COVID Model Projections

December 22, 2021

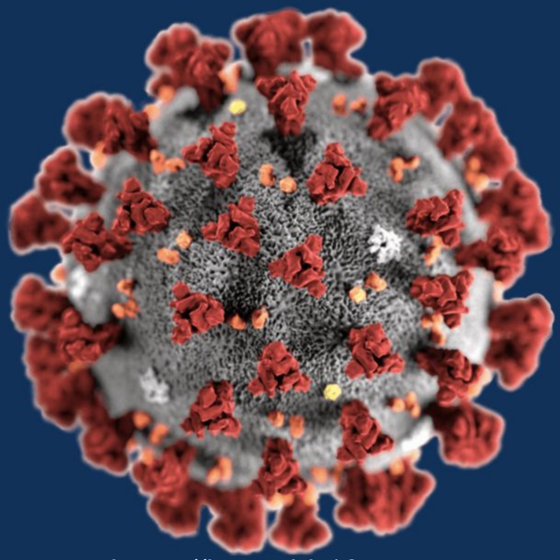
BC COVID-19 Modelling Group

@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

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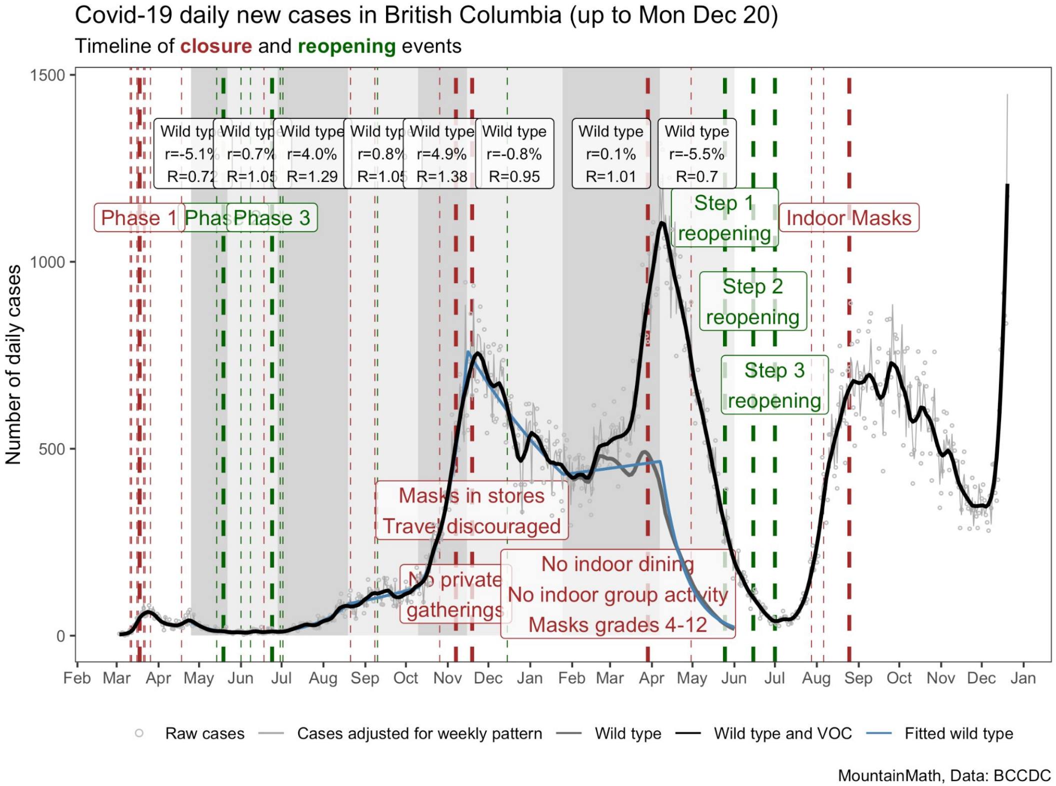
Independent and freely offered advice, using a diversity of modelling approaches.

Overview

Omicron is now established and spreading within BC

- Case rates have risen rapidly to the **highest levels seen during the pandemic**
- Model estimates show cases rising in BC at rates of 13-29% per day
- Omicron spike is most pronounced in Fraser and Vancouver Coastal Health
- Models predict that demand on hospitals will be extreme in January, reaching much higher levels than witnessed to date, even if Omicron is less severe.
- Rapid spread means we have little time to act, but we can slow the spread of Omicron in BC as we did with previous variants: **getting vaccinated, wearing tight fitting masks, improving ventilation, avoiding large indoor gatherings, and improving rapid testing and isolation**
- Slowing the spread of Omicron buys time to **deliver booster shots**, which raise antibodies to levels that can neutralize even Omicron and prevent infection

