

COVID Model Projections

August 17, 2022

BC COVID-19 Modelling Group

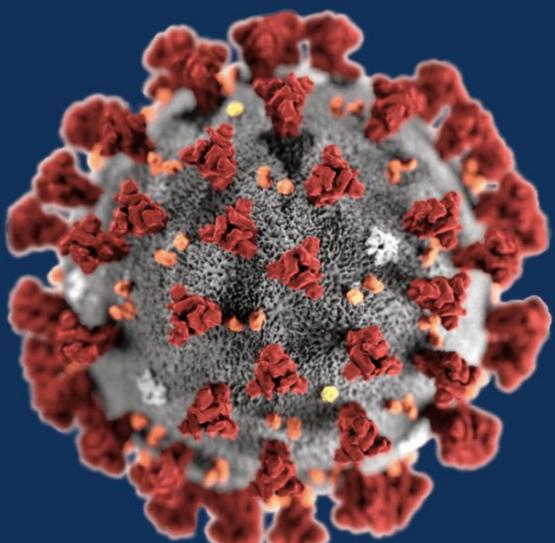
[@bcCOVID19group](https://twitter.com/bcCOVID19group)



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

Sarah Otto (UBC, co-editor)
Eric Cytrynbaum (UBC)
Dean Karlen (UVic and TRIUMF)
Jens von Bergmann (MountainMath)
Caroline Colijn (SFU)
Rob James (evidently.ca)
Rob DuMont
Ailene MacPherson (SFU)
James Colliander (UBC and PIMS)
Daniel McDonald (UBC)
Daniel Coombs (UBC)
Elisha Are (SFU)
Bryn Wiley (UBC)

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

Overview

Contents of this report:

- Current COVID-19 trends in BC
- The rise and fall of Omicron BA.4 & BA.5
- Interpretation of COVID-19 hospital admission data and long-term projections
- The future of the BC COVID-19 Modelling team

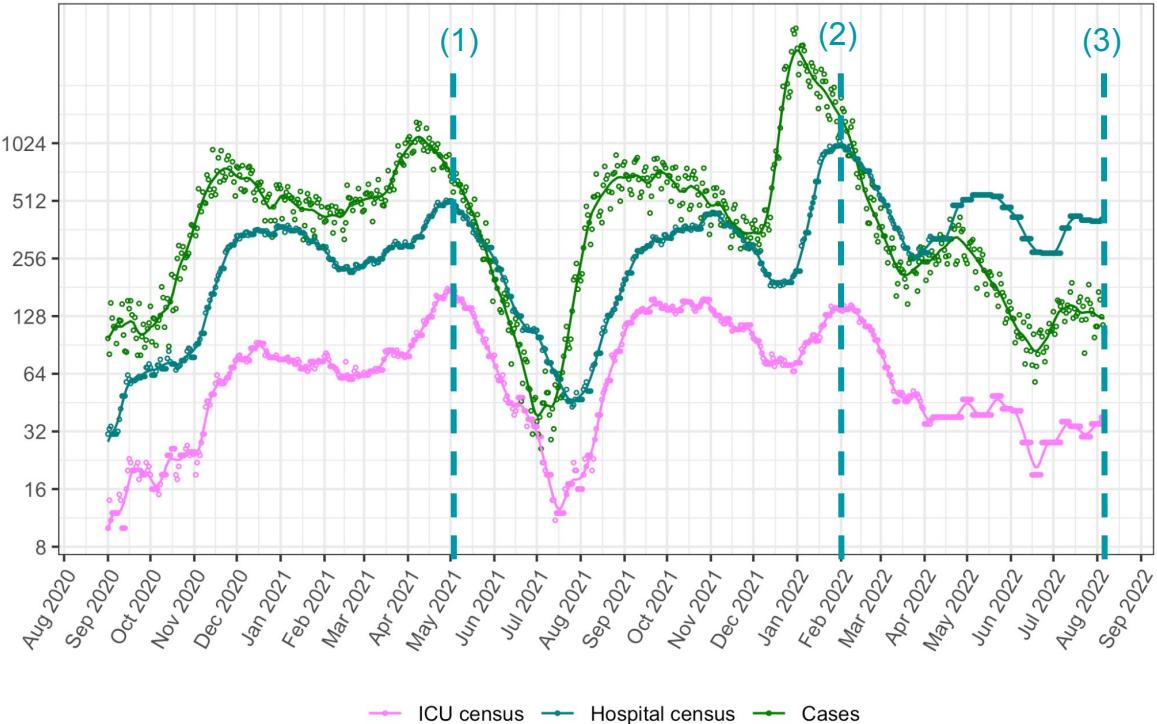
OLD

Summary: The BA.5-driven Omicron wave has risen and fallen in BC and across Canada and is being caused by a faster rate of spread by the BA.5 variant. The number of infections and severe cases leading to hospitalization are expected to rise through July. The height of the BA.5 wave and its impact are challenging to predict.

Current COVID-19 trends in BC

Hospital trends in BC

British Columbia COVID-19 cases, hospital and ICU census



Reported case numbers are rising, while the number of people in hospital and ICU are no longer declining in BC (see Appendix for data on admissions and deaths).

Number in hospital with COVID-19:

Pre-Omicron

(1) Highest = 515 (28 April 2021)

Omicron wave:

(2) Highest = 1038 (31 January 2022)

(3) Current = 385

Data: BCCDC for cases, Canada Covid-19 tracker for hospital and ICU census

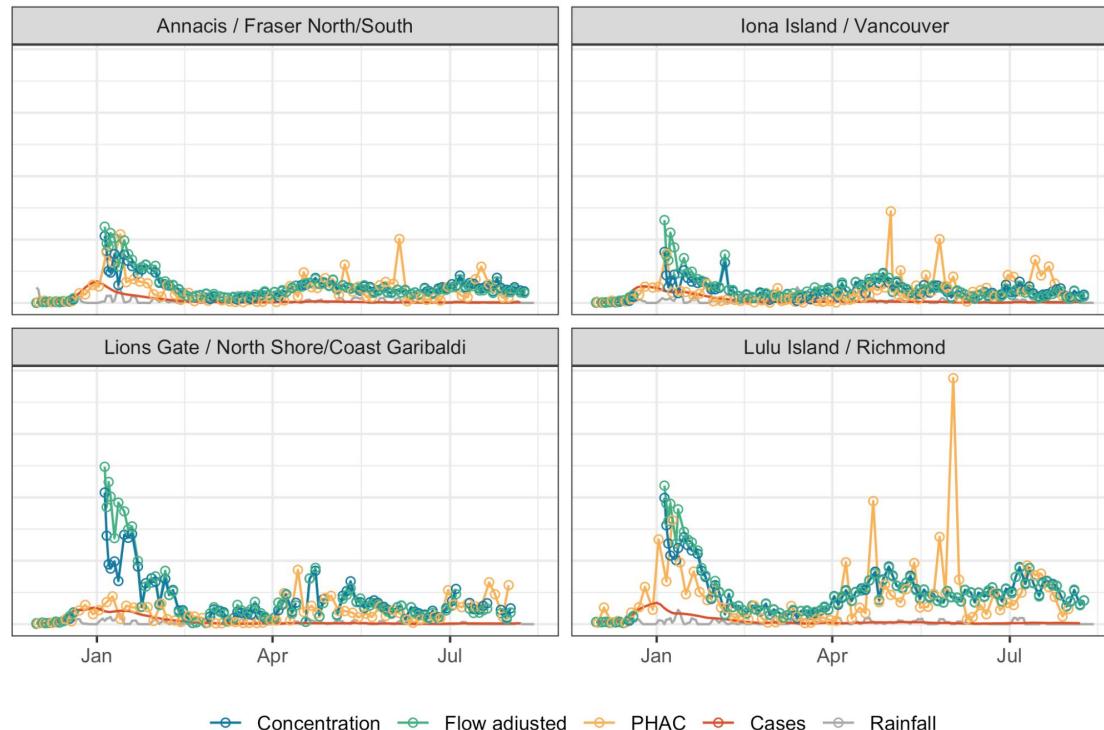
Wastewater trends in Metro Vancouver

Wastewater signals are also showing signs of a rising number of Omicron infections.

But wastewater data are noisy and best contribute to a joint estimate of infections, along with data on reported cases and hospital admissions.

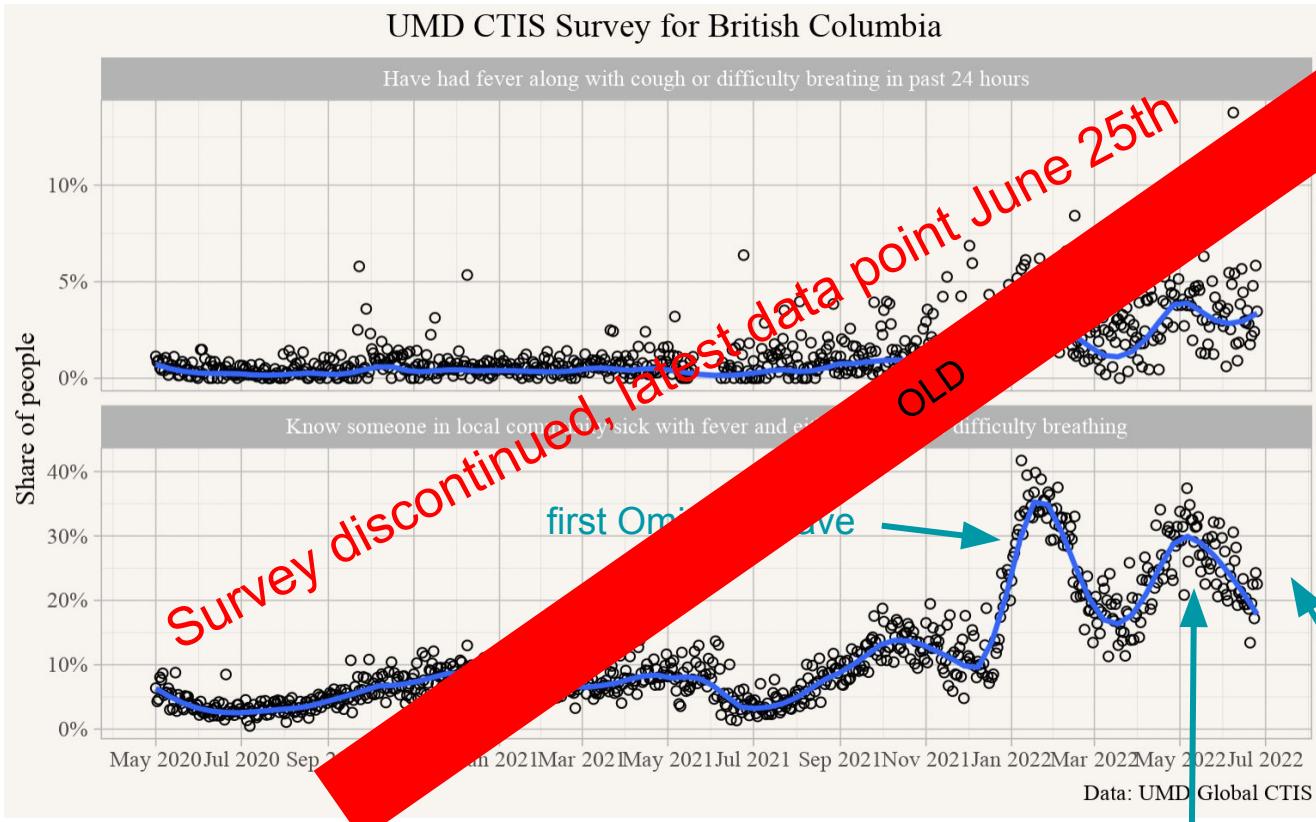
We request that the province provide the raw data for wastewater and updated hospital admissions across time for a **more timely and unbiased estimate of current COVID-19 infections.**

Recent wastewater COVID concentration vs case counts



— Concentration — Flow adjusted — PHAC — Cases — Rainfall

Survey of COVID-19 trends in Metro Vancouver



The [COVID-19 Trends and Impact survey](#), in collaboration with Facebook, was an alternative source of information as individuals shared information about their infections (top) or about others who are infected (bottom) with COVID-19*.

Unfortunately, this social-media data on infections is no longer being collected.

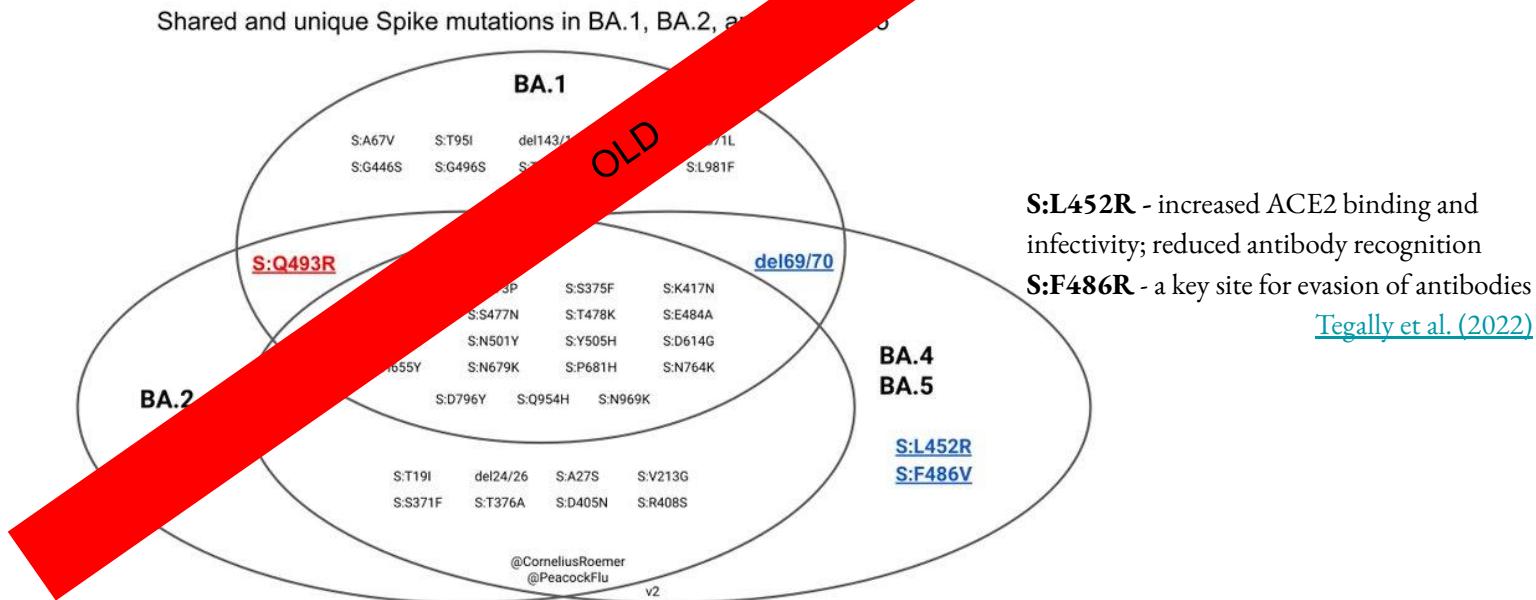
no data for third Omicron wave

The Rise of Omicron BA.4 & BA.5

Omicron lineages BA.4 and BA.5

What is driving this rise in cases? The more rapid spread of BA.4 and BA.5, particularly BA.5.

