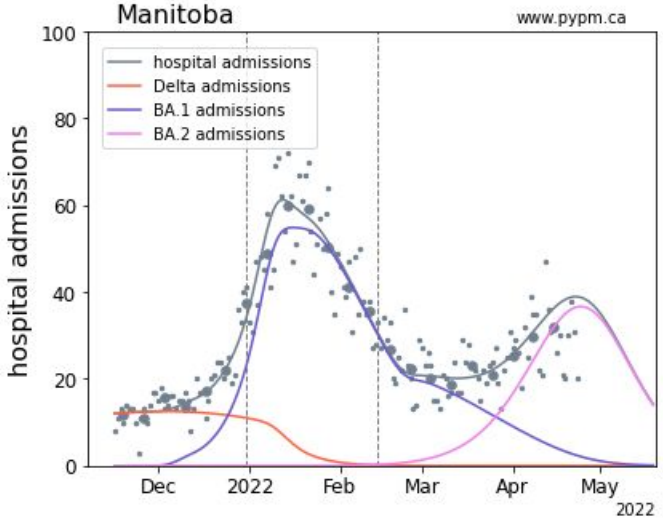
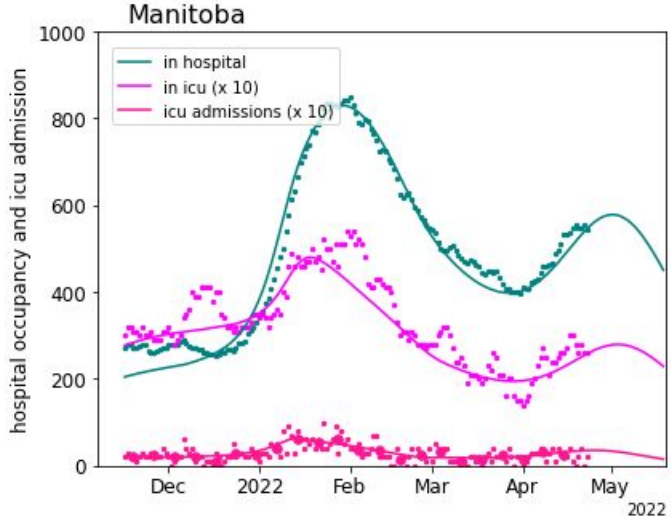