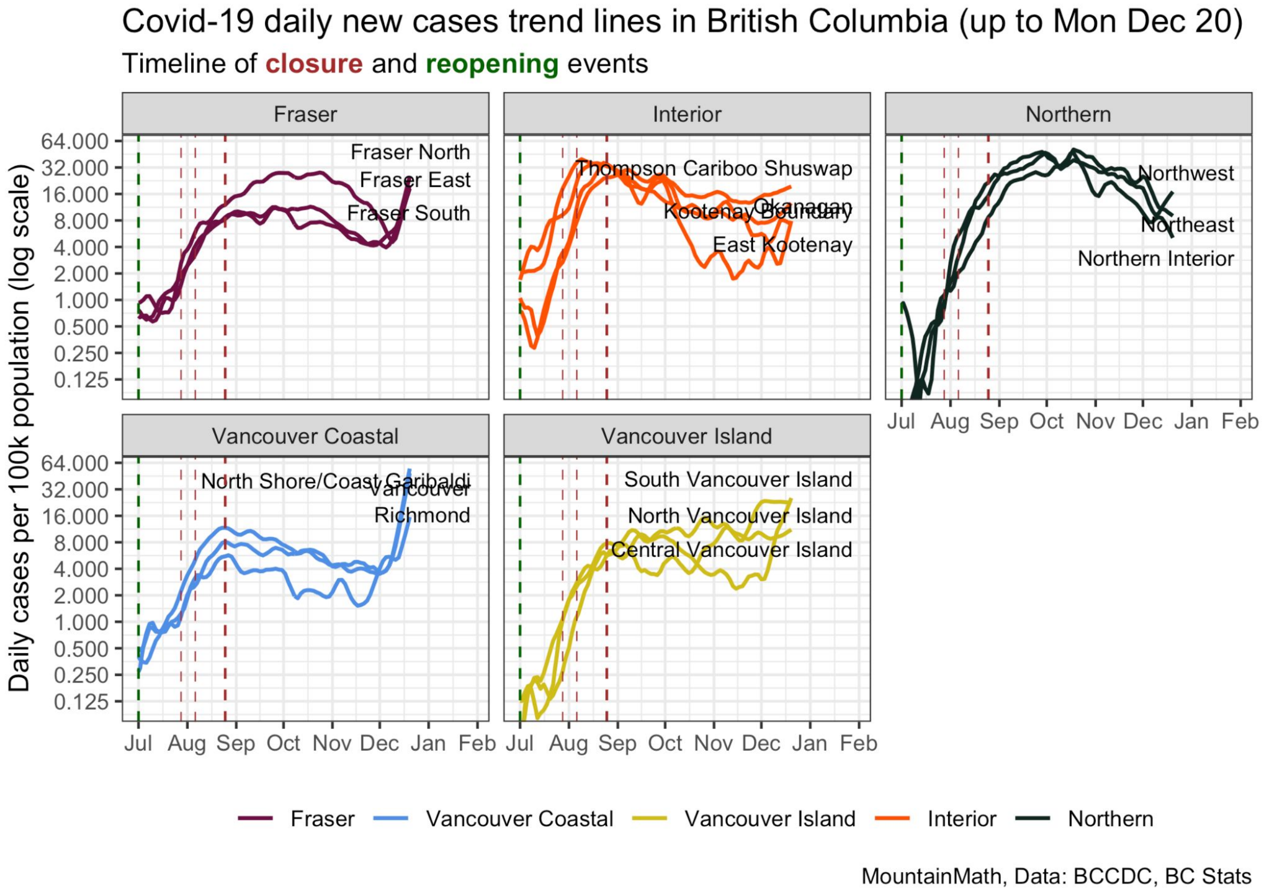
State of the COVID-19 Pandemic in BC



After the long decline in cases seen since September, the establishment of Omicron has lead to a dramatic rise in cases, reaching the highest levels yet seen in BC.

Source (J. von Bergmann) Case data from BC COVID-19 Database (http://www.bccdc.ca/health-info/diseases-conditions/covid-19/data). Vertical lines give dates of public health measures (major as thick lines, minor as thin lines). Grey dots are raw case counts, grey lines is cases abused for weekly pattern, black STL trend line and blue fitted periods of constant exponential growth. *Central Okanagan – July 29: masks, August 6: restrictions on group gatherings; Interior – August 21: masks; August 23: some restrictions on group gatherings. BC – August 25 mask mandate; BC's Vaccine Card to come into effect on September 13 (first dose) and October 24 (second dose)

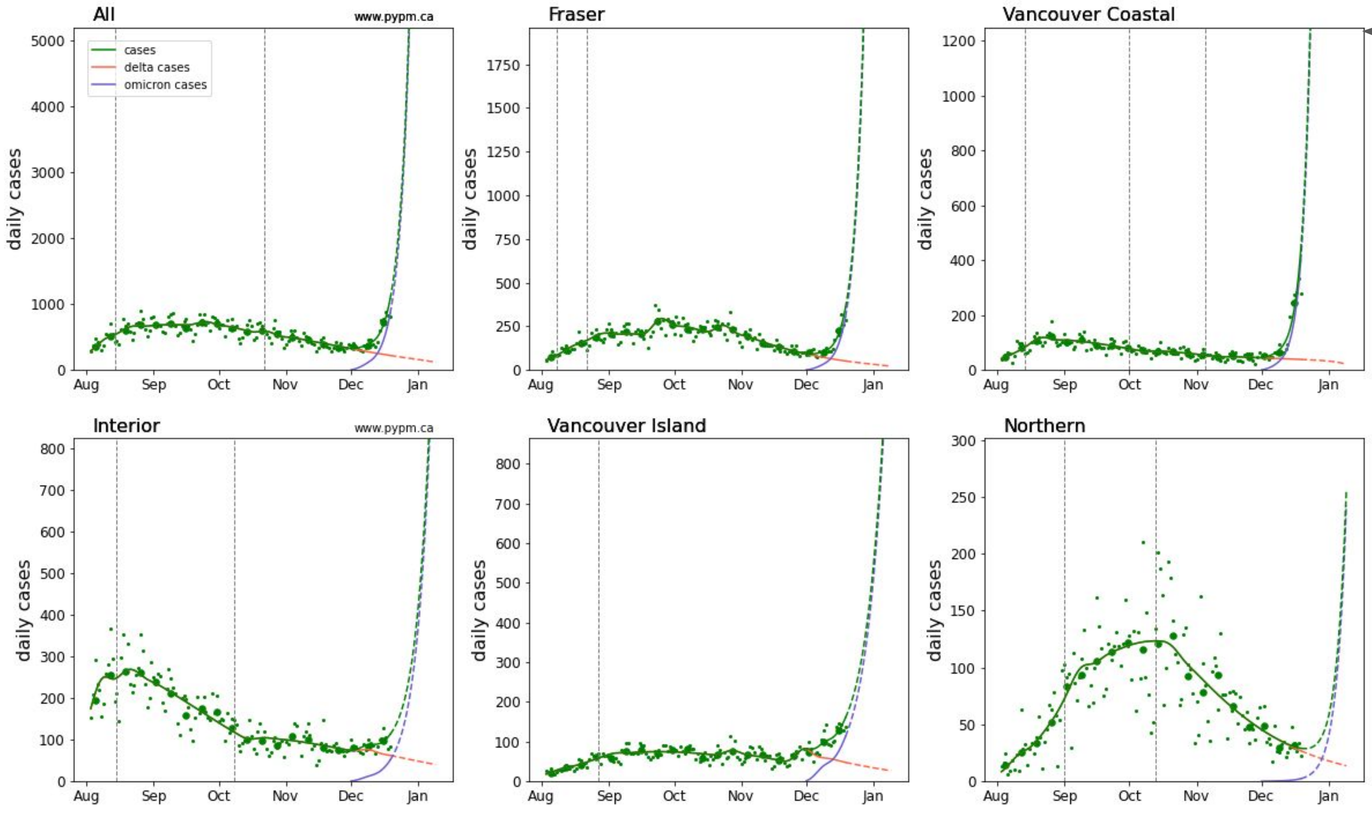
COVID-19 in BC Health Regions



We don't have timely surveillance data for Omicron, so we are left to infer Omicron from the change in case trajectories.