BA.4 and BA.5 are sub-lineages of Omicron that share many mutations with BA.1. This diagram shows shared mutations in the spike protein ("S:") have previously been associated with increased infectivity and immune evasion.



Omicron Sub-Lineages

Early data from South Africa suggests an 8% per day selective advantage for BA.4 and 12% for BA.5 ([Tegally et al. 2022](#)), relative to BA.2. Similar rates of spread are observed across the United States (see Appendix).

Faster spread may result from a combination of **higher inherent transmissibility and immune evasion** ([Khan et al. 2022](#); [Hachmann et al. 2022](#)).

Together, BA.4 & BA.5 comprise ~80% of global infections [July 8 covSPECTRUM]

Global proportion

Estimated proportion through time



$$s = 9\% \text{ per day}$$

83% per week

Current adv. 

79-
86%

Confidence int. 

Estimated proportion through time



$$s = 12\% \text{ per day}$$

122% per week

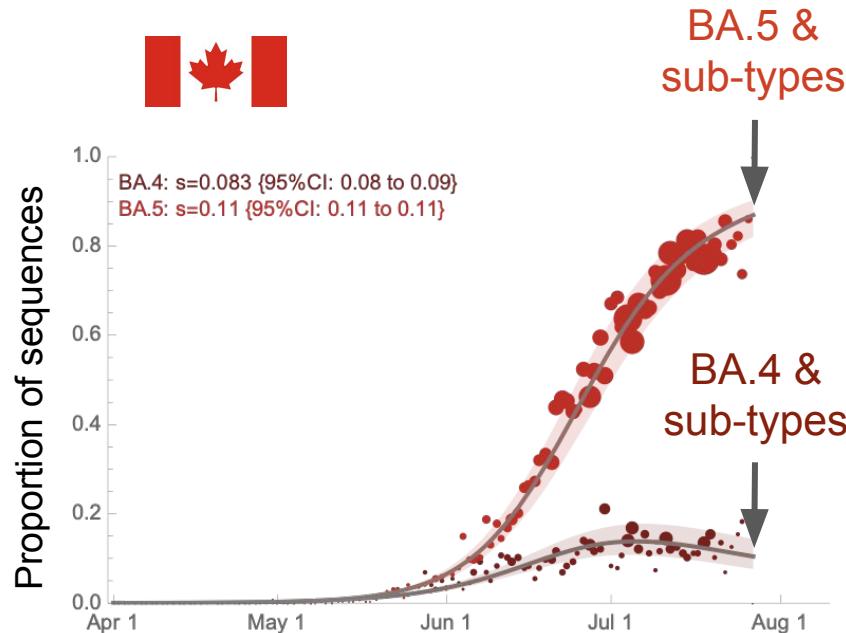
Current adv. 

117-
126%

Confidence int. 

Spread of Omicron sub-lineages in Canada

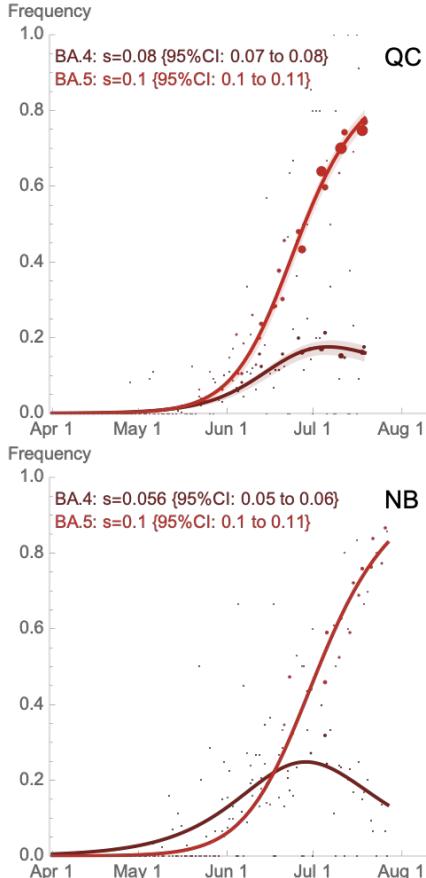
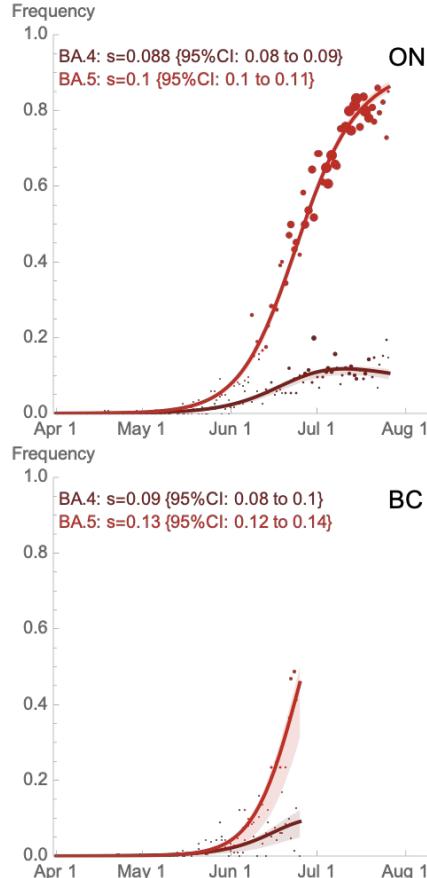
→ BA.5 (and its many sub-types, including BE.# and BF.#) are now predominant across Canada.



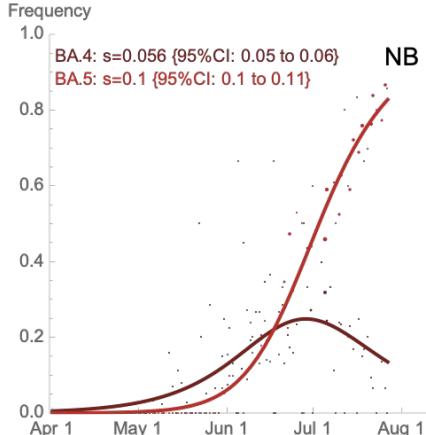
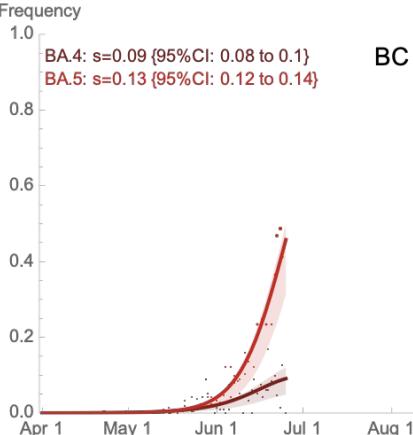
Source (S. Otto) Canadian metadata was downloaded from GISAID for the Omicron GRA clades (Alberta sequences were removed as AB first identifies variants and preferentially sequences some subtypes). A model of selection was fit to the numbers of each type using maximum likelihood based on a trinomial distribution given the expected frequencies on each day. Hessian matrix used to obtain confidence intervals.

Spread of Omicron sub-lineages in Canada

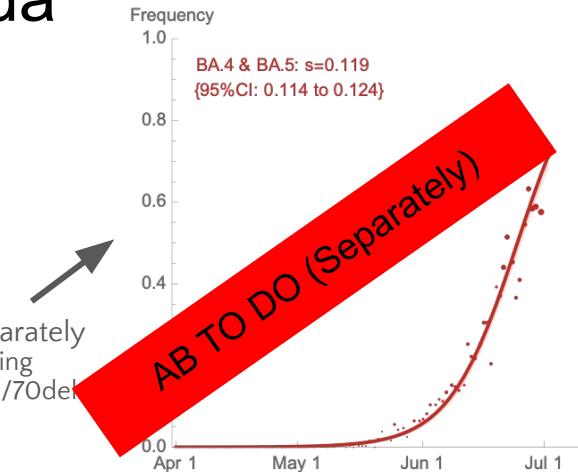
Proportion of sequences



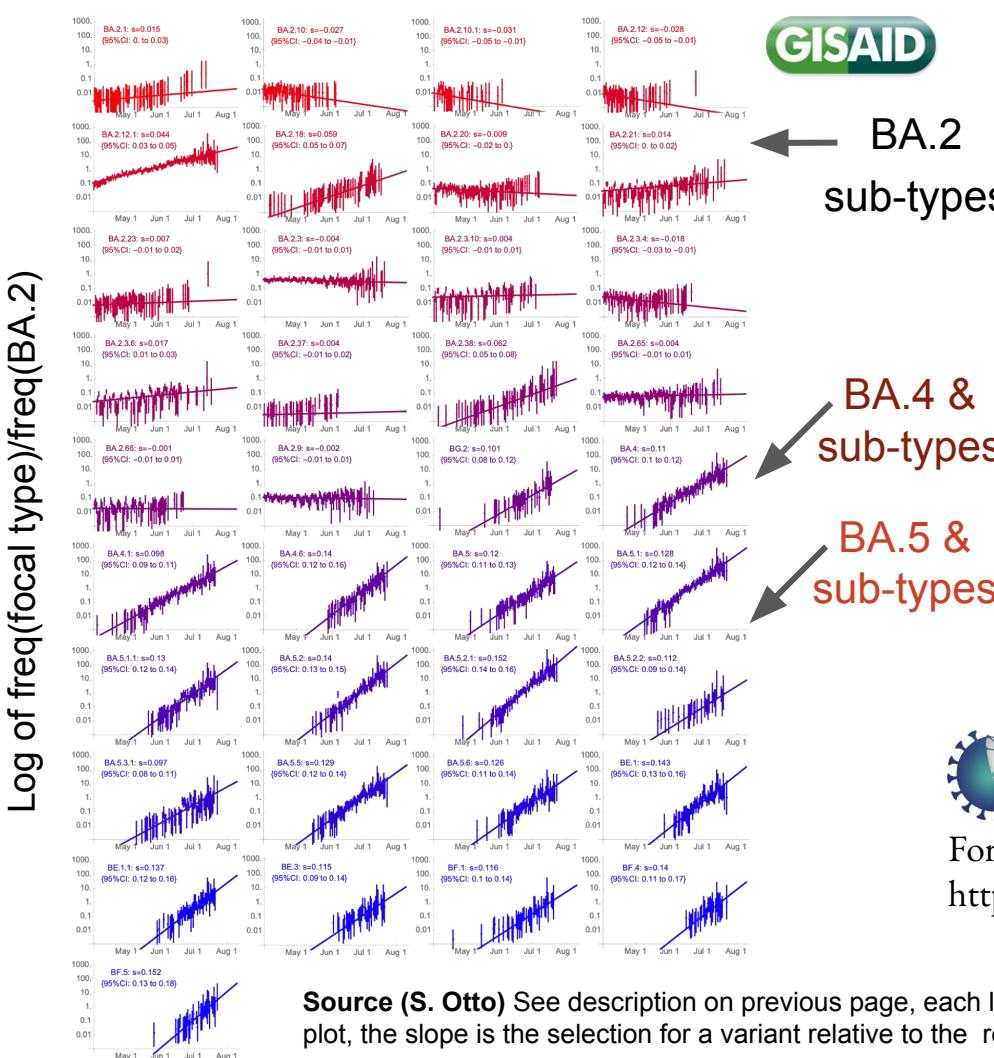
BC



Alberta analysed separately
(based on PCR typing
combining recent S:69/70del
as BA.4 & BA.5)



**Provinces show similar trends,
with BA.5# now dominating.**



We are tracking the spread of different variants across the country.

Some sub-lineages of BA.5 (e.g., BA.5.2, BE.# & BF.#) are growing slightly faster (steeper slopes in graphs to the left), but no lineage is showing substantially faster growth than BA.5.



CoVaRR⁺Net

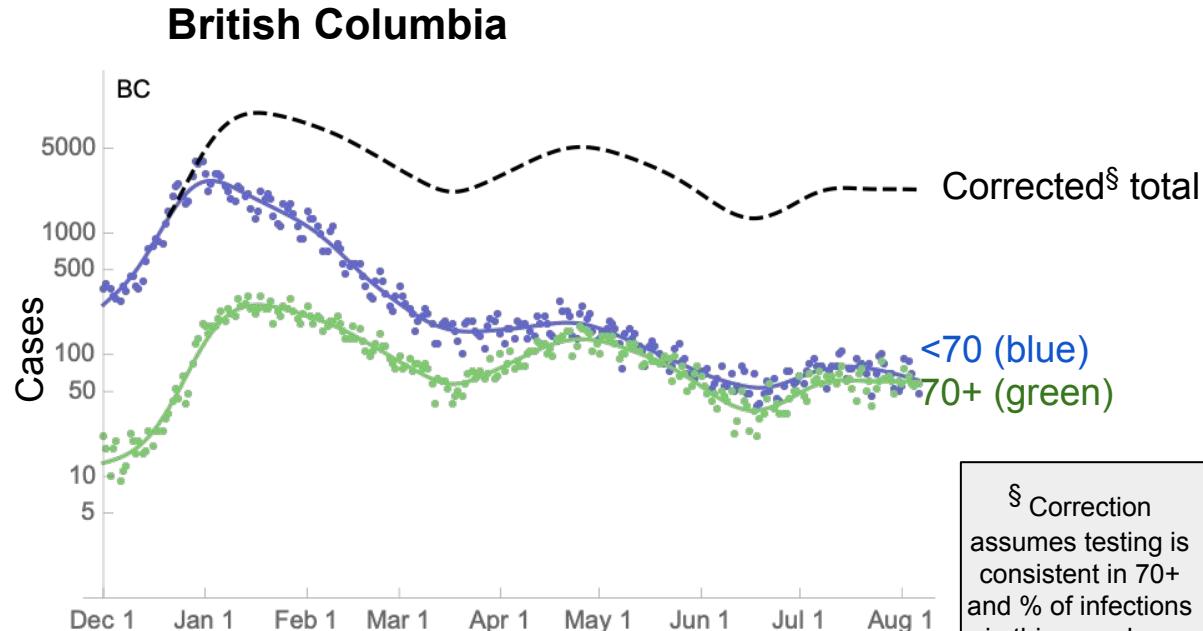
For updates on variants in Canada, see CoVaRR-Net's duotang:
<https://covarr-net.github.io/duotang/duotang.html>

Implications of the spread of BA.5 for COVID-19 cases

What does this imply for case numbers?