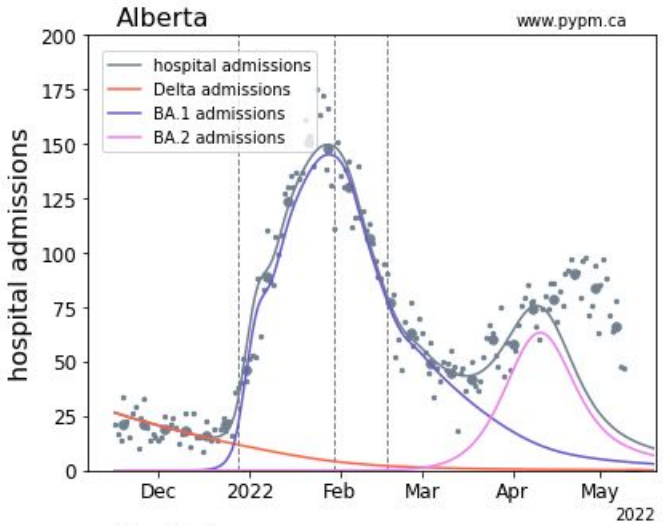


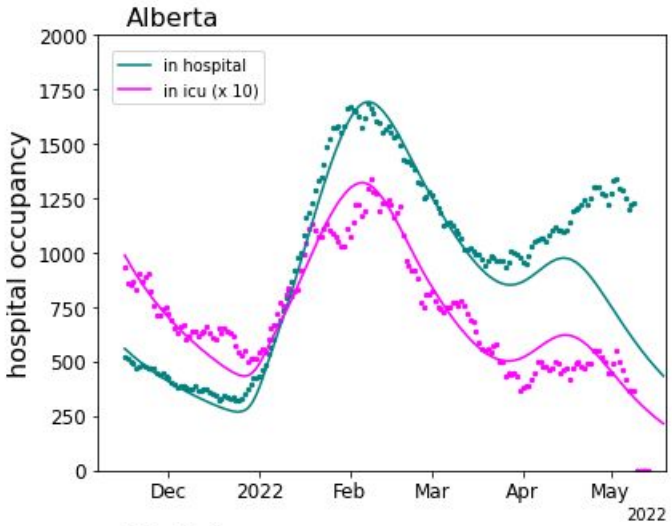


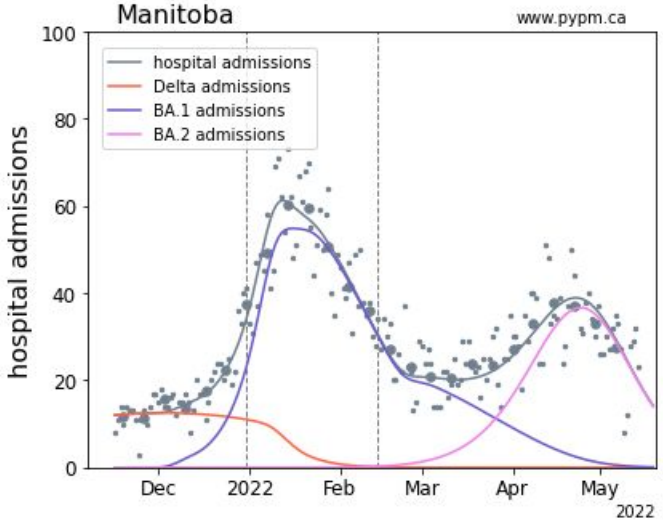


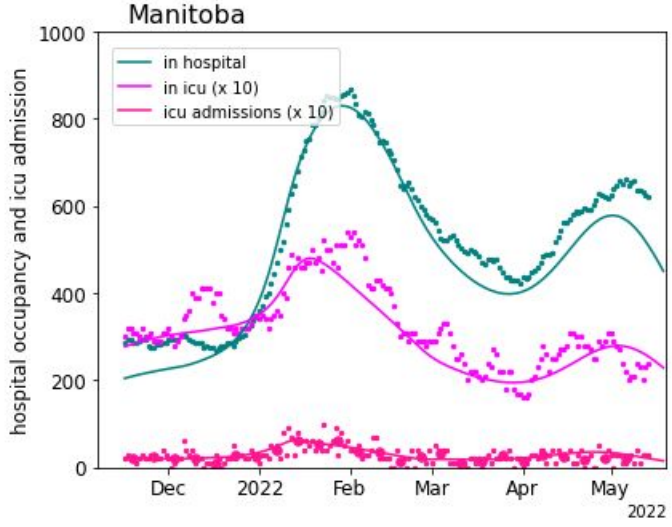
April 27 AB and MB Projections (from last report)

Model predicted that peak hospital admission was near its peak for both provinces.









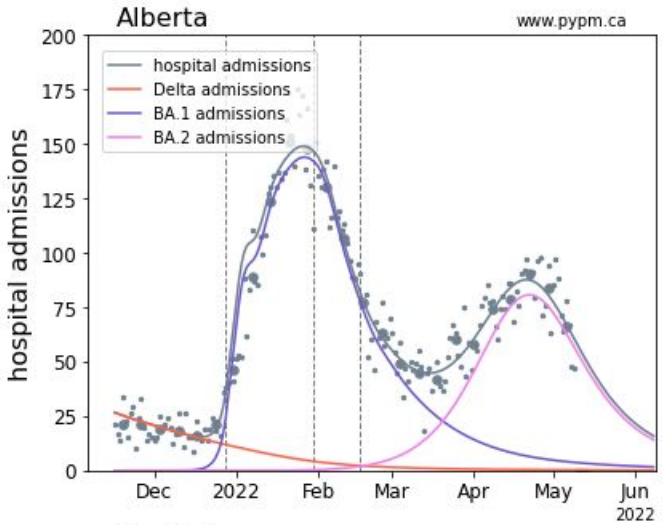
April 27 AB and MB Projections (with data update)

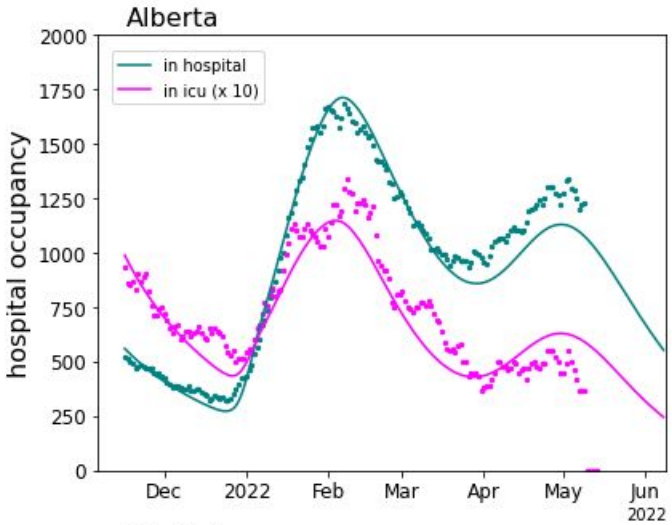
In the Alberta model, immunity grows too quickly.

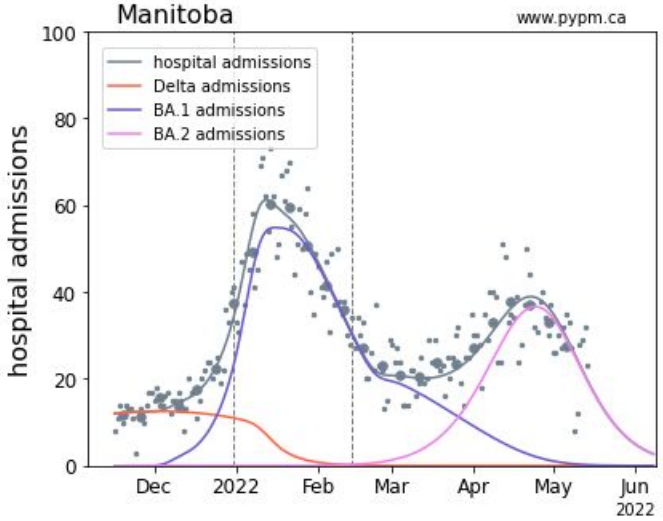
- The probability for BA.2 to produce symptoms was 40% of Delta (instead of the intended value of 60%).