All Vancouver and Fraser Health Regions show a clear upward trend, as does South Vancouver Island. We can be fairly certain that Omicron is established in these communities.

Omicron model fits to BC data



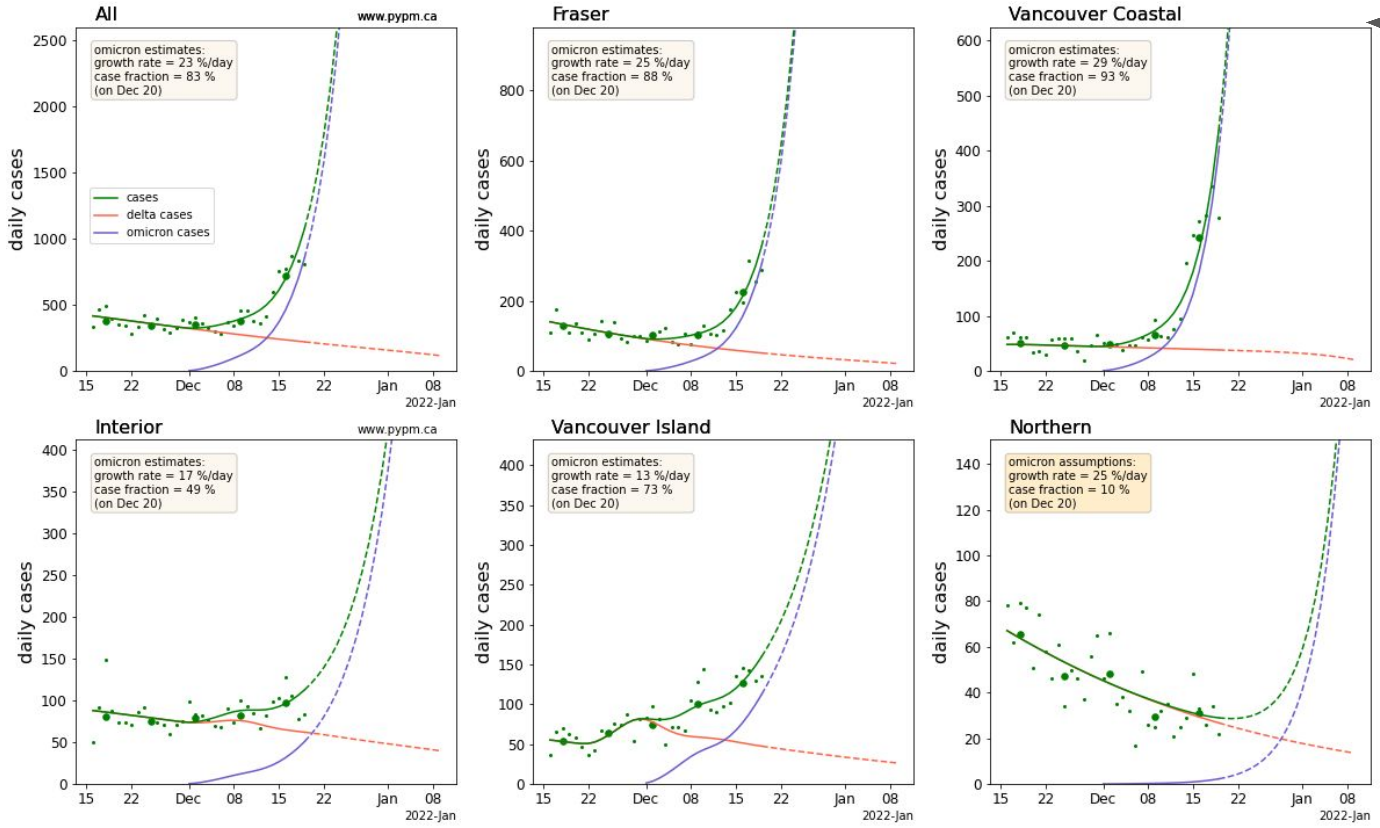
Maximum in each panel corresponds to 1 case per day per 1000 people in the region.

Cases are expected to exceed 1 in 1000 in the coming weeks if transmission is not substantially reduced.

Northern HA does not yet show signs of growth in cases arising from Omicron

Source (D. Karlen). See www.pypm.ca. These models include vaccination but have no age structure. Vertical lines show fitted dates for transmission rate changes. The larger dots show weekly averages.

Omicron model fits to BC data (zoomed in)



Maximum in each panel corresponds to 1 case per day per 2000 people in the region.