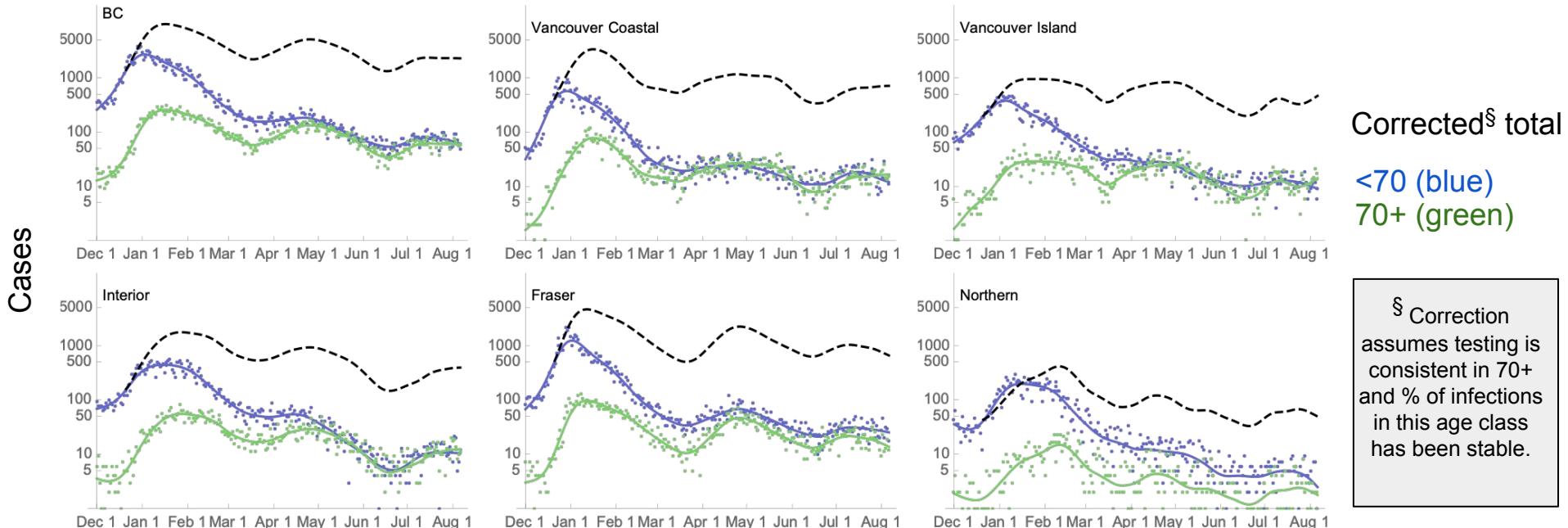
We can use case numbers reported in individuals aged 70+ (green) to assess trends, as this age group has been more consistently tested.

Cases among those 70+ in age are currently stable*.



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

BC: Age-corrected case counts

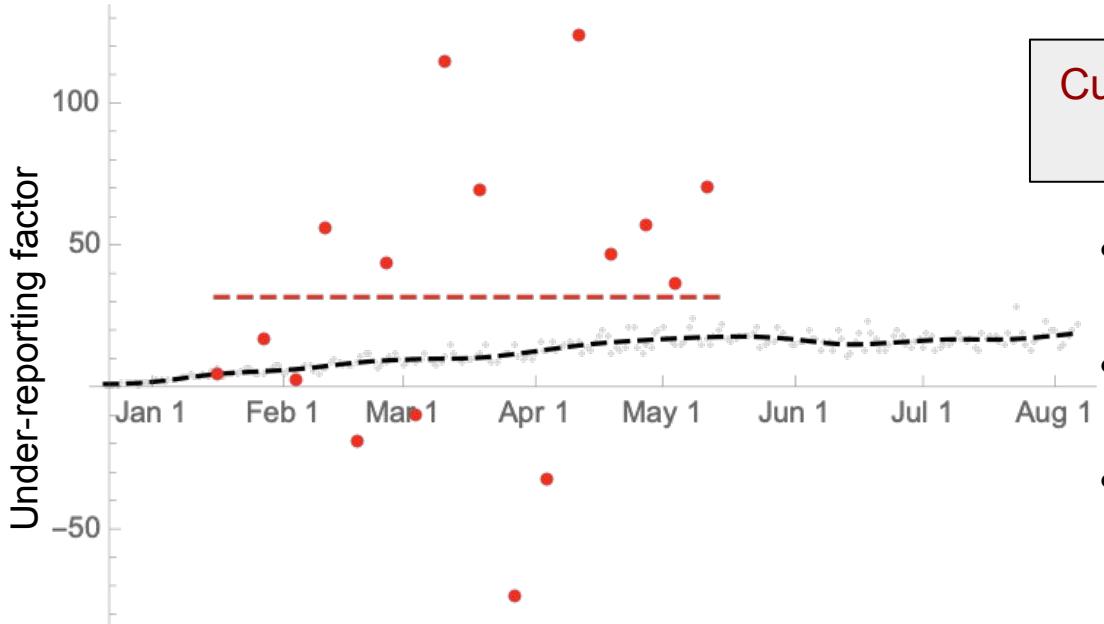


→ Reported cases among those aged 70+ (green) have stabilized across the province.
Black curves provide a rough guide of total cases, had testing continued in all age groups[§].

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: Underreporting

How much are cases under-reported in BC?



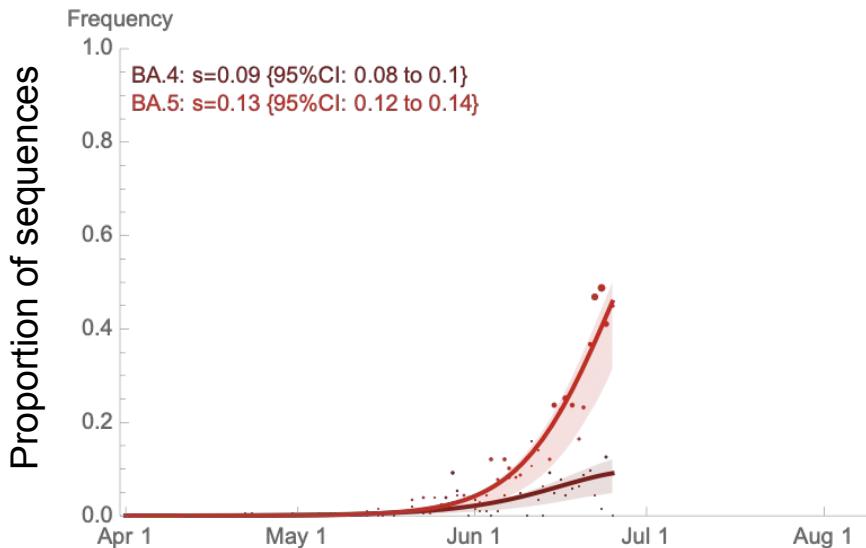
Current underreporting of cases in BC is likely 20-100 fold.

- 20-fold if we assume that the % of infections in the 70% age class has been stable, ignoring under-reporting in this age class (black curve)
- 160-fold if we correct the above by the overall underreporting estimated in BC by Skowronski et al. (2021)
- 32-fold if we use the CITF serology data to estimate the rise in infections among blood donors from the previous sampling period relative to the total reported cases in that period (red dots, dashed gives the mean). Note that the serology data is noisy (!) and blood donors are a non-representative subset of the population.

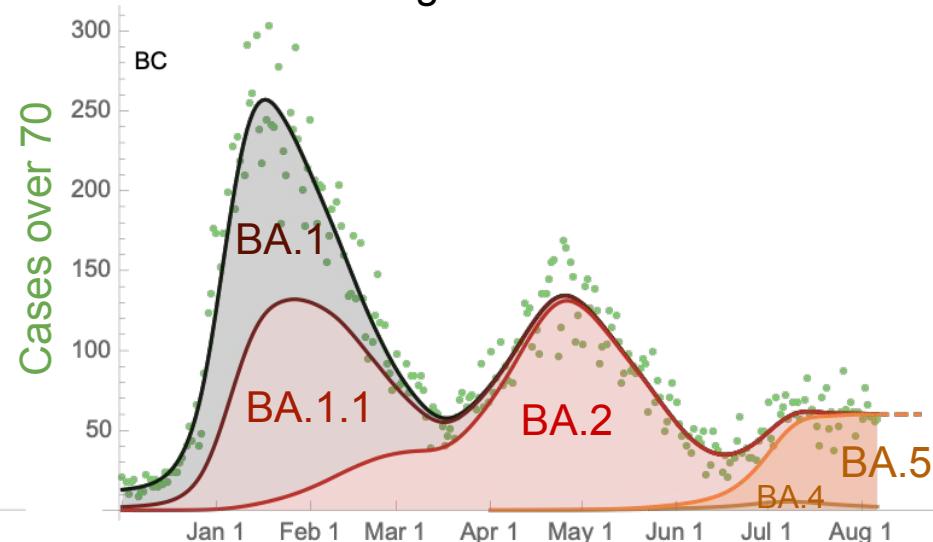
Source (S. Otto) New cases per day in 10-year age groups were downloaded from the [BCCDC COVID-19 data portal](#). Cubic spline fits to log-case data were obtained (curve) and estimates for those <70 obtained by applying the fits for those 70+, shifted up to match the projection for that age class on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

What does this imply for case numbers?

Fitting models of selection allows us to estimate frequency changes among variants.

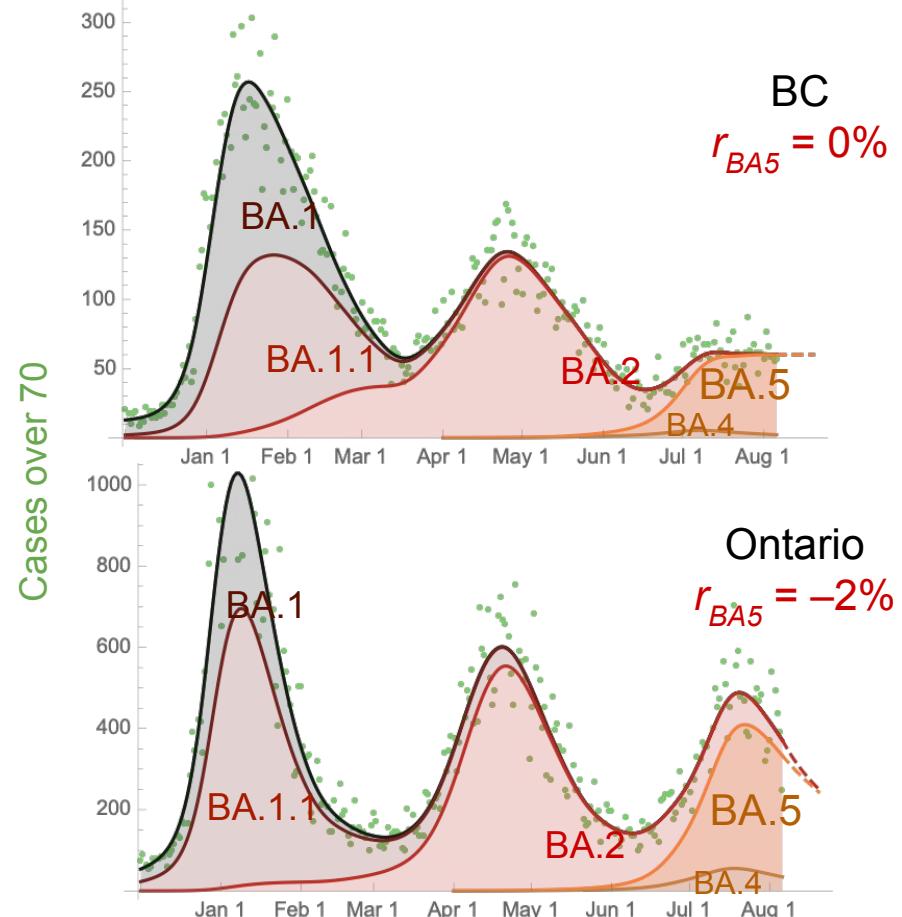


Multiplying by the # of cases in those over 70 allows us to **estimate** growth in numbers of each Omicron sublineage.



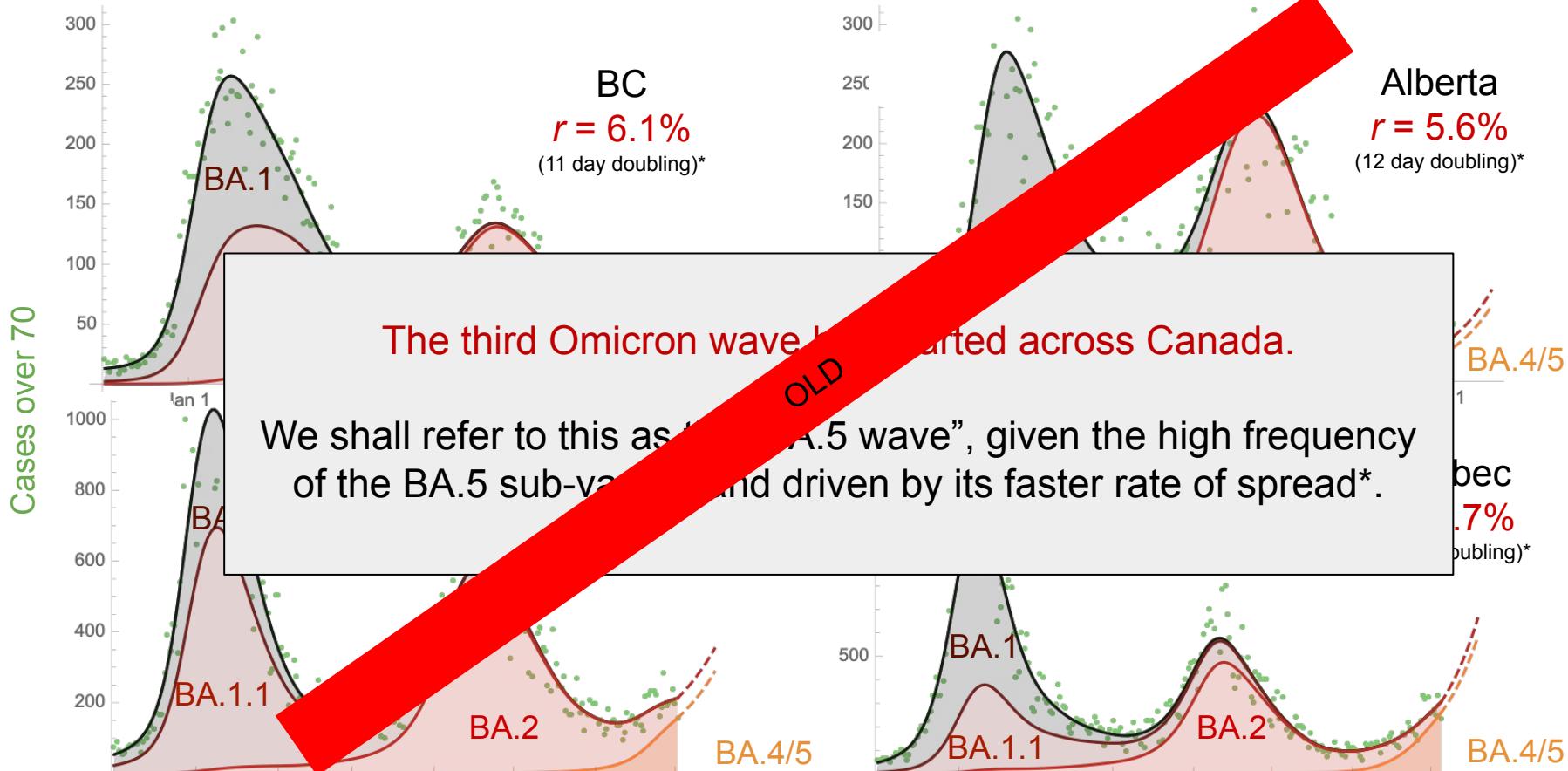
→ Estimated numbers of BA.5 have plateaued. The plateau is more prolonged than expected, consistent with the spread of slightly faster BA.5# sub-variants.