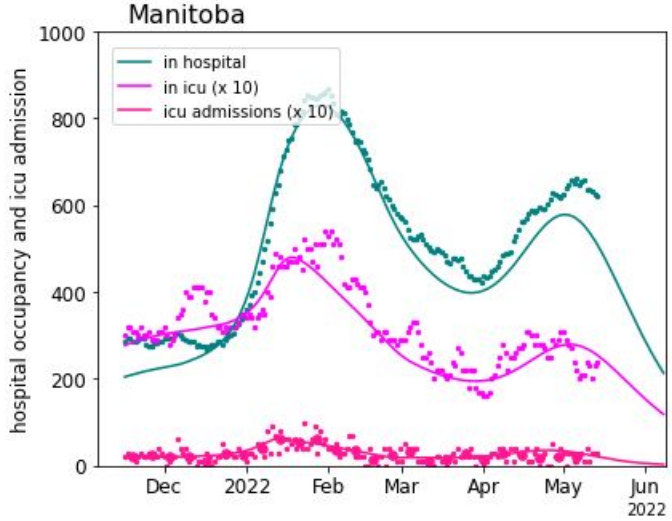
Manitoba model predicted the peak remarkably well.

- The parameter was set at 60% as intended.









Updated AB and MB Projections

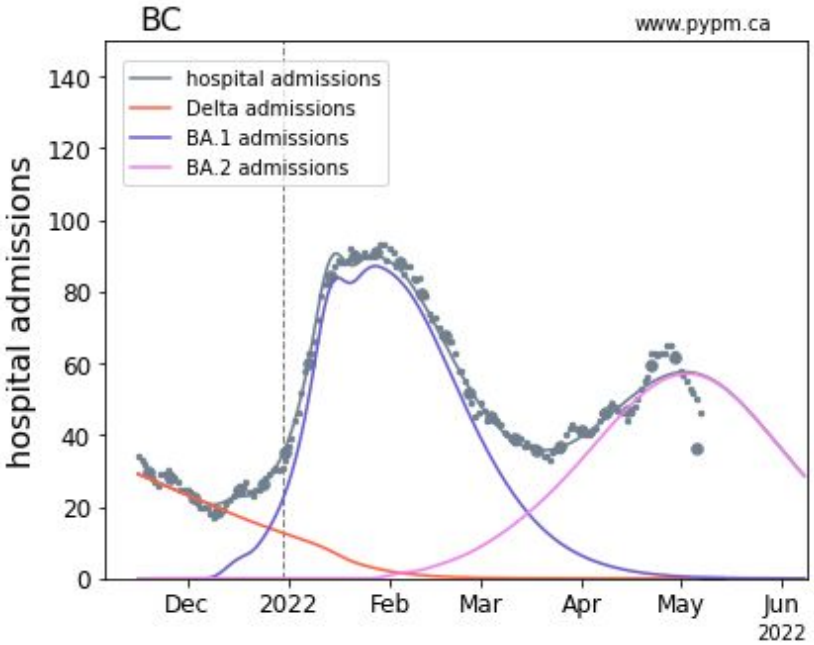
Alberta model immunity parameters adjusted:

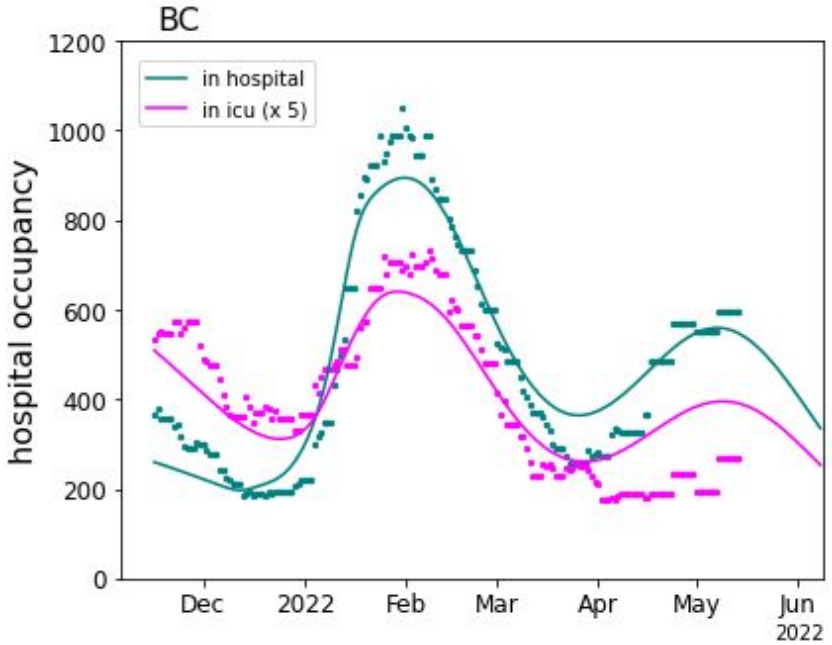
- The probability for BA.2 to produce symptoms set to 60% of Delta.
- The probability that symptoms lead to hospitalization changed from 33% to 40% of Delta.

