COVID Model Projections

February 2, 2022

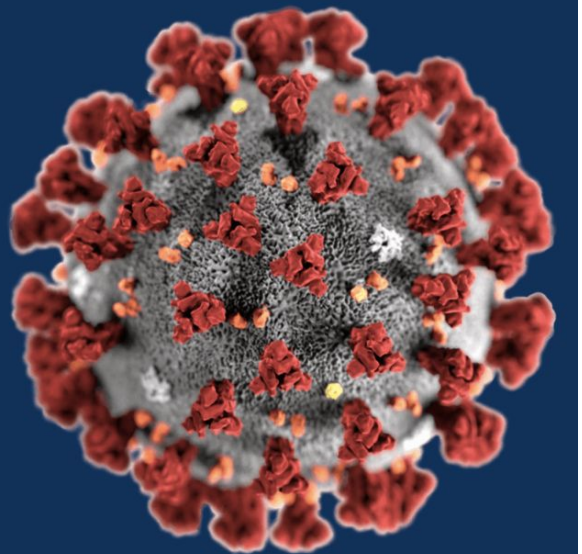
BC COVID-19 Modelling Group

@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

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

Overview

Omicron is causing rapid growth in health care demand in BC

- General BC case data are no longer useful to track the growth due to testing capacity limits and changes in testing policy for BC.
- Case data for those over 70 and hospital data suggest the growth rate declined from about 20% per day to about 10% per day.
- In the absence of reliable case data, hospital admissions can provide a good measure to track the pandemic and its impact as it has less lag than hospital occupancy data. Currently, hospital admission data are updated at irregular intervals.
    - Access to accurate, timely, and consistent daily hospital admission data would allow for better projections of health care demands. We ask BC to make such data public.
- With the reduced growth rate, the projected peak in hospital demands is lower and delayed until February, if we continue with current restrictions.
- BC projected hospital demands similar to those experienced recently in US.

OLD

Reliable data is essential for reliable inference

All data streams available publicly in BC to monitor the Omicron pandemic are unreliable, as a result of changing data standards and missing or inaccessible data.

- **Case counts:**
  - Eligibility for testing has shifted repeatedly (no group is consistently monitored)
  - Testing rates by age have plummeted for most age groups (data not downloadable)
  - Rapid Antigen Tests have replaced PCR testing (data not shared)
- **Hospitalization data:**
  - The earliest and most reliable data in most jurisdictions is hospital admissions by day (not shared on a daily basis and corrections are not publicly available)
  - Criteria for hospital admissions and occupancy are unclear and differ among Health Authorities
  - Criteria have shifted during the Omicron pandemic, including more incidental cases but testing less in hospitals (no consistent data stream)
- **Wastewater data:**
  - Monitoring is narrowly confined to the Lower Mainland (lack of data)
  - Publicly available data is not normalized by flow rate (data only shared for viral concentration per liter)
  - Data for non-COVID viruses (e.g., PMMoV), which provide a standard of comparison in many other jurisdictions, is not available (data not shared)
- **Genetic data:**
  - BA.2 is replacing BA.1 in many jurisdictions, but rates of spread in BC and Canada cannot be assessed (majority of BC data not shared in a timely fashion)
  - Virus sequencing depends on testing. Testing limitations have onward consequences for genomic surveillance.

Issues with data in BC

Rough notes on data issues - please refine and add…

- Hospital admission definition change, back-corrected data for consistent time lines is missing
- Hospital admission data currently only indirectly available by scraping daily dashboard totals and taking differences. This amplifies data errors, we clean historical timelines are needed.
- Wastewater data (currently only published by Metro Vancouver), does not include important contextual information like flow rates and PMMoV concentrations that are needed to derive more reliable estimates.
- Private testing data represents an biased population sample, but could offer some indication of community prevalence, and could help detect trends and timing of a turnaround in spread. But this data isn’t being made available.