The Third Omicron Wave



* Instantaneous estimates of growth rate, r , and doubling times for BA.4 & BA.5 (mainly BA.5). These rates change with changing immunity and with protective health measures, both mandated and voluntary, to reduce transmission (e.g., wearing effective masks, increasing ventilation, and avoiding crowded indoor spaces)

The Third Omicron Wave



*We predicted that the BA.5 wave would drive a rise in cases around the beginning of July, as observed. These predictions were presented to the Variants of Concern Leadership Group Meeting on June 28, 2022 involving Federal and Provincial Public Health officials (summarized on [Twitter](#)).

Novel approach for modeling population immunity dynamics of the Omicron waves

Projections and Population Immunity

The spread of COVID-19 in 2022 is greatly influenced by population immunity.

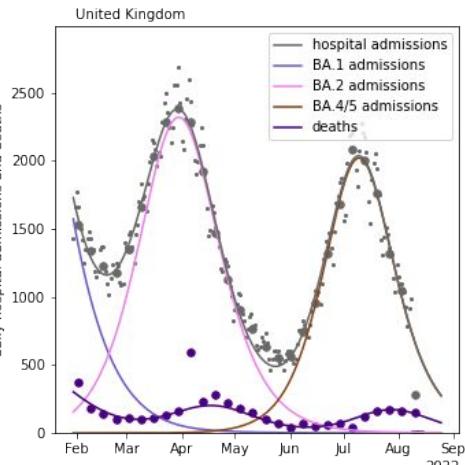
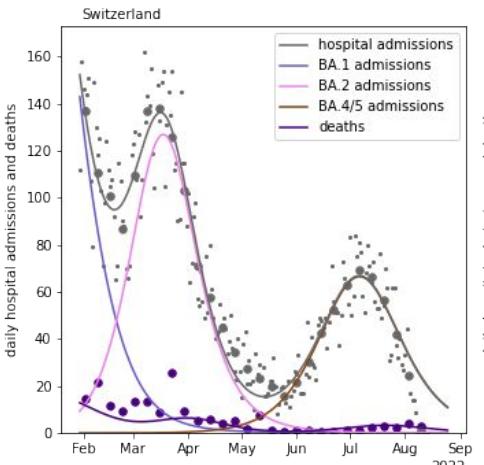
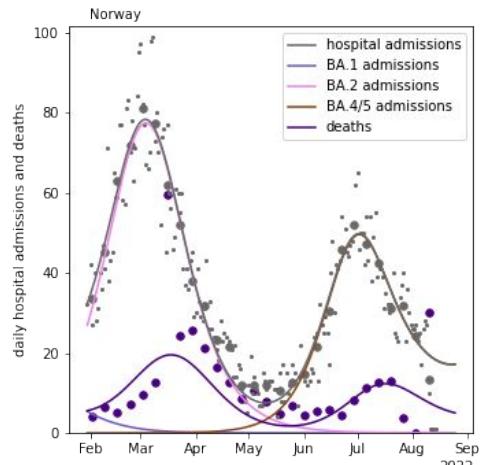
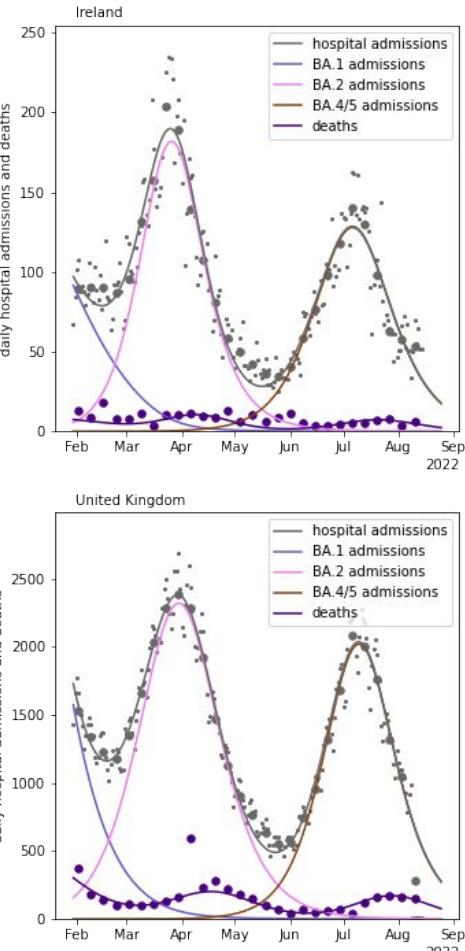
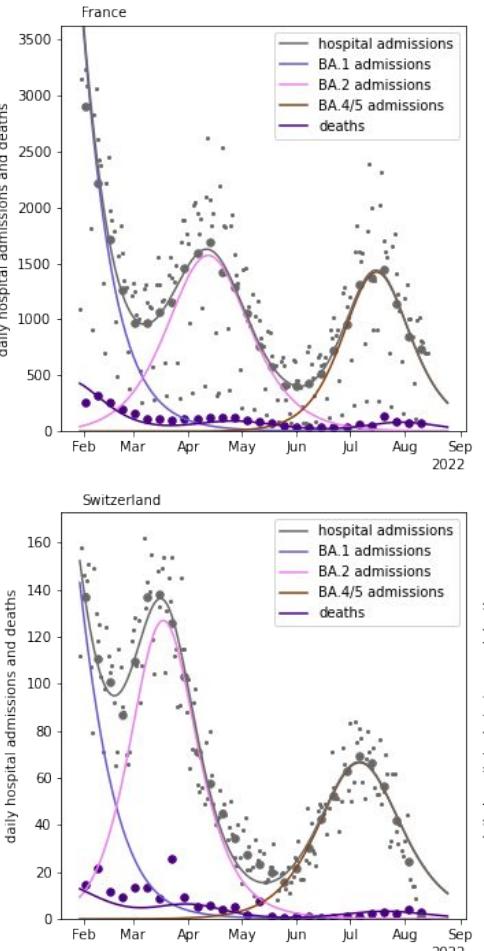
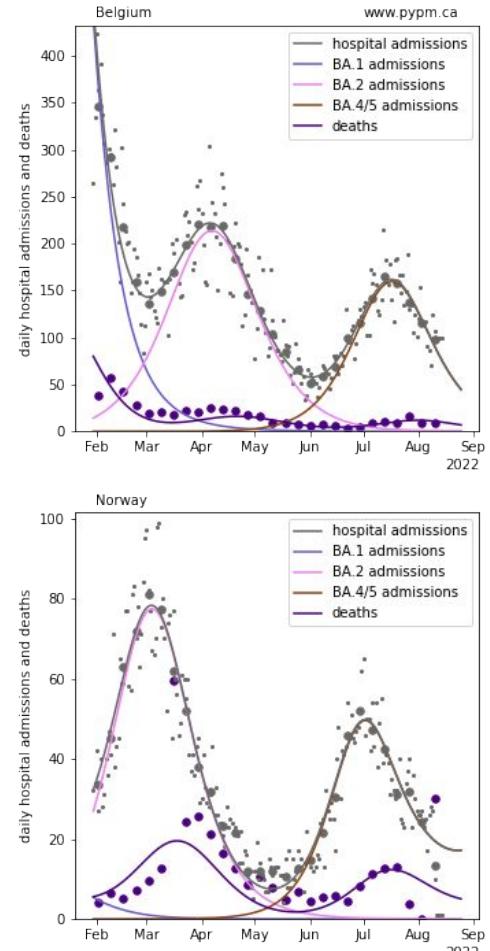
- For example, the turn around in the growth of BA.2 infections happened because of the increasing immunity primarily from new BA.2 infections (and not because of changes to public health measures or personal behaviour).

Estimating population immunity by modeling past infections and vaccination is highly uncertain, due to factors such as immunity effectiveness and waning.

The next slide shows the result of a new approach. Population immunity dynamics are deduced directly from population level data. No assumptions need to be made for immunity effectiveness or waning. Transmission rates are assumed to be constant.

- The approach fits hospital admission data well, with relatively few parameters:
 - Two parameters for each strain, and the hospitalization/infection ratio

European nations with distinct BA.2 and BA.4/5 waves



During the fall of the BA.1 wave, population immunity was very high.

This led to a much smaller wave for BA.2, despite its higher transmission rate.

The shape of the BA.2 wave helps reveal:

- (A) population immunity going into that wave
- (B) the rate at which immunity grew (ie. the number of infections that provide immunity per hospitalization)

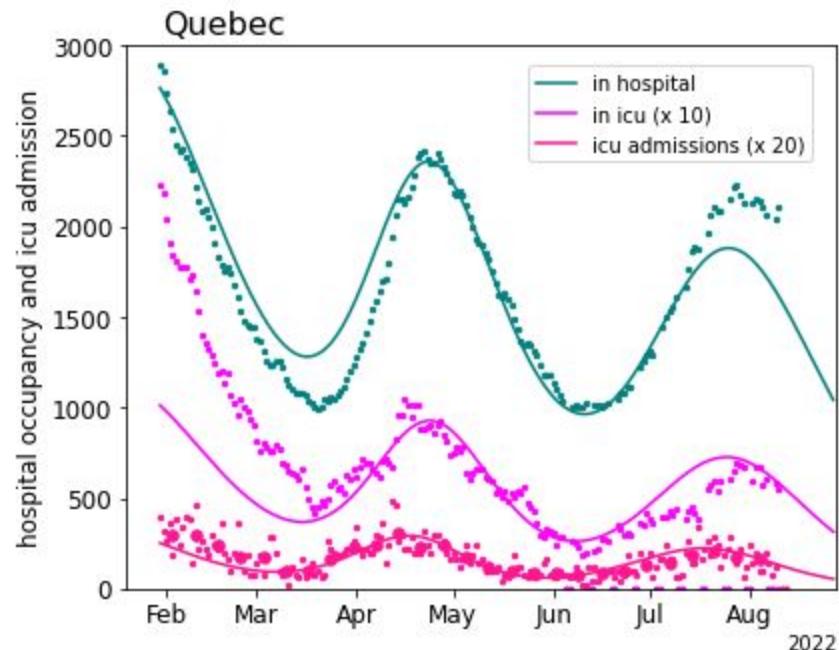
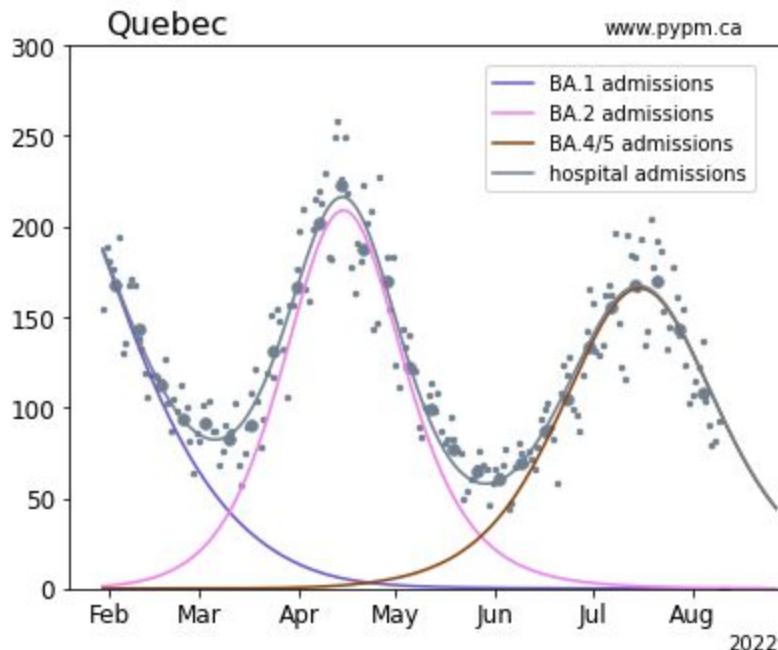
The model allows BA.4/5 to partially escape from immunity, necessary to fit data.

findings

Text to come

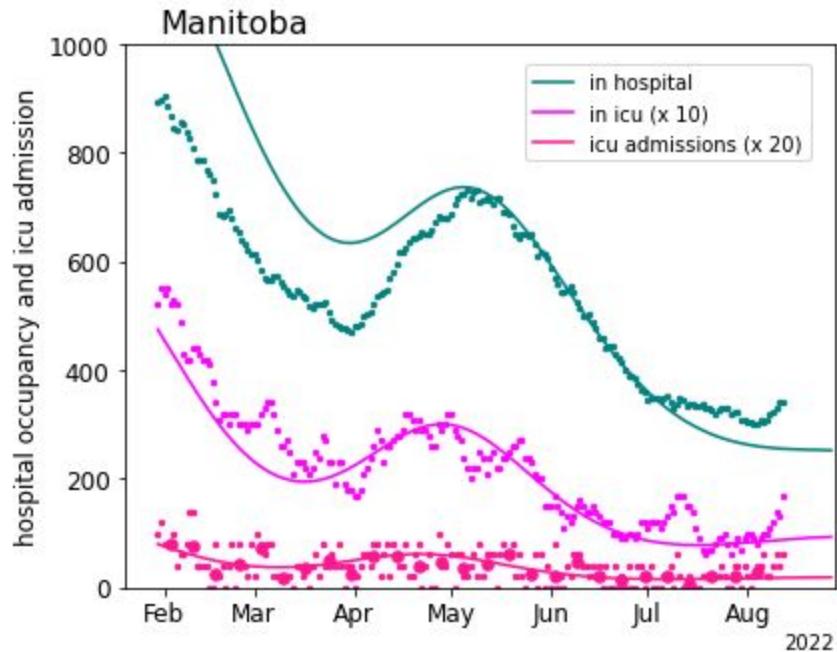
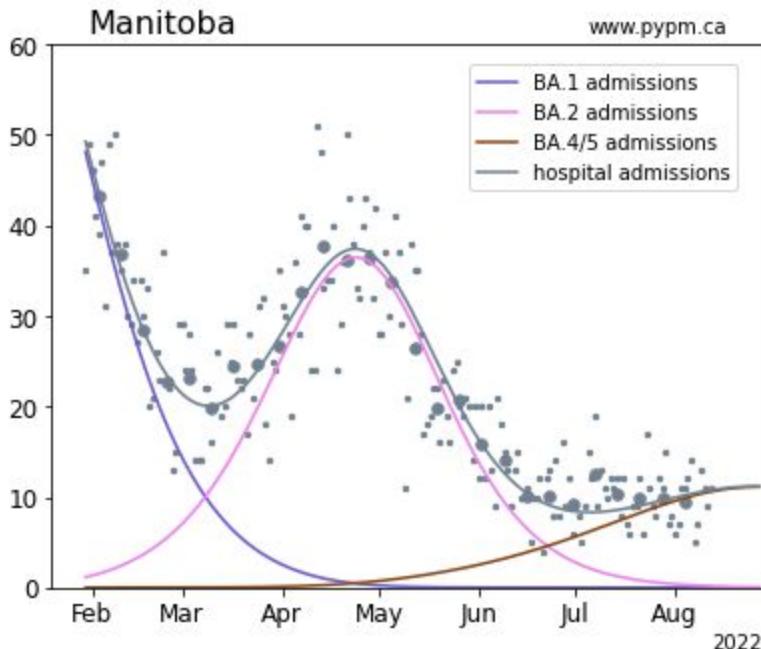
Analysis of Canadian Provincial data using the new approach