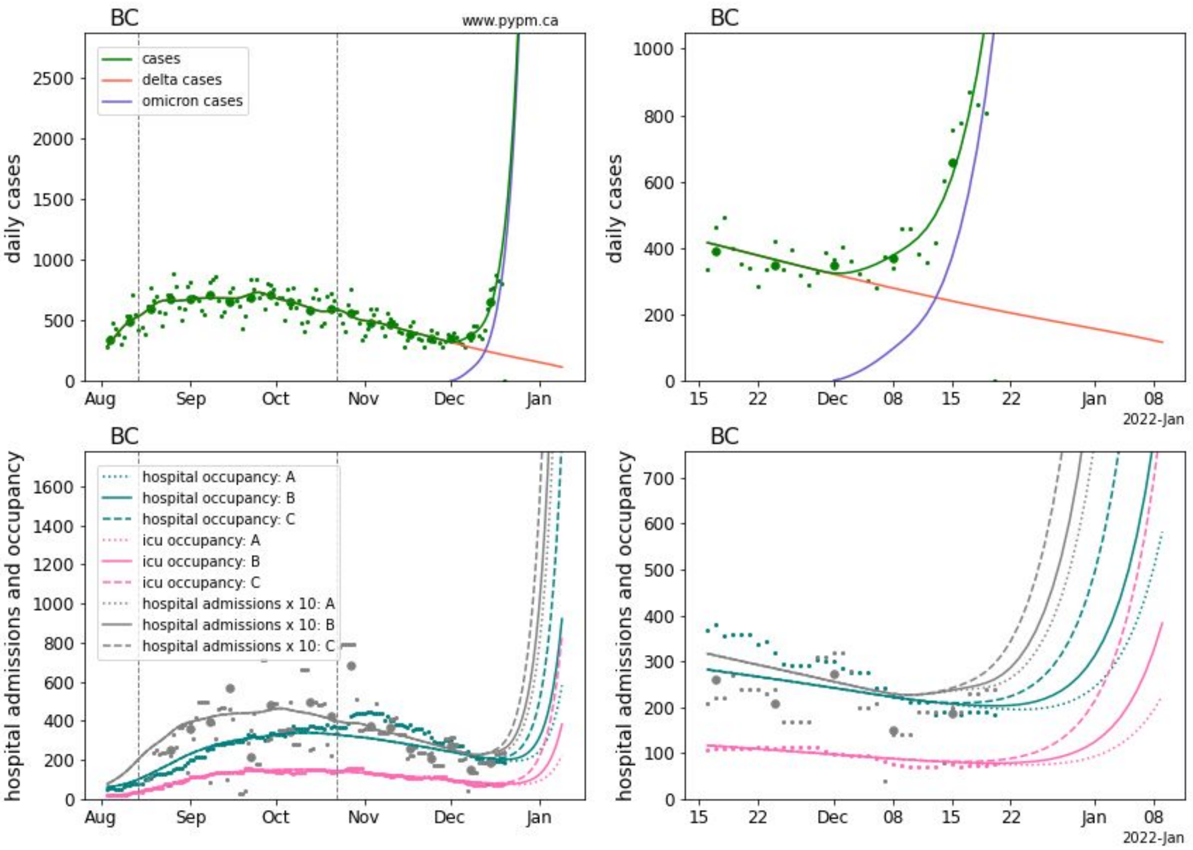
Reliable Omicron growth rates estimates are 23 - 29 % per day. (doubling times: 2.7 - 3.3 days)

More data are needed to better estimate the Omicron parameters, especially from the Interior and Island HA.

Northern HA does not yet show growth arising from Omicron, so parameters are set to hypothetical values.

Source (D. Karlen). See www.pypm.ca. These models include vaccination but have no age structure. The larger dots show weekly averages.

Omicron model projections for health care demand



The severity of Omicron relative to Delta remains uncertain.

Three scenarios are considered. **A:** 30% as severe, **B:** 50% as severe, **C:** No reduction in severity.

The probability that an immunized person needs hospitalization is reduced by multiplying by the severity factor. The length of hospital stays for all infected by Omicron is reduced by the same severity factor.

The curves show model projections of demand: no capacity limits are imposed.

All the levels considered lead to rapid growth in hospital demand, far in excess of capacity.

Source (D. Karlen). See www.pypm.ca. These models include vaccination but have no age structure. Smaller dots show daily values and larger dots show weekly averages.

Uncertainty in longer term projections

Projections further into the future become more uncertain due two main factors:

1. Unpredictable changes to future transmission rates:
    - new public health measures
    - changes in public behaviour

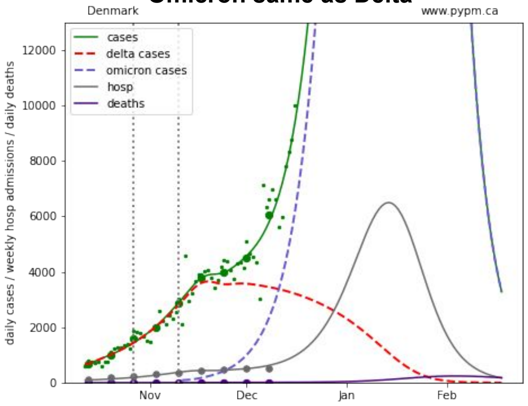
2. Unknown initial size and rate of growth of the population immunized against Omicron
    - *Herd immunity is reached when a large enough fraction of the population is immune to a disease that the number of infections begins to decline. This occurs when the immunized fraction of the population is so high that the number of new infections each day is too low to replace the number of contagious individuals removed from circulation (through recovery or isolation).*
    - The number of people who are susceptible to Omicron infection is not precisely known. Two important factors are:
        - Effectiveness of natural and vaccine immunity against omicron: The larger the effectiveness, the larger the immunized population at the start of the Omicron wave.
        - Number of people who have gained immunity via an Omicron infection: If the fraction of omicron infections that are reported as cases is smaller than expected, the immunized population is growing more quickly than expected. This could be due a different asymptomatic fraction for Omicron or changing testing practice.

These factors are coupled. With lower transmission rates, herd immunity is achieved for a smaller immunized population size. With all of these factors working in our favor, we reach the decline phase sooner, and reduce the overall burden on health care.

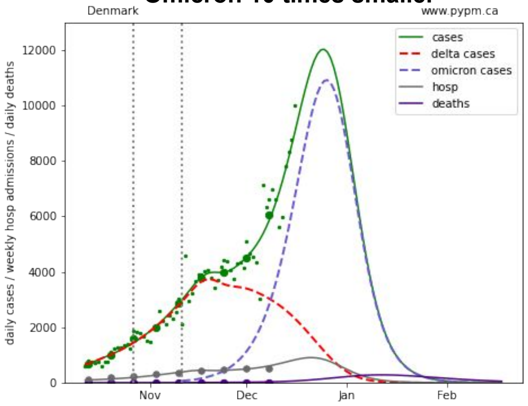
Uncertainty in longer term projections - example

As an extreme example, to illustrate the sensitivity in modelling the susceptible population, two models are fit to data from Denmark. They differ only on the assumption for the fraction of infections leading to reported cases. On the left, the fraction for Omicron is the same as for Delta (likely to be the case). On the right, the fraction is 10 times smaller for Omicron than for Delta (highly unlikely).

Reporting fraction:
Omicron same as Delta



Reporting fraction:
Omicron 10 times smaller



Models assume low vaccine effectiveness against Omicron: 20%

Both models fit the current data, even though the overall impact of Omicron is significantly different.