No adjustments of Manitoba model needed.

Hospital projection for BC

- Hospital admission data derived from BCCDC graphs*.
- Data well described by model with constant transmission rates for BA.1 and BA.2 in 2022.

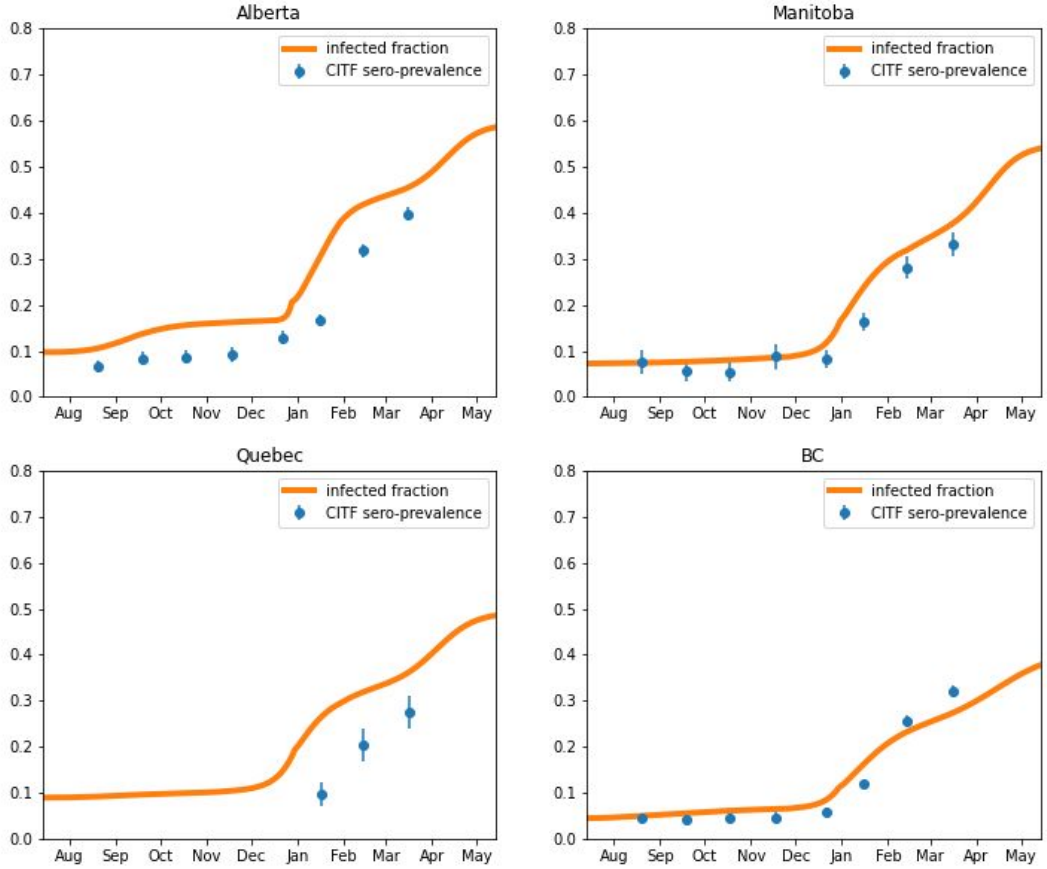




Source (D. Karlen) As in previous reports, the model has no age structure. Two Omicron strains are included (BA.1 includes BA.1.1) with both evading 80% of natural immunity from previous strains and 80% of 2 dose vaccinations. Booster doses are assumed to provide 80% effectiveness against infection. Omicron BA.1 and BA.2 infections are assumed to produce symptoms with a probability of 60% of that for previous strains. The probability that symptoms lead to hospitalization is 35% of that for previous strains. Vertical lines show fitted dates for transmission rate changes. The larger dots show weekly averages.

* Based on daily hospital admissions reported on the BCCDC COVID-19 Surveillance Dashboard (“Outcomes by Vax 2”) , averaging over the fraction of 2- and 3-dose vaccinated and unvaccinated individuals from COVID-19 vaccination in Canada (the small fraction of partially vaccinated individuals were excluded).

Infected fraction of the population (models vs data)



A significant contribution to population immunity has come from Omicron infections.

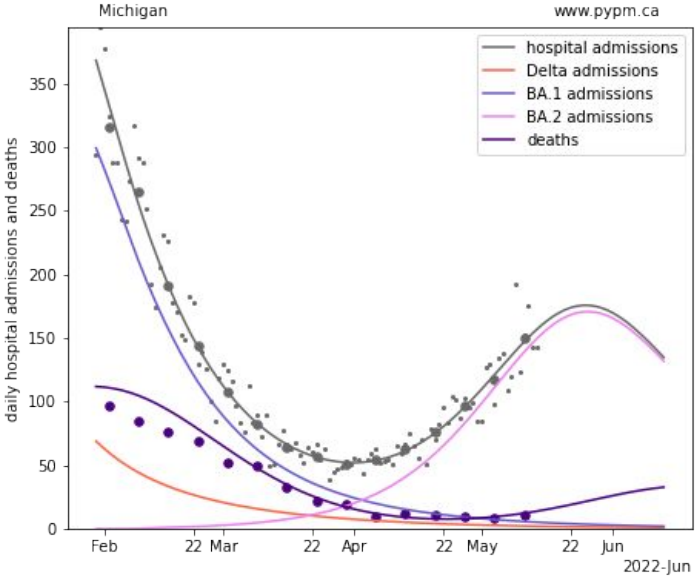
Figures on the left compare model estimates of the fraction of the population ever infected by COVID-19 (yellow curves) to data collected by the CITF representing infection rates in blood donors.