Hospital admissions: Quebec

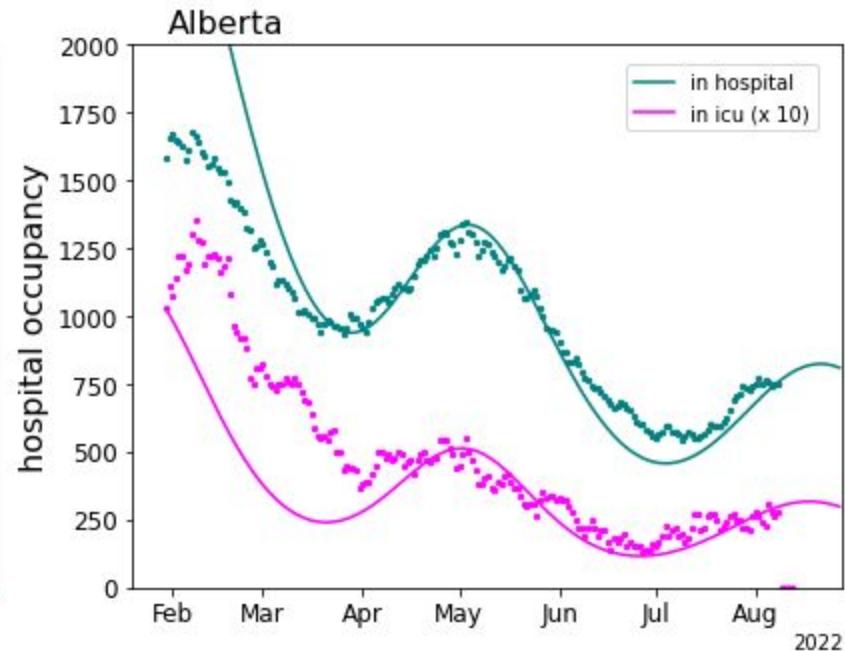
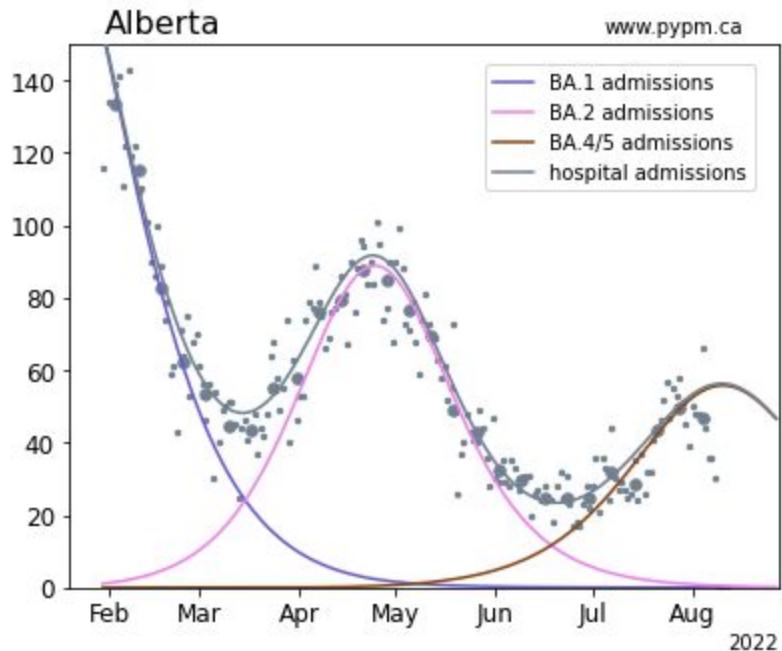


Text to come...

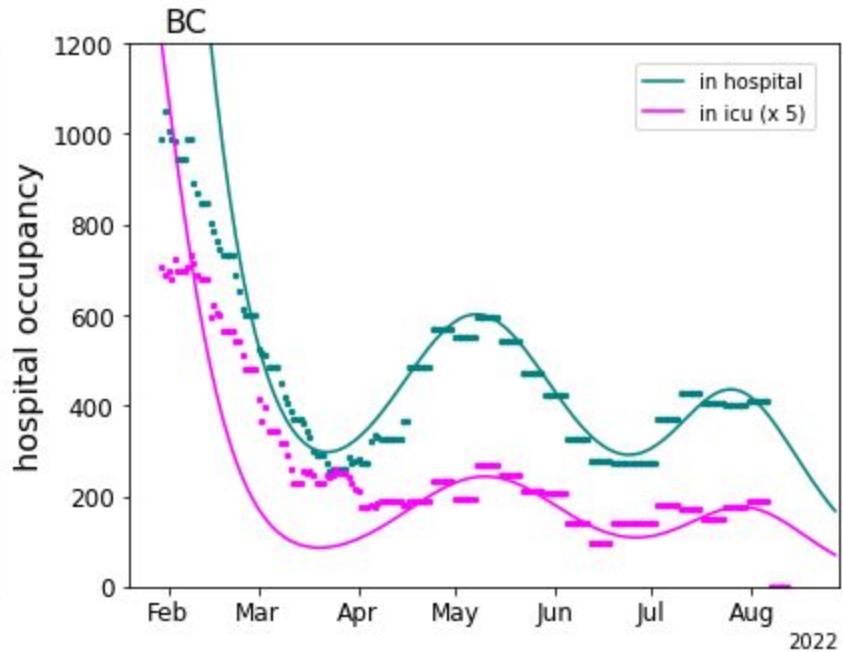
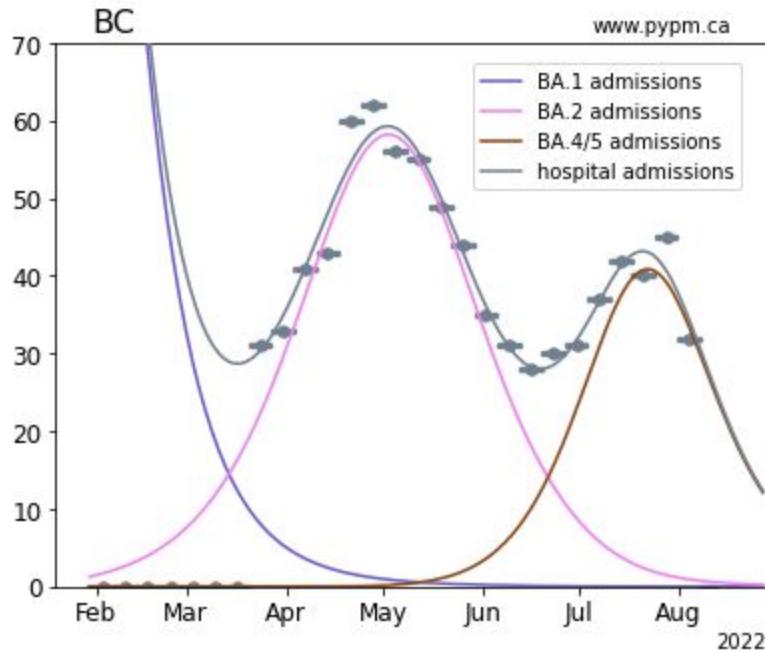
Hospital admissions: Manitoba



Hospital admissions: Alberta



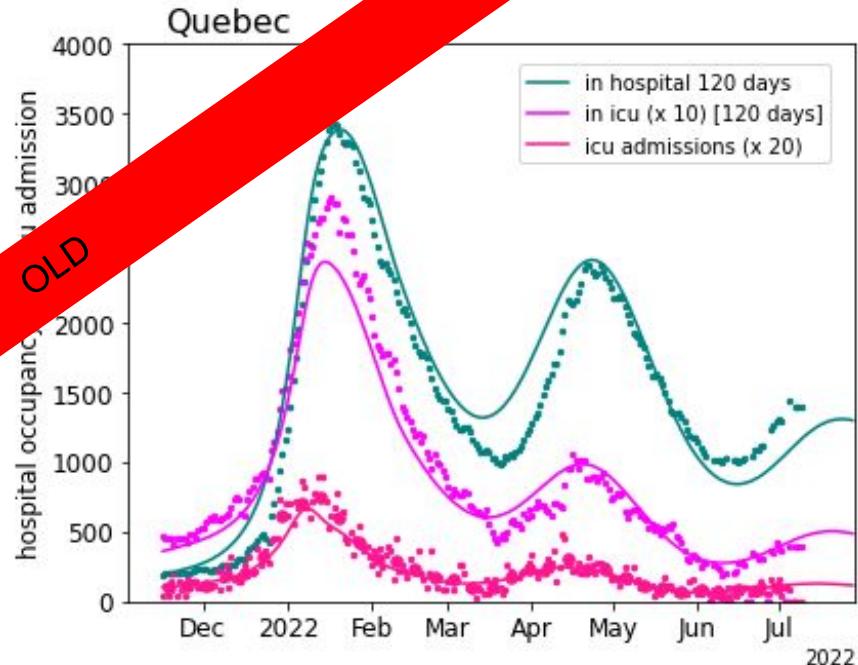
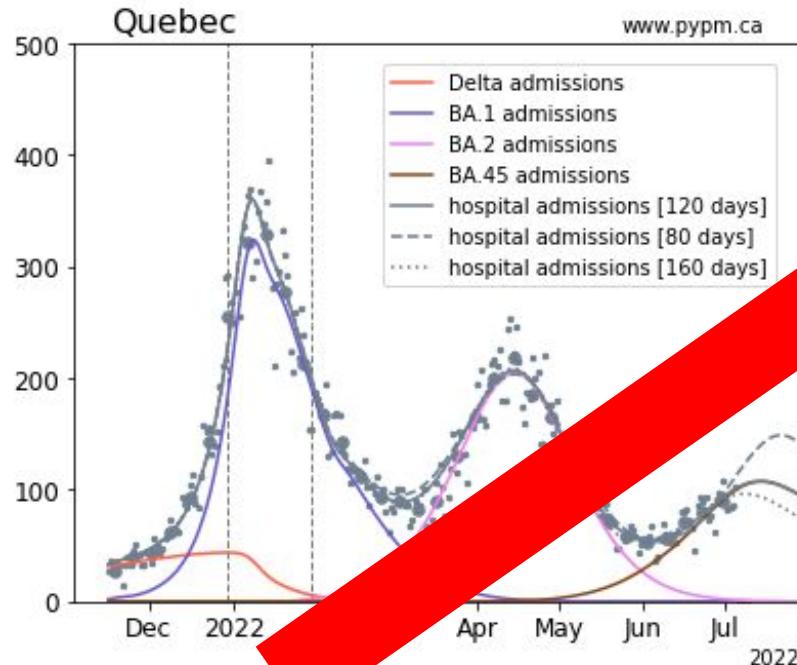
Hospital admissions: BC



Fit sensitive to last week of data... (correction applied)

Hospital admissions: Quebec

The [pypm](#) model was fit to COVID-19 hospital admission data to characterize transmission and population immunity. The model now includes BA.4 and BA.5 (combined and labelled as BA.45). In order to fit recent data it is necessary to reduce immunity gained from Omicron infections. The effect is modelled with shorter mean waning times (80, 120, 160 days shown).



Source (D. Karlen) As in previous reports, the model has no age structure. Three Omicron strains are included with all 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 infections are assumed to produce symptoms with a probability of 60% of that for previous strains. The probability that symptoms lead to hospitalization is 45% of that for previous strains. Vertical lines show fitted dates for transmission rate changes. The larger dots show weekly averages. Fit selection coefficient for BA.45 wrt BA.2 is 0.12 per/day.