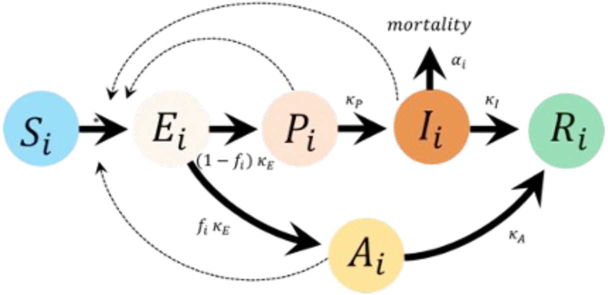
Intermediate values for the reporting fraction (more likely) would also fit the data and would lead to a more modest reduction in the health care burden.

Alternative model accounting for uncertainty with Omicron

The following slides show model projections for the daily number of cases and number in hospital due to Omicron, assuming a 20% growth per day (doubling time of 3.5 days) and accounting for the proportion of vaccinated individuals by age in BC.

Because data on the severity of Omicron and on vaccine protection are currently poorly known, we can **use models to explore possible outcomes, accounting for uncertainty in**:

- **$VE_{infection}$**: Vaccine Effectiveness against infection, allowed to range from 10–90% (data from the UK[1] suggests VE of 35% unboosted and 75% boosted with very large uncertainty, see Appendix)
- **Severity**: The severity of Omicron relative to previous variants, measured as the proportion of cases requiring hospitalization, allowed to range from 10–100% (data from the UK[2] suggests similar severity, given age and vaccine status)
- **P_{severe}**: The probability of a severe case with Omicron for a vaccinated individual relative to an unvaccinated individual, allowed to range from 15-65%.



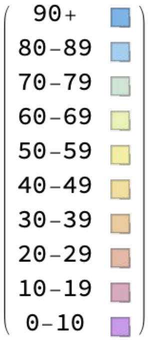
SEAPIR Model (Day et al. 2020)

10 age classes

{0-9,10-19,...80-89,90+}

2 immune classes

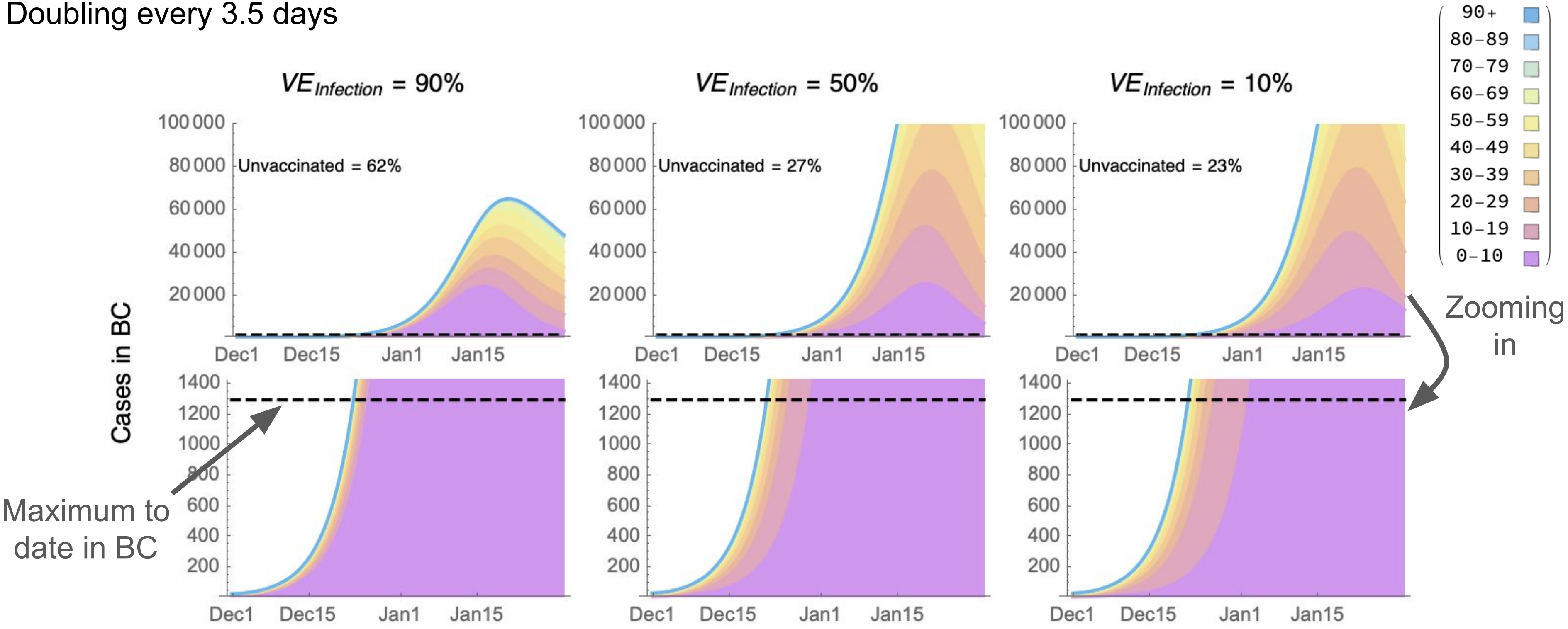
- Vaccinated (or recovered)
- Susceptible



Source (S. Otto). Modified from model analyses reported by CoVaRR-Net Pillar 6, modified to focus on predictions for the population of BC and adjusting the initial number of cases to account for an observed incidence of ~1000 Omicron cases on December 21. [1]Andrews et al. [2]Ferguson et al.