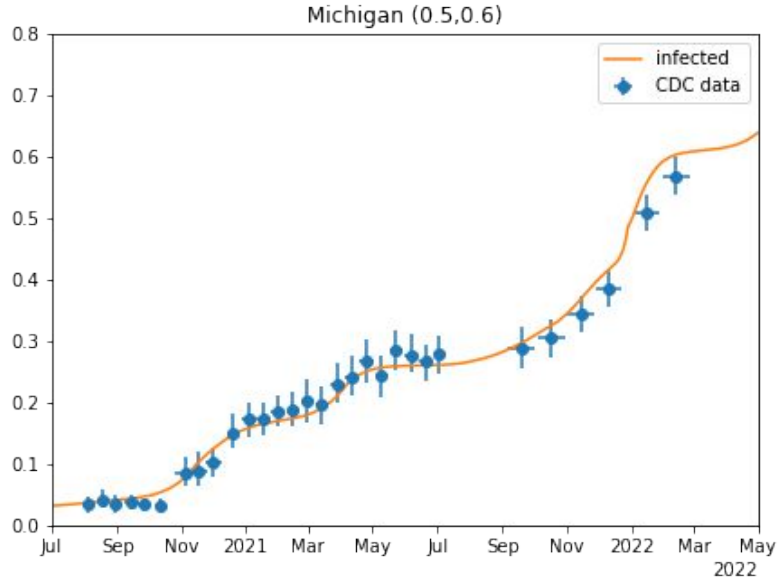
Models for Alberta and Quebec appear to have higher infected fractions than seen in data.

Source (D. Karlen) Model curves are from the updated models shown in the previous pages.

Analyses of US States

- Unlike BC, AB, MB, and QC, almost all US states have yet to reach peak hospital admissions.
- See www.pypm.ca. Right figure: fraction of population infected in model (yellow curve) compared to anti-nucleocapsid sero-prevalence data from CDC (blue points).
  - Omicron infections provide natural immunity to a large fraction of the US population.