Alberta and Manitoba Projections

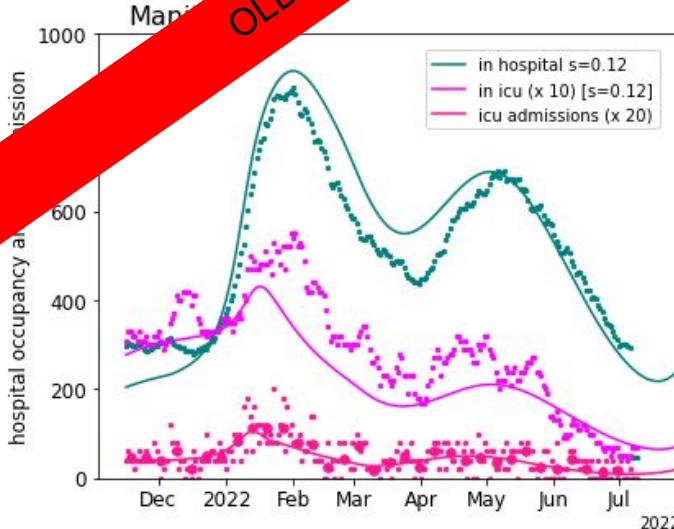
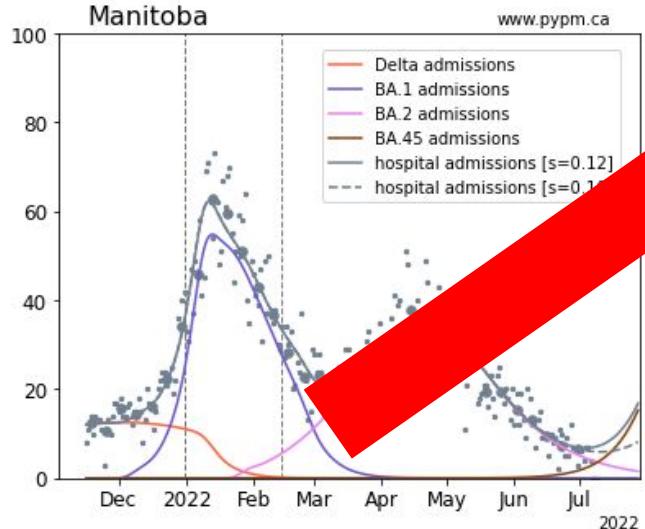
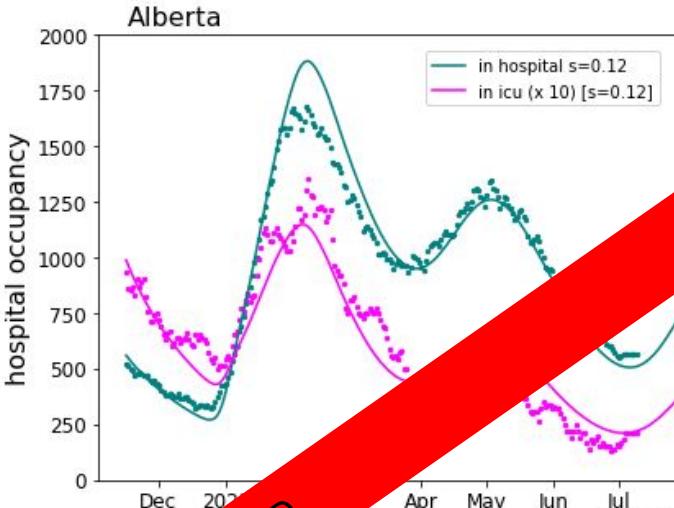
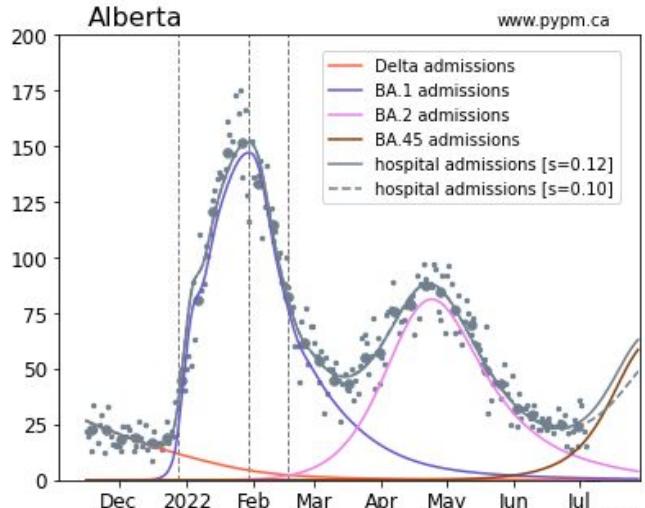
BA.4 & BA.5 are dominant about one month later than in Quebec.

Omicron natural immunity waning set at a mean of 120 days in these models.

Two selection coefficients shown (0.12 and 0.1).

Hospital and ICU occupancy curves (right figures) assume no changes to length of hospital stays over period shown.

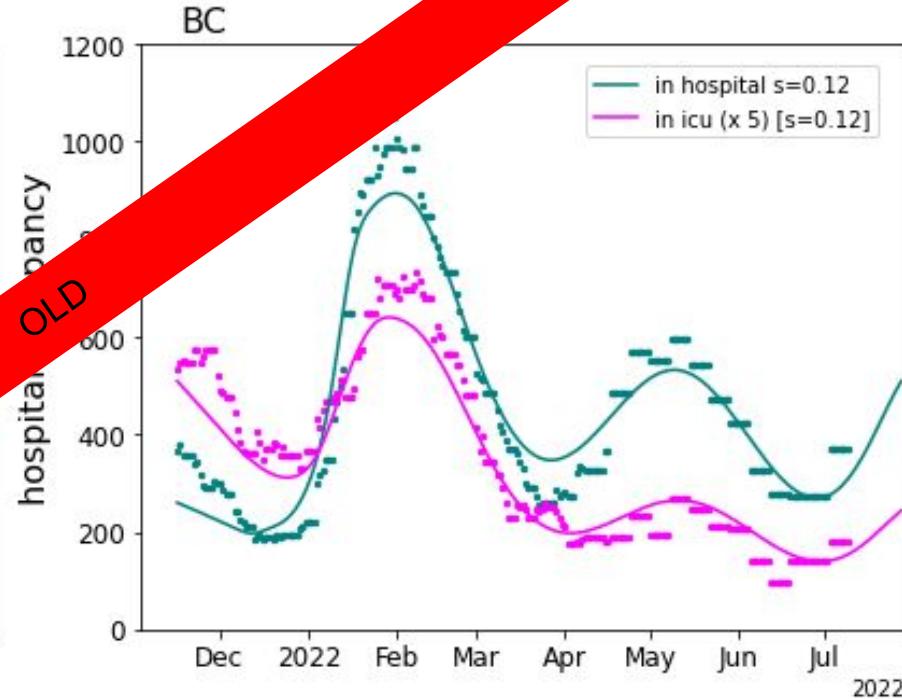
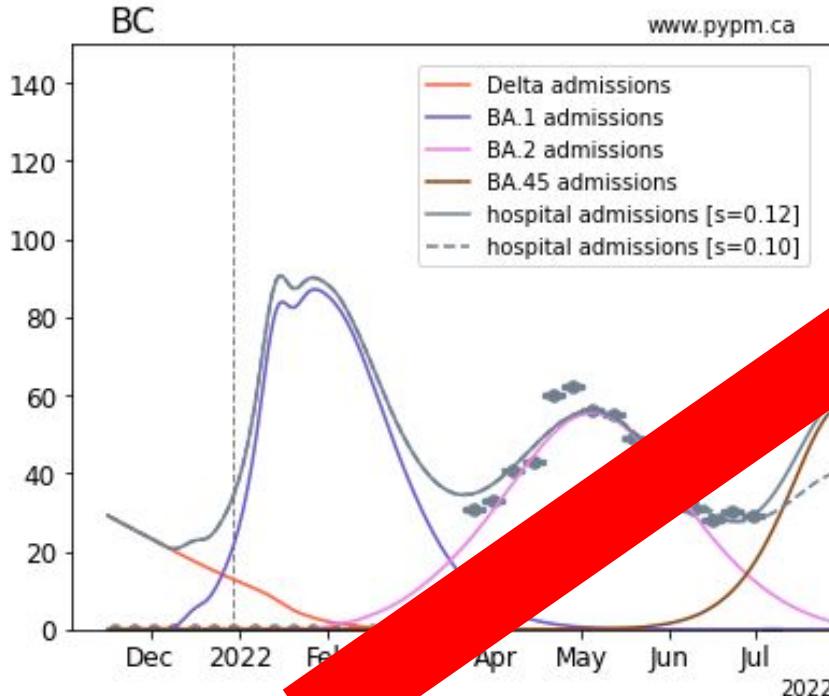
Hospital admissions expected to start growing in the near future.



Hospital projection for BC

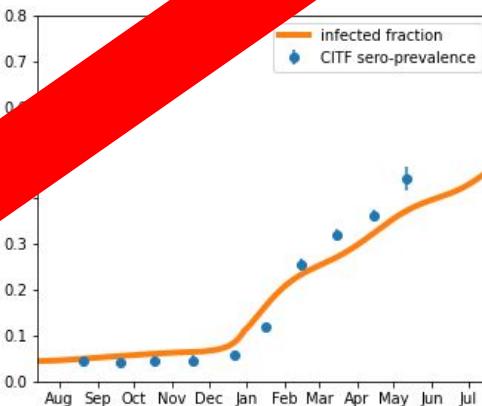
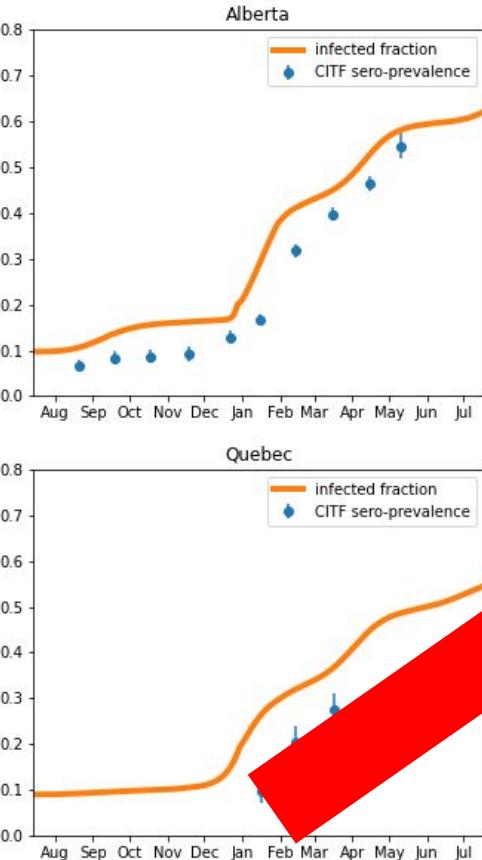
Model is fit to corrected hospital admission data from BCCDC weekly reports (available since mid-March)

- Our assessment in our May 18 report that hospital admission had peaked was correct.



Source (D. Karlen) As in previous reports, the model has no age structure. Three Omicron strains are included with all 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 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 average. Mean Omicron natural immunity waning is set at 120 days.

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.

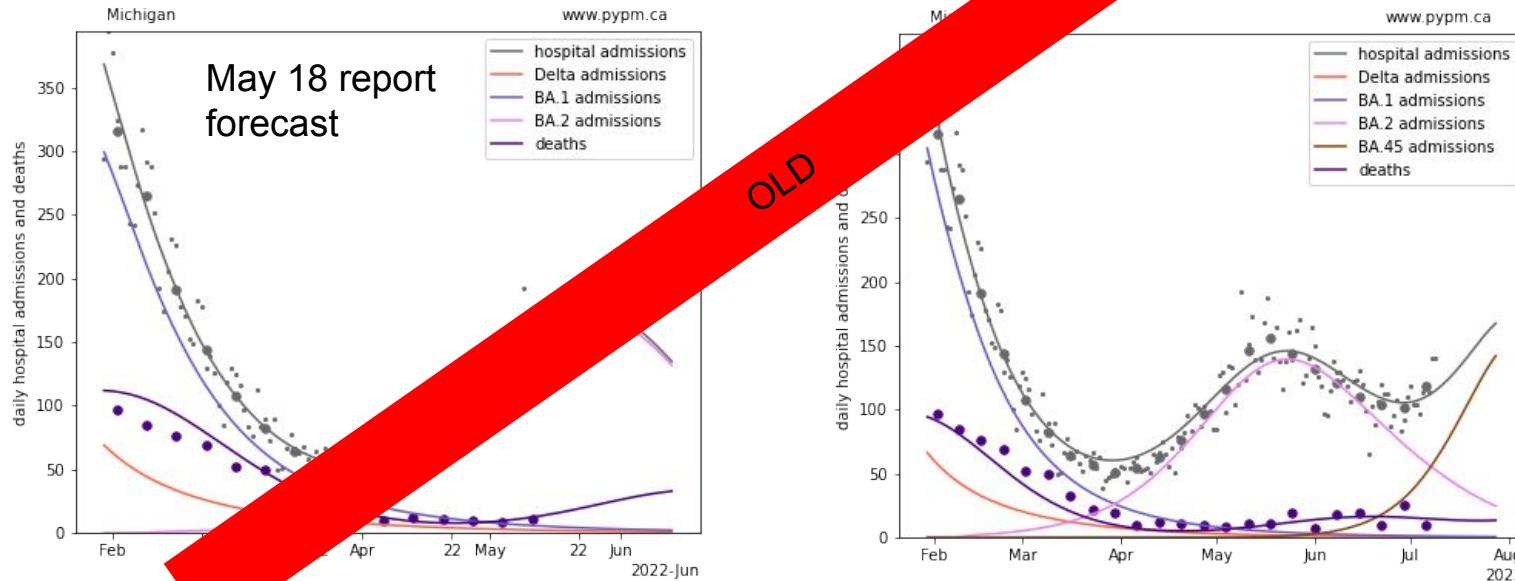
OLD

Hospital projections in the USA

Unlike BC, AB, MB, and QC, in most US states, BA.4/5 arrived while BA.2 was still dominant.

See www.pypm.ca for each state. Some states, like Michigan, have a distinct forecast for BA.4/5.

- Left: Michigan forecast from May 18 report. Correctly predicted the BA.2 turn-over, confirming immunity model.
- Right: Current Michigan forecast incorporates new strains.

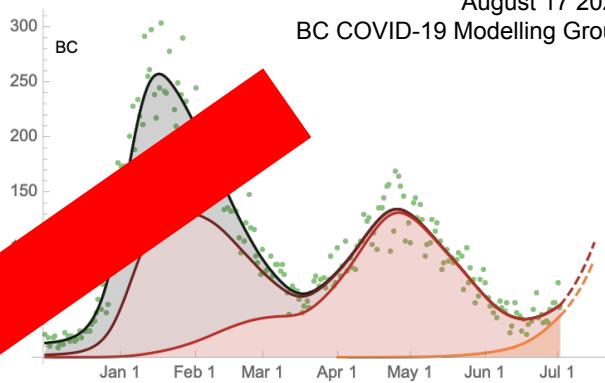


Source (D. Karlen) As in previous reports, the model has no age structure. Omicron strains evade 80% of natural immunity from previous strains and 80% of 2 dose vaccinations. Booster doses are assumed to provide 80% effectiveness against infection. Omicron infections are assumed to produce symptoms with a probability of 60% of that for previous strains. The probability that symptoms lead to hospitalization is 30% of that for previous strains. No transmission rate changes occur during the period shown. Non-exponential behaviour (turn-overs) are due to growth in immunity. The larger dots show weekly averages. See: <https://pypm.github.io/home/docs/studies/usa20220710/>

Impact of the BA.5 wave

The Third Omicron Wave

The **height and impact of the BA.5 wave are challenging to predict**, depending on the interplay of several factors.