Projected cases: uncertainty in vaccine effectiveness (VE)

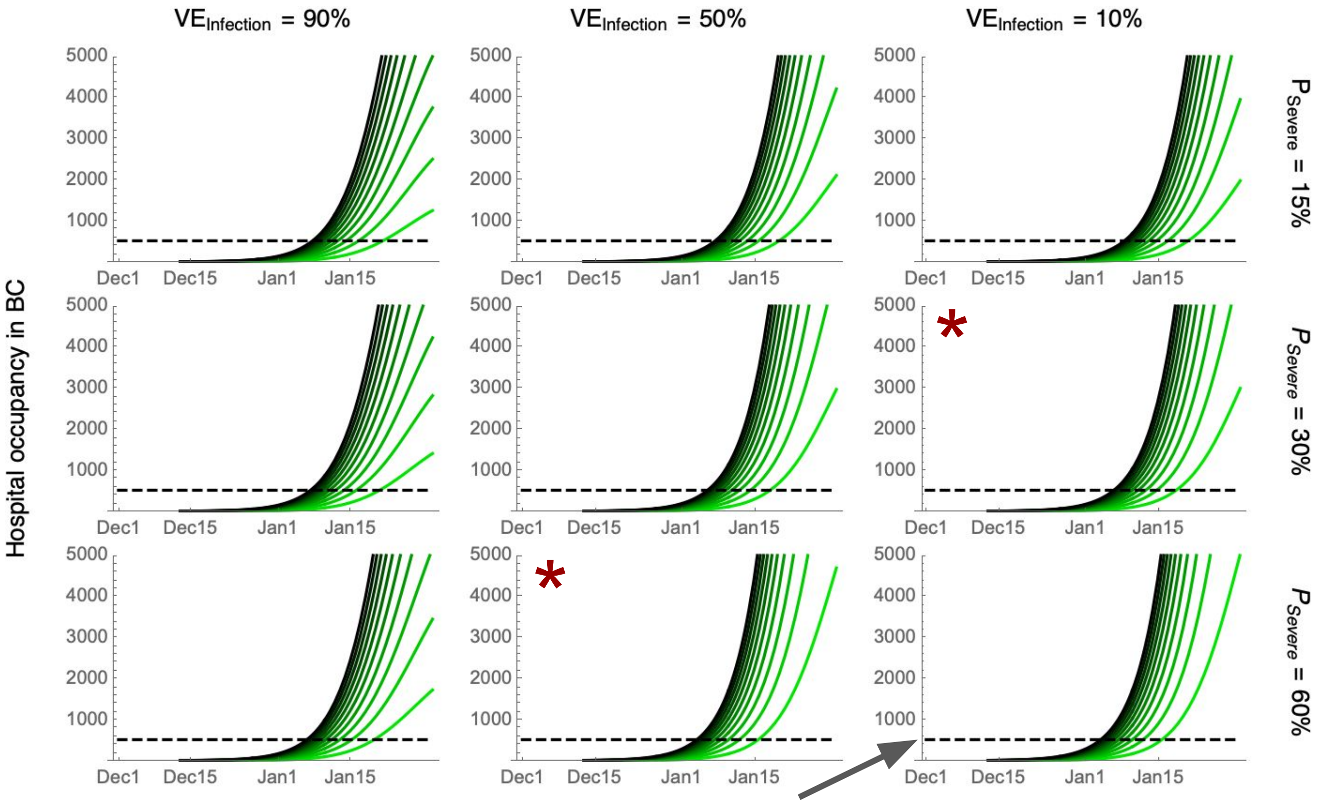
Doubling every 3.5 days



Case numbers are predicted to far exceed levels yet seen in the pandemic in January regardless of whether Omicron's advantage is from transmission (left) or escape (right) or a mixture (middle).

Projected number in hospital: uncertainty in severity and VE

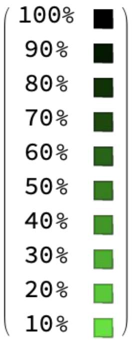
Doubling every 3.5 days



Maximum to date in BC

Regardless of the value of the unknown parameters, we expect number of people in hospital to exceed that previously seen in the pandemic by mid January.

Omicron severity relative to previous variants:

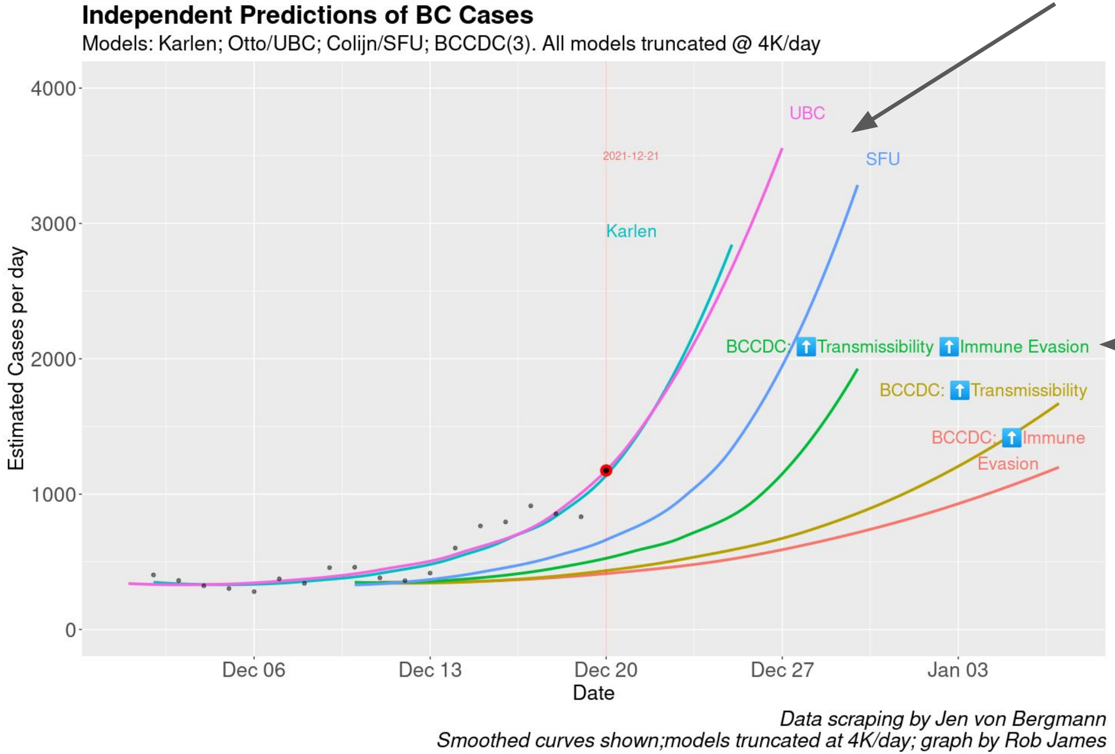


Probability of a severe case among vaccinated relative to unvaccinated individuals, given infection with Omicron.