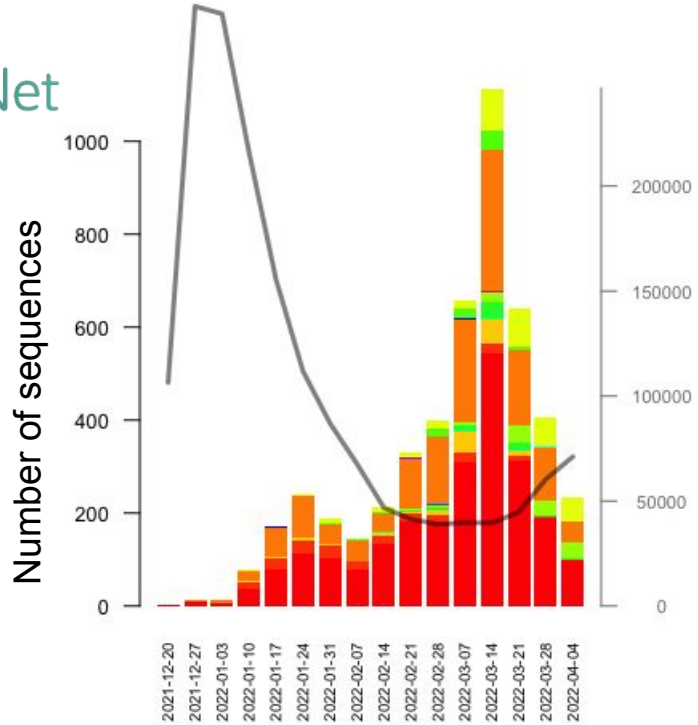


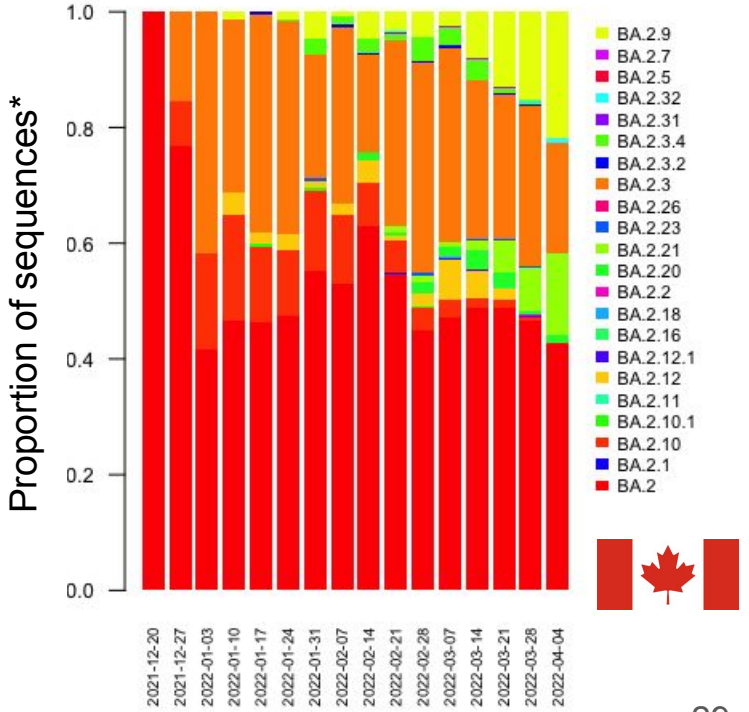
Source (D. Karlen) As in previous reports, the model has no age structure. Two Omicron strains are included (BA.1 includes BA.1.1) with both evading 80% of natural immunity from previous strains and 80% of 2 dose vaccinations. Booster doses are assumed to provide 80% effectiveness against infection. Omicron BA.1 and BA.2 infections are assumed to produce symptoms with a probability of 60% of that for previous strains. The probability that symptoms lead to hospitalization is 30% of that for previous strains. Vertical lines show fitted dates for transmission rate changes. The larger dots show weekly averages. See: https://pypm.github.io/home/docs/studies/usa20220515/

Keeping an Eye out for New Variants of Concern

COVID-19 continues to evolve and diversify, with over 20 BA.2 sublineages found in Canada. CoVaRR-Net (Coronavirus Variants Rapid Response Network) tracks these lineages in Canada and evaluates the risk of increased transmissibility, likelihood of causing severe disease, and resistance to vaccines.

CoVaRR-Net



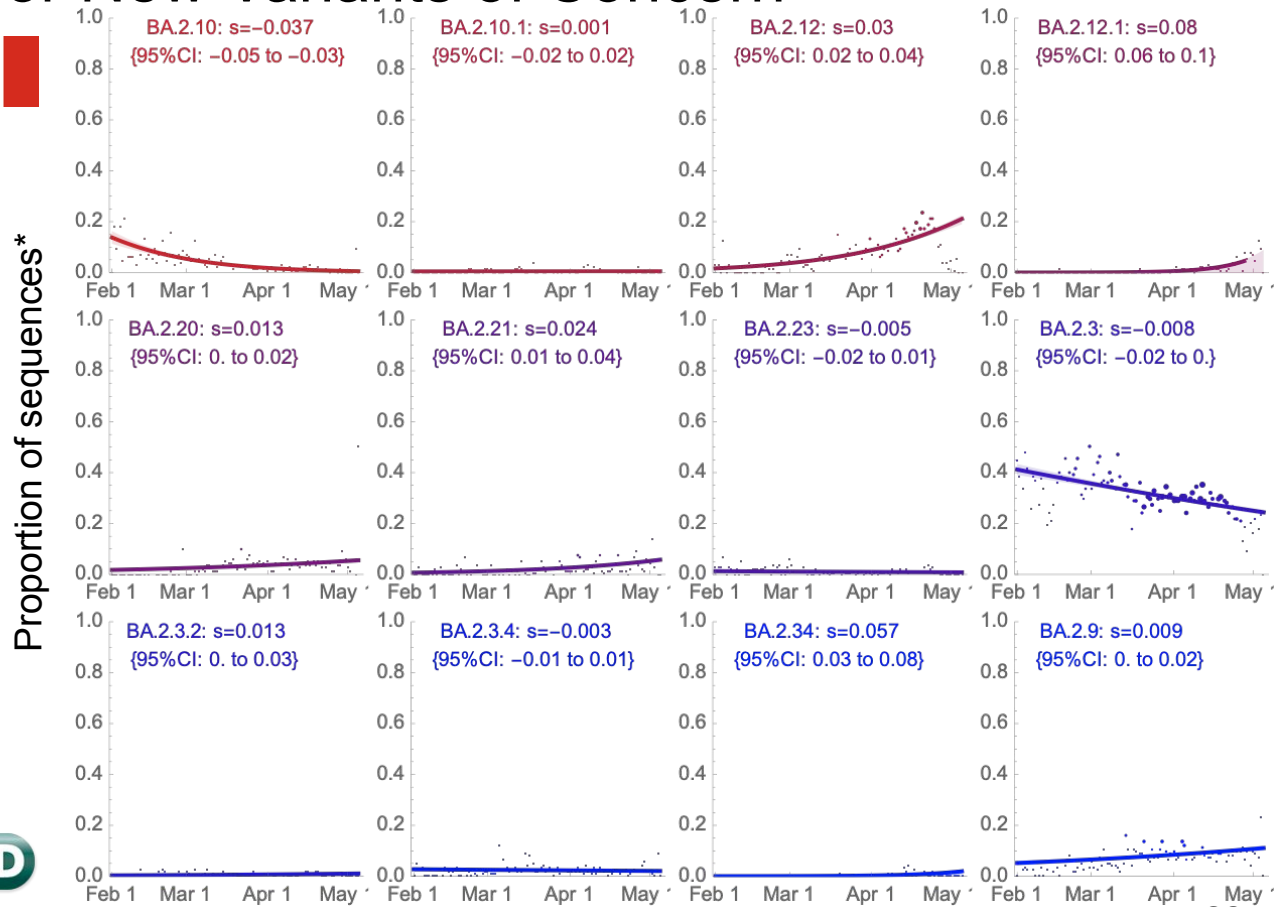


Source: CoVaRR-Net Modelling Resources link. *Proportions are out of all BA.2 sequences per week (based on date of sample collection).