1. **Antibody levels** caused by the combination of vaccines and previous Omicron infections
2. **Efficacy of neutralizing antibodies** in preventing infection against BA.4 & BA.5
3. **Risk-reduction measures** preventing infections via NPI measures and boosters

OLD

} Infections

The subsequent **impact on severe disease, hospitalizations, and deaths** depends on:

4. **Ability to clear infections** due to existing cellular & humoral immunity
5. **Virulence** of BA.4 and BA.5

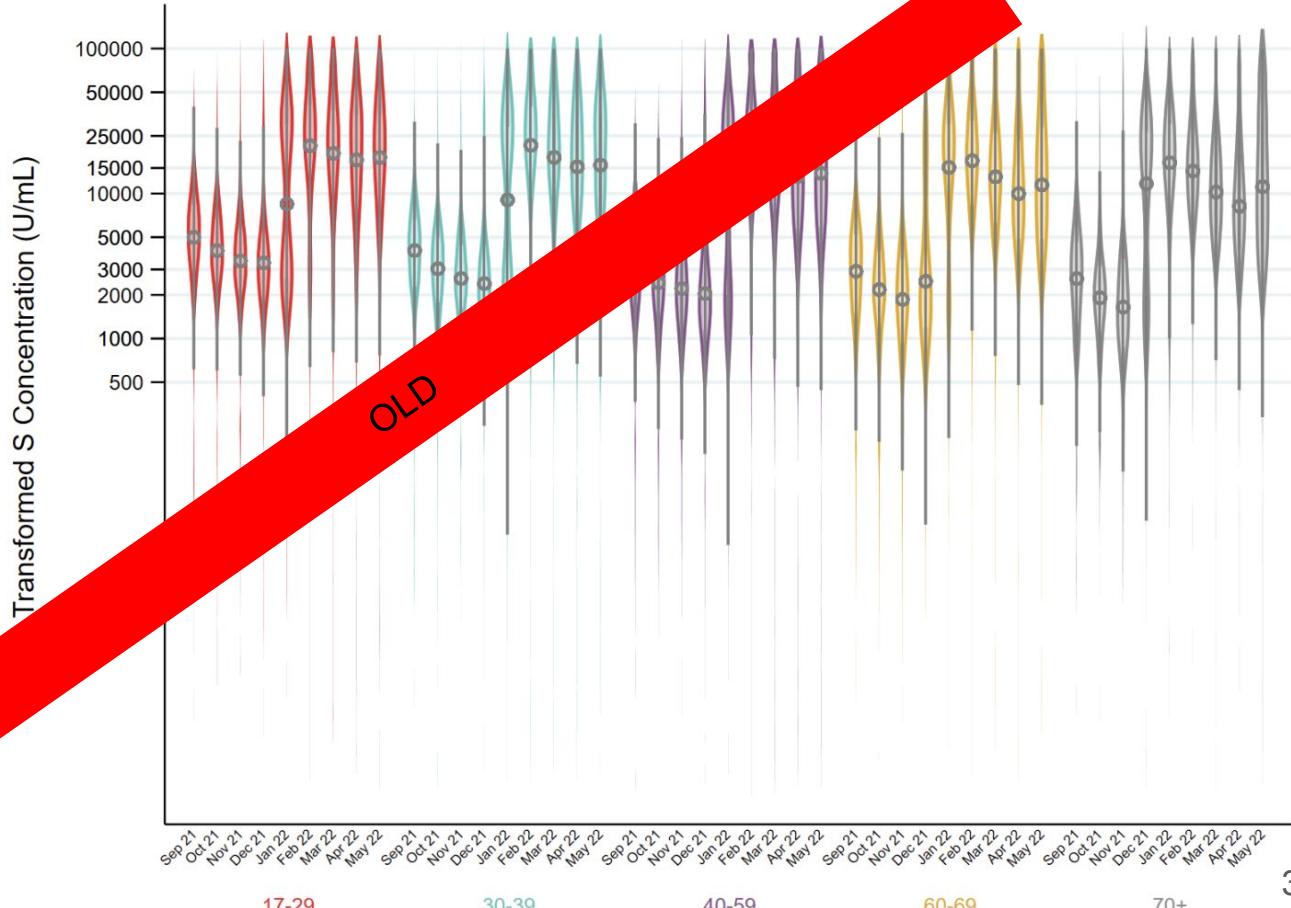
} Disease

Factors determining the impact of the BA.5 wave

1. Antibody levels

The COVID-19 Immunity Task Force & Canadian Blood Services data finds high standing levels of spike antibodies among adults in all age groups in Canada (blood donations through mid-May 2022), protecting against infection.

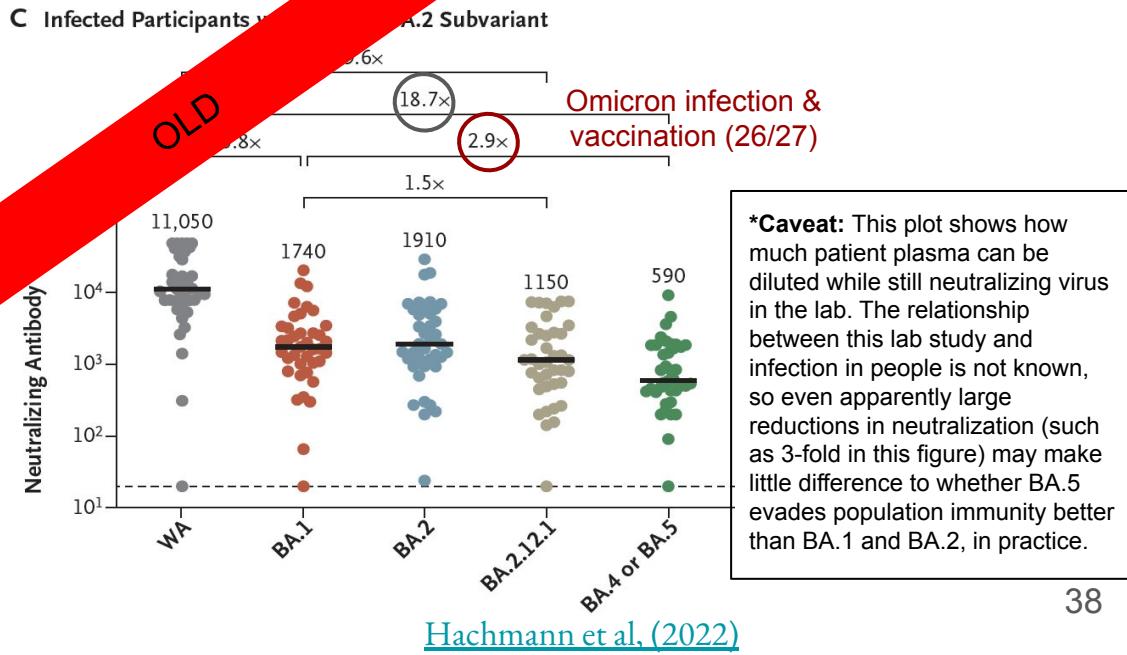
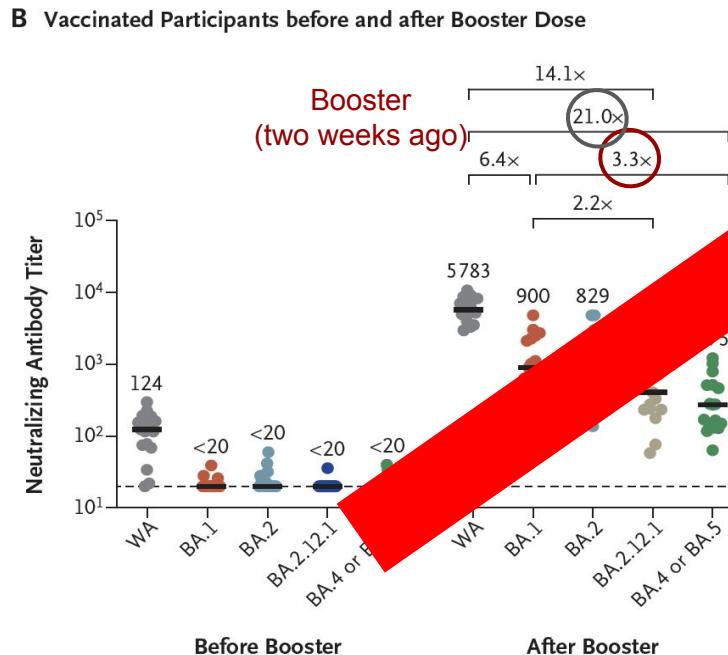
Good news



Factors determining the impact of the BA.5 wave

2. Efficacy of neutralizing antibodies: Lab studies suggest that the ability of these antibodies to neutralize SARS-CoV-2 and prevent infection is substantially compromised for BA.4 & BA.5.

- Circled numbers show protection from boosters (left) and recent infections on the right (relative to BA.1 (red: ~3-fold less) or relative to the Wuhan strain (gray: ~20-fold less), based on lab assays*.



Factors determining the impact of the BA.5 wave

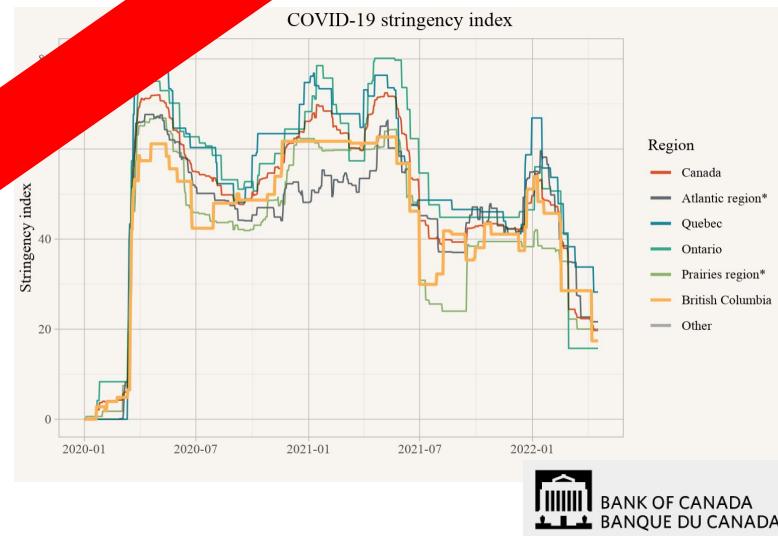
3. Risk-reduction measures:

Risk-reduction behaviours (such as effective masking and seeking well-ventilated spaces) reduce individual risk.

Risk-reducing behaviour can have more effect during the upswing of a wave, rather than during a downturn, because each infection averted prevents more subsequent infections during this phase of the wave.

The stringency of public health measures has been at their lowest level since the pandemic began, with little appetite to mandate protections. However, collective public efforts are powerful. For example, masking and behaviour has been shown to have more to do with social expectations and norms than with mask-wearers (Leech et al. 2022).

OLD

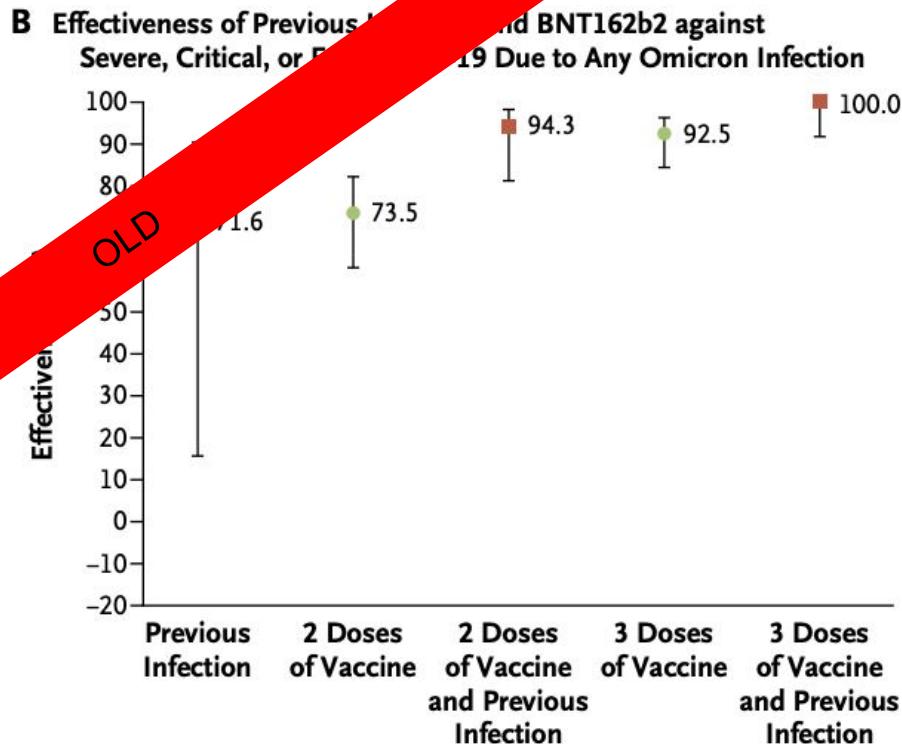


Factors determining the impact of the BA.5 wave

4. Clearing infections: Vaccines protect against severe disease by building memory T and B cells that make more antibodies and kill infected cells once virus is detected.

Altarawneh et al. studied protection against severe disease caused by Omicron BA.1 and BA.2. Relative to unvaccinated people, they found that people who had a primary (two-dose) vaccine series were ~3x less likely to experience severe disease. This relative level of protection rose to ~10x with the time) recent booster dose or with vaccines plus infection.

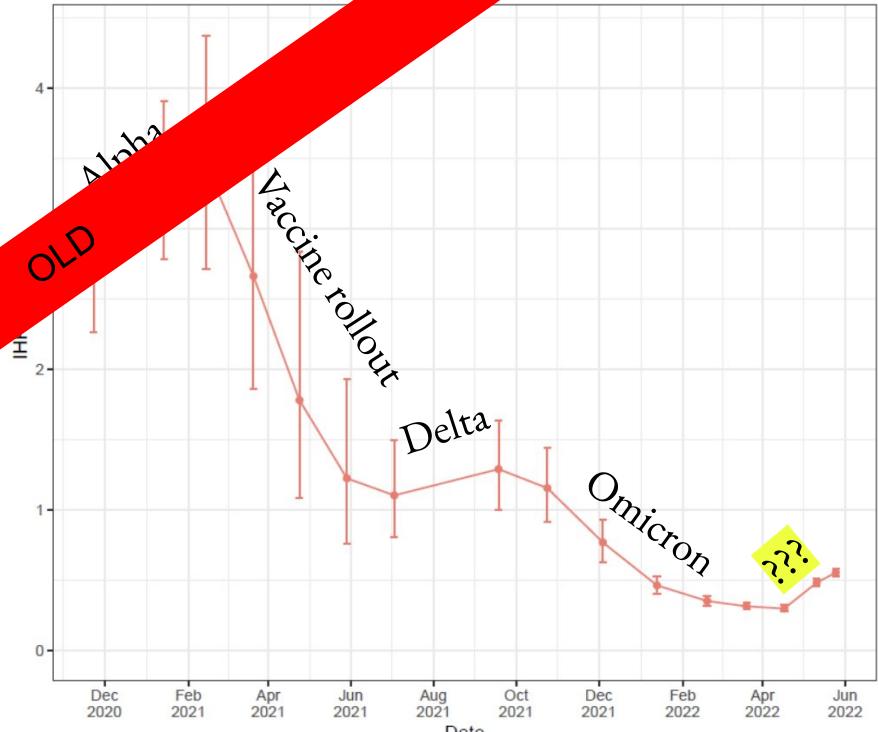
We don't yet have comparable data for BA.5.



Factors determining the impact of the BA.5 wave

5. Virulence: The relative severity of BA.5 is not known. Early indications from other countries suggest it is similar to, but potentially slightly more severe than BA.1 and BA.2.