*Consistent with vaccine effectiveness against severe disease of 70%, as estimated for Omicron in South Africa

Models agree: BC is facing an Omicron tidal wave

Recent projections align with the rapid growth in cases observed this week (Karlen, UBC, and SFU models)



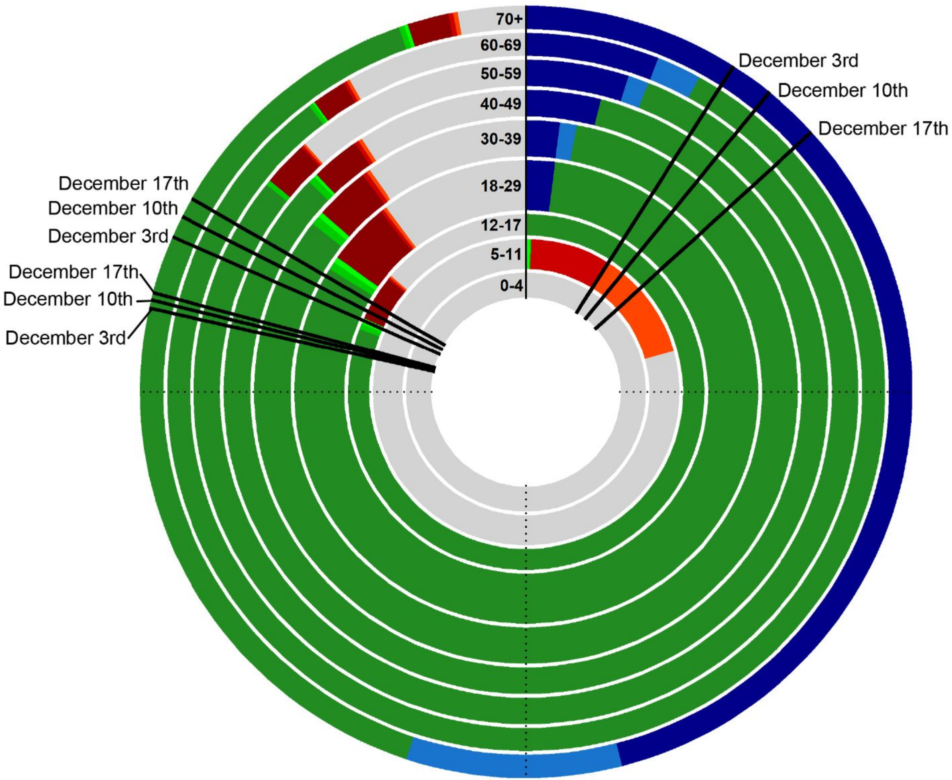
The growth rate of cases (dots) is consistent with the models used in this report, as well as the model produced by the BCCDC that assumes Omicron has high transmissibility and high immune evasion, except that Omicron established sooner (shifting green curve to the left).

BCCDC models were built before Omicron numbers were well established (released 14 Dec). (BCCDC confidence intervals not shown)

Vaccination status by age

December 17th update includes data through December 11th

The fraction of BC's entire population with one or two doses increased **0.85%** and **0.31%** respectively over the past week



Booster Progress

The fraction of BC's entire population with three doses increased **2.4%** over the past week

Single vaccinated before:
December 11th
December 4th
November 27th

Double vaccinated before:
December 11th
December 4th
November 27th

Triple vaccinated before:
December 10th
December 3rd

Source (B. Wiley). Design by Blake Shaffer (https://blakeshaffer.shinyapps.io/app_vaccines/) BC Vaccination data for first and second doses from https://health-infobase.canada.ca/covid-19/vaccination-coverage/, with area of each circle segment proportional to BC's population in that age class. Data for third doses from http://www.bccdc.ca/health-info/diseases-conditions/covid-19/data. BC 2021 Population projections for vaccination percentages from BC Stats: https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/population/population-projections

Responding to Omicron

Previous measures taken in BC have brought the growth rate down of other variants, but we have never faced a variant growing so rapidly.

Public health measures that reduce growth in cases can lower the peak demand for health care and buy time for boosters.

Boosters raise antibody levels and allow the immune system to recognize Omicron (see Appendix), substantially reducing peak hospital demand and cumulative cases.

- For example, if everyone who is vaccinated receives a booster, causing vaccine effectiveness against infection to rise as seen in slide 18 (from 35% months after the standard two doses up to 75% after a booster), then a 20% daily growth rate of Omicron could be slowed to 10.5% (a 6.6 day doubling), and the peak hospital demand in January reduced by a factor of 160.

Boosters are needed as soon as possible to allow time for neutralizing antibodies to rebuild and prevent a spike in hospital demand.

Uncertainties in these projections

Might these projections be wrong?

There remains substantial uncertainty and the following more optimistic possibilities remain:

- While initial data suggest some reduction in severity (25% in South Africa, but only 5% in the UK), the confidence intervals on these estimates are broad. If much less severe (by more than a factor of ten), then peak hospital demand could be manageable.
- Similarly, if the fraction of undetected cases rises substantially with Omicron (e.g., due to testing capacity limits, long lines, etc.), then herd immunity against Omicron could develop much more quickly than expected (see alternative possible fits of data from Denmark exploring this possibility on slide 10). A larger fraction of undetected cases, without a rise in hospitalization demand, also implies that Omicron would have to be much less severe.

As more data on Omicron emerges, the plausibility of these more hopeful scenarios can be evaluated, but with the data available, currently the models predict a severe hospital crunch that necessitates controlling transmission now.

Key messages

State of the Omicron wave in BC:

- The Omicron wave is clearly underway in BC, with Omicron infections growing at an estimated rate of ~23% per day (3 day doubling time)
- Different models agree that demand on the health care system will likely become extreme in mid-January without effective counter-acting measures. Only if Omicron is much less severe (more than 10-fold reduction in severity) would rising case numbers not lead to a crunch on hospitals.

Challenges:

- **Need for strong action:** Rapid growth in cases requires even stronger public health measures to keep cases from burgeoning. Rapidly rolling out booster shots can help by quickly reducing the number of individuals vulnerable to infection with Omicron.
- **Need for early action:** The major tool we have to reduce health care demand is to reduce transmission earlier, before hospitals are in crisis.
- **Monitoring will be difficult:** Once testing and hospitals reach capacity, it will be challenging to know how many cases are undetected.
- Data blackout over the holidays will exacerbate challenges monitoring and responding to Omicron
- **Underreporting:** As self-administered rapid antigen tests become more common, we will lack information about these cases unless an effort is made to log and publicly report them.