Keeping an Eye out for New Variants of Concern

Here we estimate the daily selective advantage, *s*, of all sublineages of BA.2 that have totalled at least 50 sequenced cases in Canada, measured relative to the main BA.2 lineage (see Appendix).

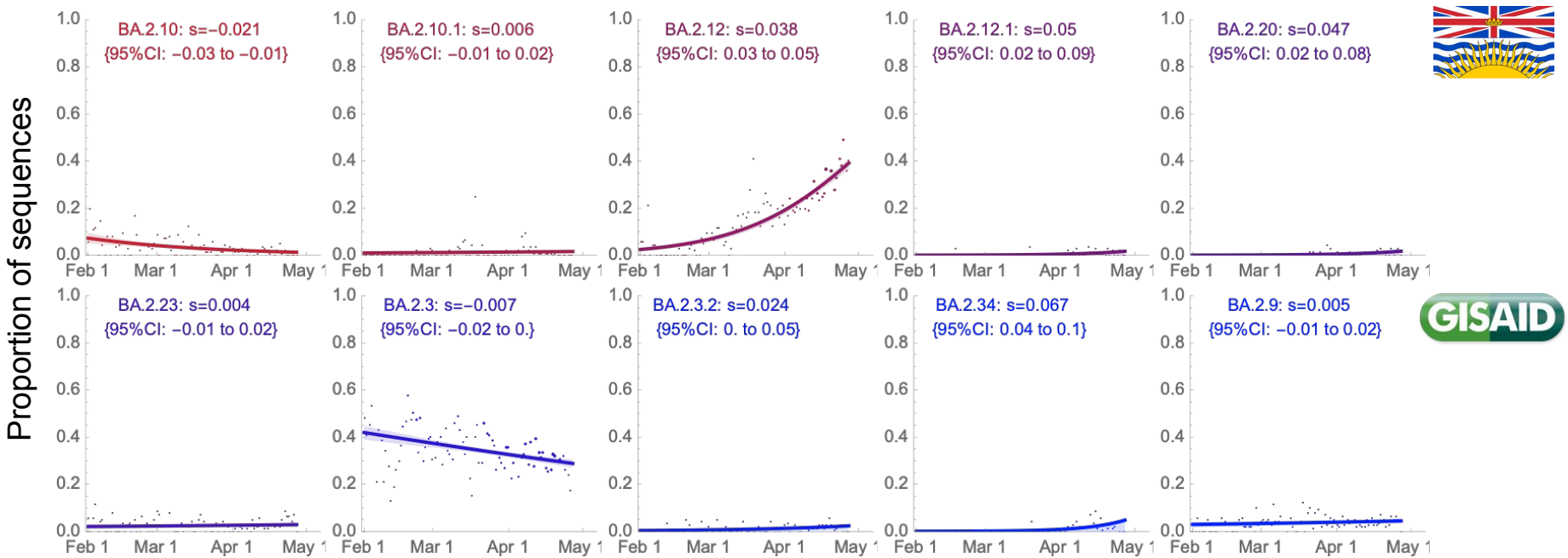
→ BA.2.12.1 currently shows the highest rate of growth (*s* = 8%), but numbers are low and mixing across provinces can cause shifts in frequency that mislead estimates of selection.



Source (S. Otto): Canada sequences for Omicron (GRA clade) were downloaded from GISAID on 16 May 2022. See methods at the CoVaRR-Net Modelling Resources link.
*Proportion is out of target and reference strains (e.g., proportion of BA.2.10 out of BA.2.10 and BA.2).

Keeping an Eye out for New Variants of Concern

Here we estimate the daily selective advantage, *s*, of all sublineages of BA.2 in British Columbia that have totalled at least 20 sequenced cases, all measured relative to the main BA.2 lineage (see Appendix).



→ Rates of selective spread of current variants are modest (a few % per day), and some are based on very few cases (e.g., BA.2.12.1 and BA.2.34), but we will continue to monitor.

Source (S. Otto): BC sequences for Omicron (GRA clade) were downloaded from GISAID on 16 May 2022. See methods at the CoVaRR-Net Modelling Resources link.
*Proportion is out of target and reference strains (e.g., proportion of BA.2.10 out of BA.2.10 and BA.2).

Omicron lineages BA.4 and BA.5

→ BA.4 and BA.5 are very similar to BA.2 (see diagram of spike mutations) but are distinguished because they lack some of the mutations characteristic of BA.2 (like S:Q493, NSP4 L438 and Orf6 D61), suggesting that they branched off earlier in the evolution of Omicron.