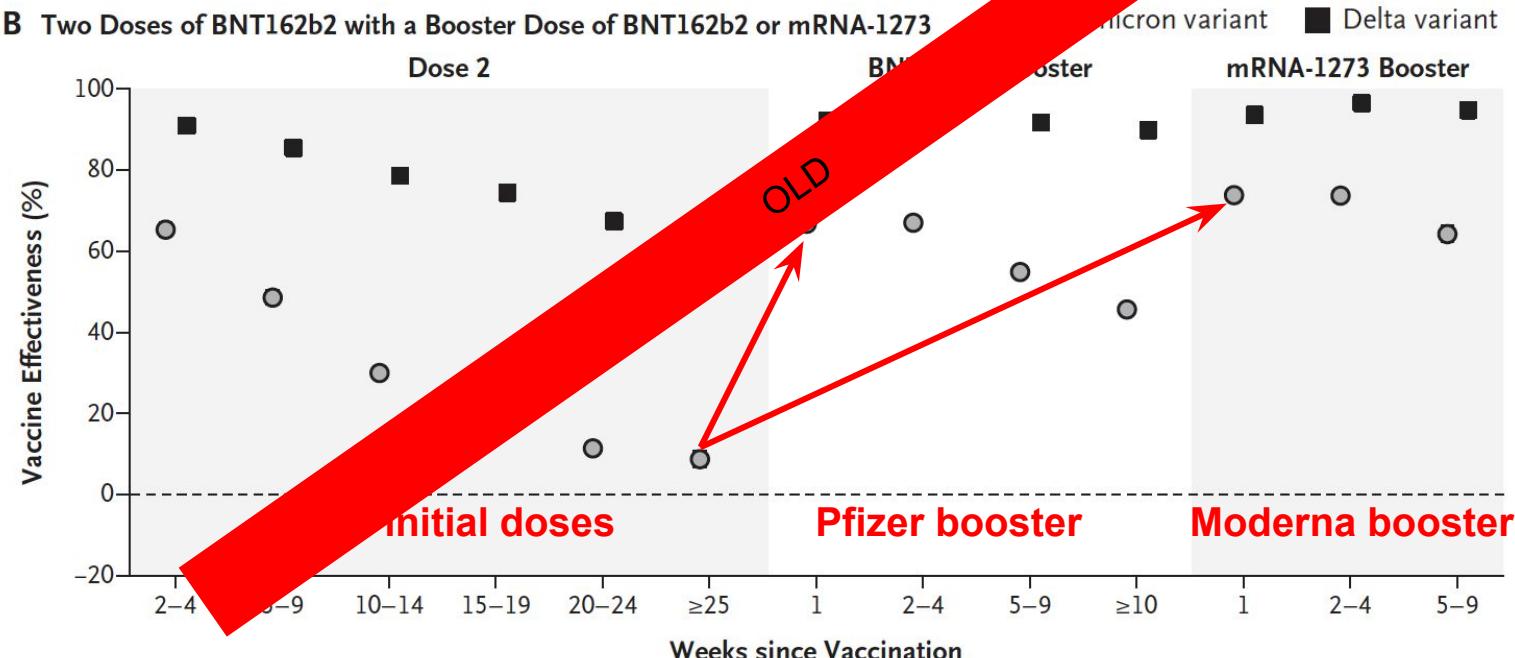
- In its [43 technical briefing](#), the UK Health Security Agency reported a recent uptick in their modelled estimates of hospitalization rate per infection (IHR) over time. This may be due to slightly increased intrinsic severity of BA.5 or population factors such as waning immunity.
- [South African scientists](#) reported a (but not significantly) higher hospitalization rate per BA.5 case compared to previous Omicron sub-variants, hazard ratio 1.12; 95% CI 0.93-1.3.



Lowering the BA.5 wave

Is it too late to get a booster to avoid COVID-19 during the BA.5 wave? No!

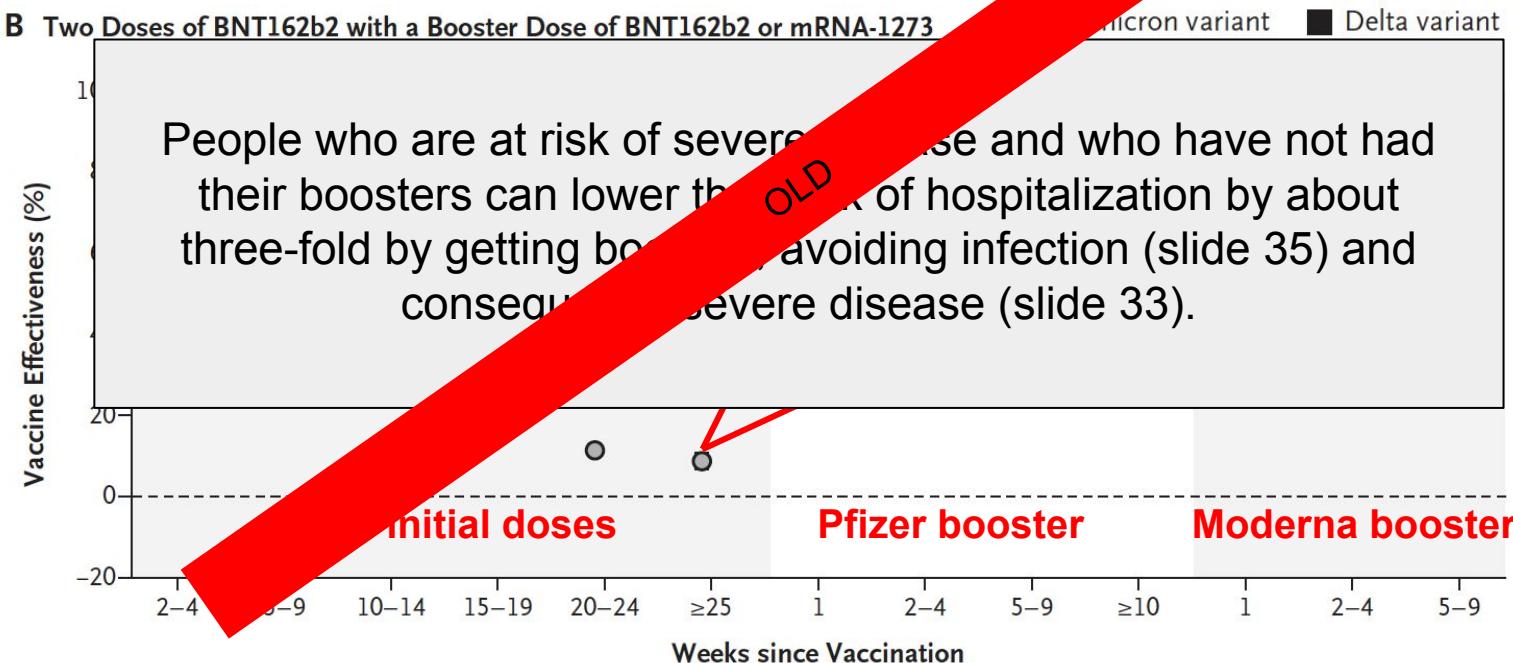
Data on boosters show that antibody levels rise quickly – within a week – after a booster. This figure shows how quickly vaccine effectiveness against symptomatic disease with Omicron (BA.1) rebounds following boosting (Andrews et al.).



Lowering the BA.5 wave

Is it too late to get a booster to avoid COVID-19 during the BA.5 wave? No!

Data on boosters show that antibody levels rise quickly – within a week – after a booster. This graph shows how quickly vaccine effectiveness against symptomatic disease with Omicron (BA.1) rebounds following boosting (Andrews et al.).



Key messages

The next Omicron wave has started in BC and across Canada.

This wave is driven by the spread of sub-variant BA.5, which is predicted to represent >80% of cases, as of this week.

- The selective advantage of BA.5 over BA.2 has been high and similar across provinces, states, and countries ($s \sim 12\%$ per day).

As correctly predicted in our previous reports, the BA.2 wave was smaller than the BA.1 wave, despite its transmission advantage over BA.1. OLD

- The lower peak was due to enhanced immunity from boosters & natural immunity from BA.1 infections.

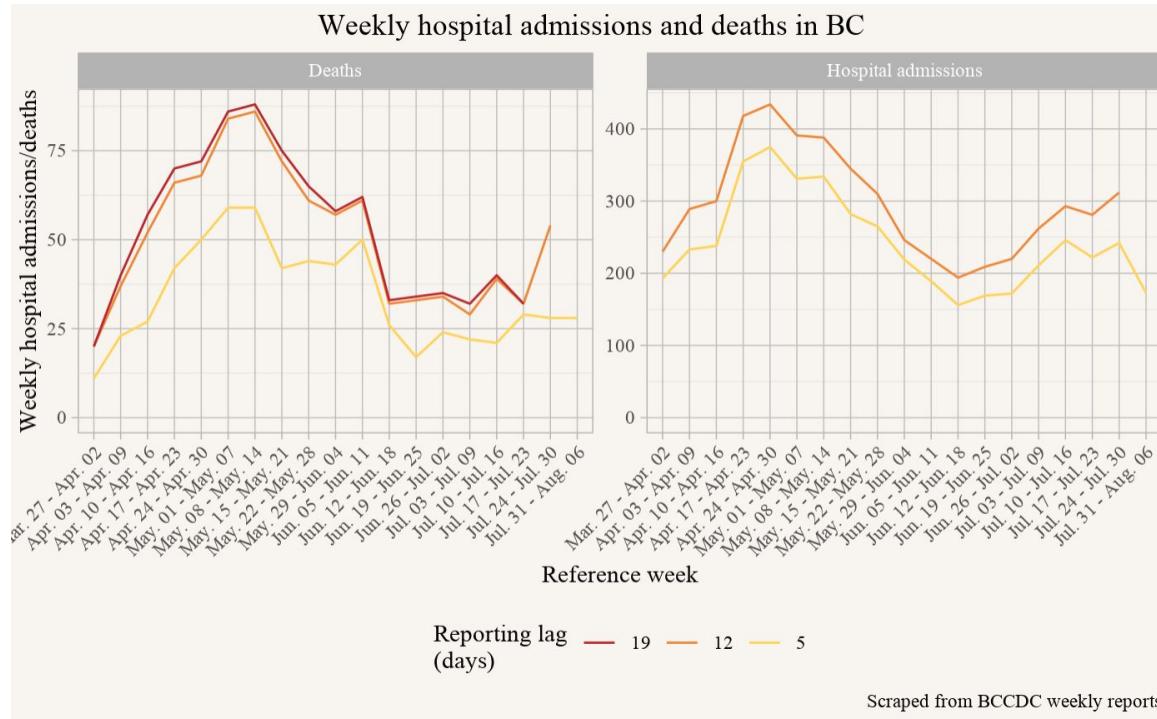
With waning immunity and increasing potential for BA.5 to evade immunity, hospital admissions are expected to return to a plateau in BC and Alberta, as observed already in [Ontario](#), Quebec (slide 20), and in several states (see [pypm analyses](#)).

Projections about the impact of the BA.5 wave on severe cases, hospitalizations, and death are difficult given uncertainty in population-level immunity to the new variants and about the risk reduction measures that will be taken.

Appendix: Hospital admissions and deaths in BC

Hospital admissions data and deaths are reported weekly in BC but 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

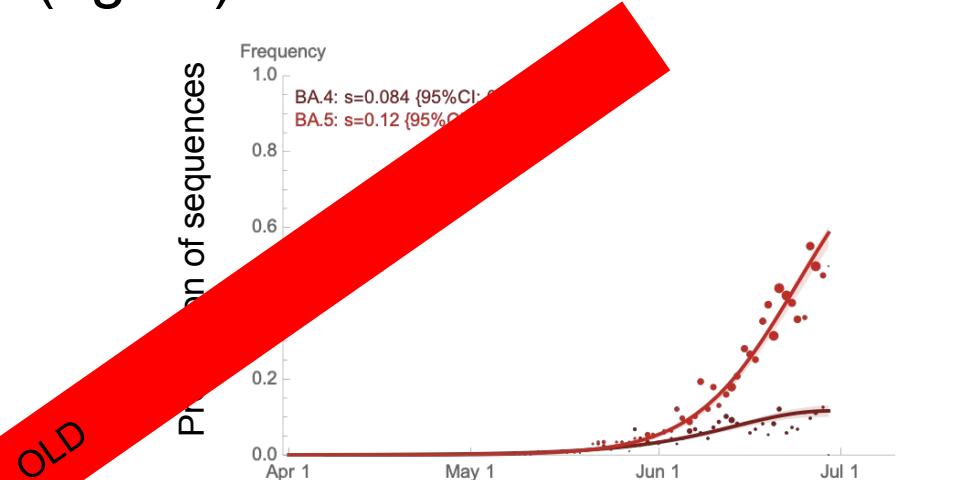
BC hospital admissions are revised upwards by ~20% and deaths substantially more (sometimes doubling!) when updated.

Appendix: Interpreting selection (again)

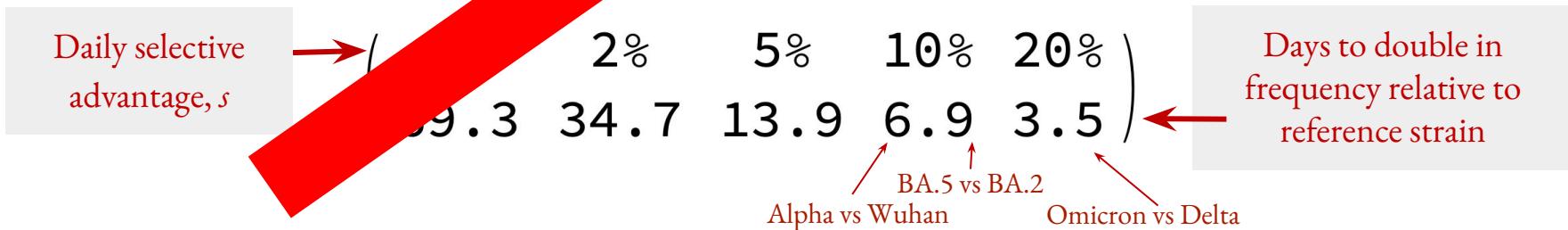
What is “ s ” and what does it mean to be modest?

s measures the selective advantage per day relative to a reference strain (e.g., measuring the rate of spread of BA.5 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., $X_T = \text{freq(BA.5)}/\text{freq(BA.2)}$). s is estimated from the numbers of sequences of the two types over time by maximizing the likelihood of observing the data (see [link](#)).



Appendix: Spread of BA.4 and BA.5 in the USA

BA.5 is spreading at a faster rate (pink) than BA.4 (blue) across the United States. Estimates obtained by combining the BA.4 and BA.5 are shown in orange.

The **selection coefficients** shown here measure the rate of exponential growth in the frequency of a variant of interest (e.g., BA.5) relative to a reference variant (here BA.2) (see previous slide).