Appendix: Further details on model comparison

BCCDC Dec 14: https://news.gov.bc.ca/files/12.14.21_PHO_modelling.pdf "We consider 3 scenarios with lower severity: 1) transmission is increased between 1.5 - 3 times that of Delta, 2) immune evasion to transmission is 30-60%, and 3) a combination of increased transmission and immune evasion. … Scenarios do not account for boosters which will impact severity and transmission. Further establishment of variant in the community is assumed to be on Dec 9th."

Karlen/PYPM.ca Dec 20:https://pypm.github.io/home/docs/studies/prov20211220/
Daily growth rate: 23% Omicron prevalence: 83%

Otto/UBC/CoVaRR-Net: Dec 21: Omicron incidence set to 1000 on this date Daily growth rate: 20%.
https://covarrnet.ca/model-projections-for-the-spread-of-omicron-and-the-potential-impact-on-hospital-occupancy/

Colijn/SFU: Dec 17th: Daily growth rate: 20%, Omicron prevalence: ?

Appendix: Vaccine protection from Omicron

How does the effectiveness of vaccines wane over time and how does this differ between Omicron and Delta?

There are two methods for assessing protection from immunization history: direct case-controls and indirect neutralization studies.

Method 1: Test-negative case-control

Pros:

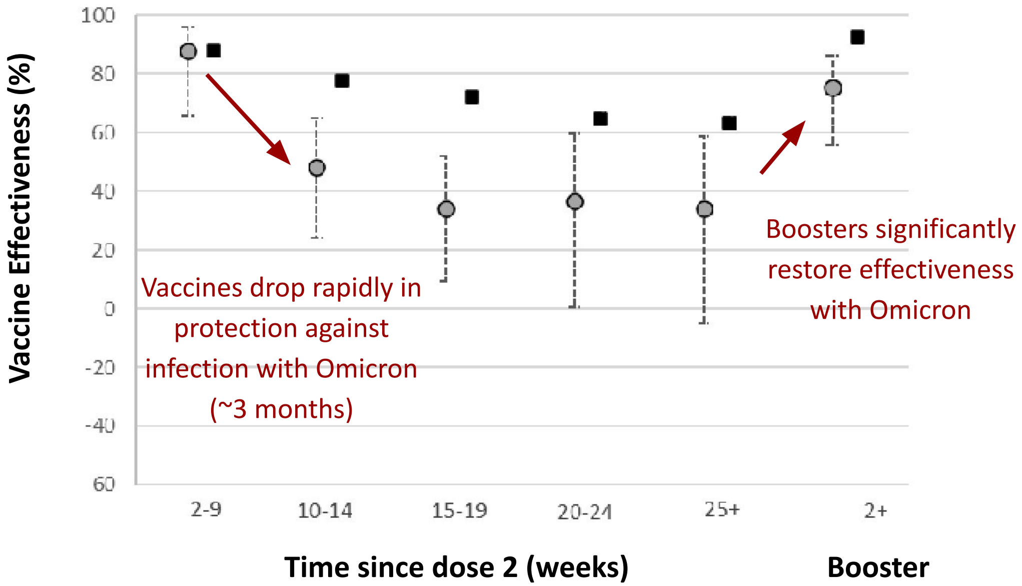
- Direct estimation of vaccine effectiveness (VE)

Cons:

- Requires direct test results

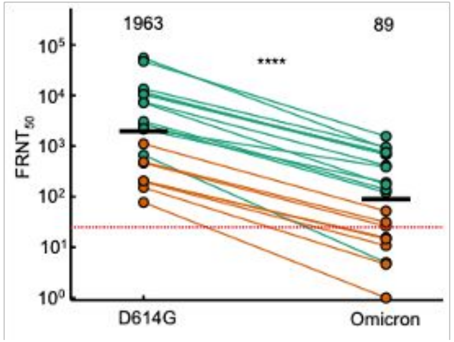
Reference: Andrews et al.

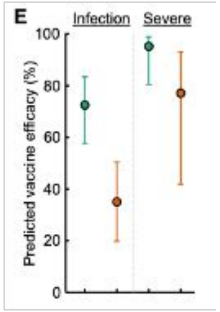
Pfizer vaccine protection against Omicron (grey) and Delta (black)



Vaccine effectiveness for infection declines with time for Delta (black), but this decline is much faster for Omicron (gray). See Andrews Fig. 1b.

Antibodies are less able to neutralize Omicron





Antibodies in blood serum are more effective against previous variants (left) than against Omicron (right). FRNT50 measures how much plasma can be diluted and still prevent virus from infecting cells. Being vaccinated and previously infected (green) provides an even stronger immune response than vaccination only (orange)). The inferred drop in vaccine efficacy against Omicron is shown on the right. Cele et al. Fig1C,E

Method 2: Antibody Neutralization

Pros:

- Faster to obtain from lab studies
- Can be used to infer VE for multiple outcomes (e.g., infection, symptomatic, hospitalization)

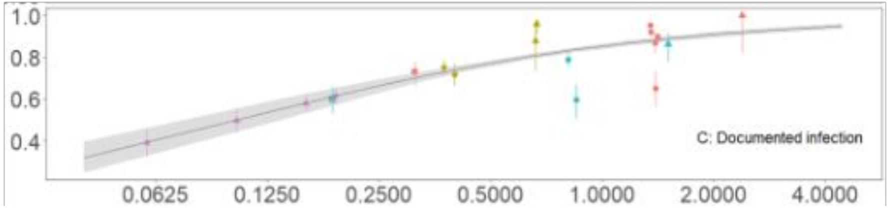
Cons:

- Indirect estimation of VE
- High among study variance (Gardner and Kilpatrick Fig 1)

References: Gardner and Kilpatrick; Cele et al.

What does Neutralization tell us about VE?

VE



Ratio of neutralization relative to WT

Neutralization ratio is indicative of VE for infection at the scale of the variation seen between variants (colours with Omicron in violet) and vaccines (symbols). Gardner and Kilpatrick Fig. 5.

How much do boosters help?

Boosters restore protection against hospitalization to levels seen before waning (here 6 months after 2nd dose) Gardner et al. Figure 6

Relative Risk (1-VE)