→ BA.4 and BA.5 show evidence of being better able to evade immune responses (Kahn et al., potentially due to **S:L452R also found in Delta and BA.2.12.1**)

Small number of cases so far in Canada*

- BA.4: 7 Canada (2 in BC) & 1567 global
- BA.5: 1 Canada (a traveller) & 1029 global

BA.4 & BA.5 are spreading faster than BA.2 in South Africa (~10% selection per day; Tegally et al.), but immunity from BA.1 wave is waning & BA.2 wave was negligible there, so the consequences for Canada are uncertain.

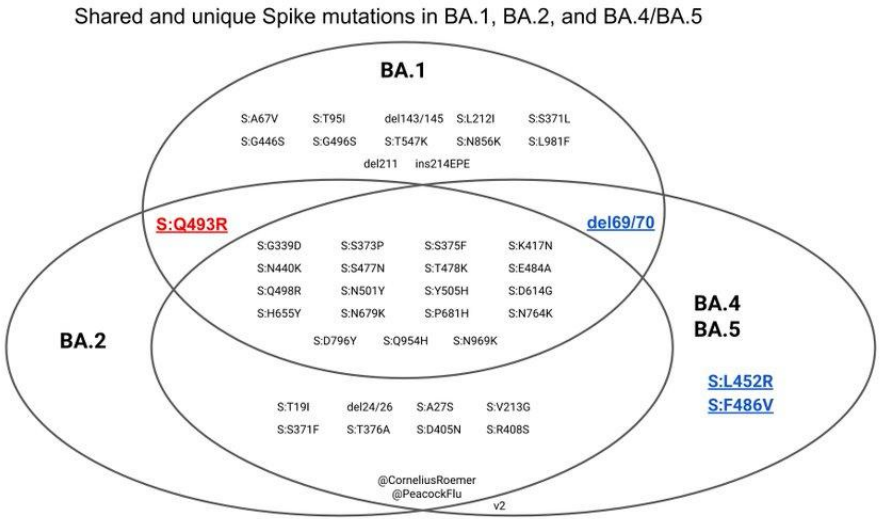


Diagram of spike mutations distinguishing Omicron lineages from Cornelius Roemer.

Source: *GISAID 16 May 2022

Key messages

State of the Omicron wave in BC:

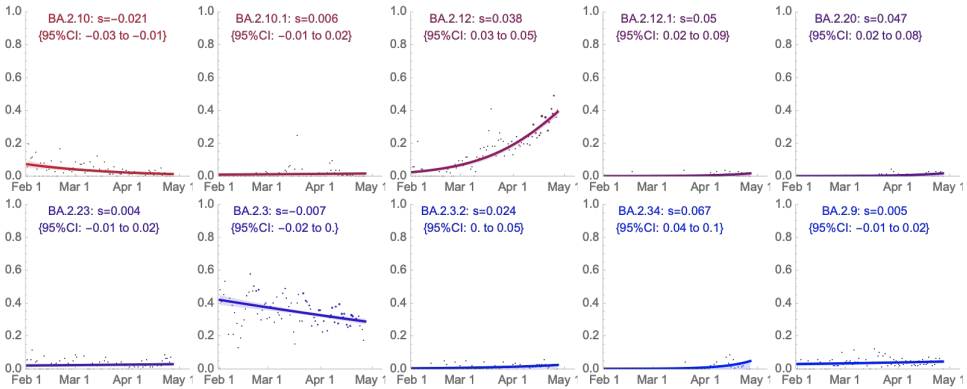
- The BA.2 wave appears to have peaked or is near its peak in BC and across Canada.
    - The smaller peaks for BA.2, despite its transmission advantage over BA.1, was predicted in our previous reports. In the models, the smaller peaks are due to natural immunity from Omicron infections and enhanced vaccination immunity from boosters. The BC hospital admission data are well described by a model having constant transmission rates for BA.1 and BA.2 in 2022.
    - Serology data provides a useful benchmark of the number of infections, for comparison in models and data analyses. Based on the CITF data set projected to the present, approximately 40% of BC have had COVID-19.
- BA.2 is now the most common variant in BC and Canada (>98%). While some BA.2 sublineages show signs of spreading faster than others, the differences are so far modest in BC (with BA.2.12.1 growing the fastest).

Appendix: Interpreting selection

What is "*s*" and what does it mean to be modest?

s measures the selective advantage per day relative to a reference strain (e.g., measuring the rate of spread of BA.2.12 relative to BA.2)*.

By modest, we mean that a strain will take about a month to double in relative frequency.



* Selection per day, *s*, satisfies $X_T = \text{Exp}(s\,T)\,X_0$ where X_T is the frequency of a lineage of interest relative to the frequency of a reference strain on day T (e.g., X_T = freq(BA.2.12)/freq(BA.2)). *s* is estimated from the numbers of sequences of the two types over time by maximizing the likelihood of observing the data (see link).

Daily selective advantage, *s* →

1%	2%	5%	10%	20%
69.3	34.7	13.9	6.9	3.5

← Days to double in frequency relative to reference strain

These sub-variants vs BA.2 Alpha vs Wuhan Omicron vs Delta

Source (S. Otto): BC sequences for Omicron (GRA clade) were downloaded from GISAID on 16 May 2022. See methods at the CoVaRR-Net Modelling Resources link