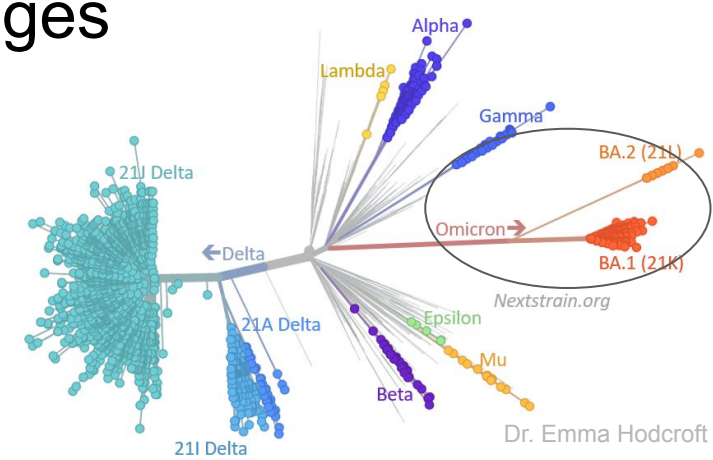
Keeping an Eye on Omicron Sub-Lineages

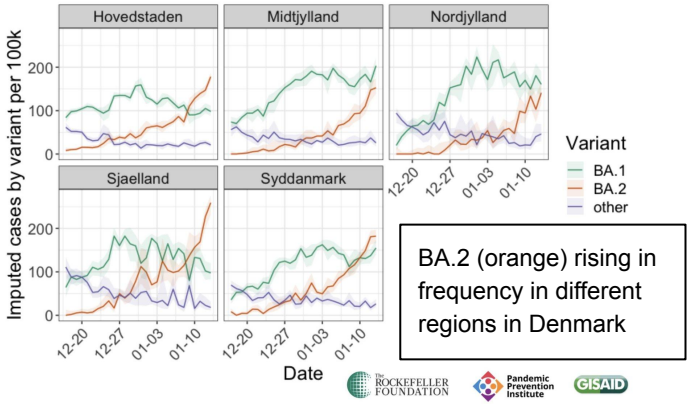
Omicron describes two major lineages, BA.1 and BA.2, that first diverged over a year ago (see evolutionary tree). BA.1 and BA.2 differ at a number of sites but share the bulk of mutations in spike.

While a relatively old lineage, BA.2 has recently started to spread in several countries (Denmark, UK, India), showing signs that it has gained a selective advantage over the more common BA.1.

Early data suggests that the advantage of BA.2 might come from a higher inherent transmissibility, rather than a greater ability to evade immunity, but reinfection rates with BA.2 are not yet known:

- Risk of infection to a household member is slightly higher in UK: 13.4% for BA.2 vs 10.3% for BA1.
- Our analysis (see appendix) finds that BA.2 is spreading faster than BA.1 at a rate of s=11%/day in Denmark and s=15%/day in the UK.





BA.2 (orange) rising in frequency in different regions in Denmark

In Canada, few BA.2 sequences have been publicly shared on GISAID (28 in total, 8 from BC), most of which are from last year, making it impossible to assess if BA.2 is spreading.

Appendix: Selection coefficient for BA.2 wrt BA.1

Selection coefficient analysis

For an exponential process, the expected number of cases reported over a period of $m = 7$ days commencing on day d is

$$E[N(d)] = \int_d^{d+m} n_0 e^{rt}\, dt = \frac{n_0}{r} e^{rd}(e^{rm} - 1)$$

For two exponential processes (1 and 2), the ratio of the daily cases is given by

$$r(d, s, d_0) = \frac{E[N_2(d)]}{E[N_1(d)]} = a \exp(r_2 - r_1)d = a \exp(sd) = \exp s(d - d_0)$$

where a is a constant, d is an integer day number, and s is the selection coefficient $s = r_2 - r_1$. The constant a defines the relative prevalence for the period commencing on day 0. A more suitable parameterization specifies the time d_0 for which the two have equal prevalence.

There are other strains in the samples and the sampling fraction can change with time. The problem can be considered to be a binomial problem, only considering the omicron samples.

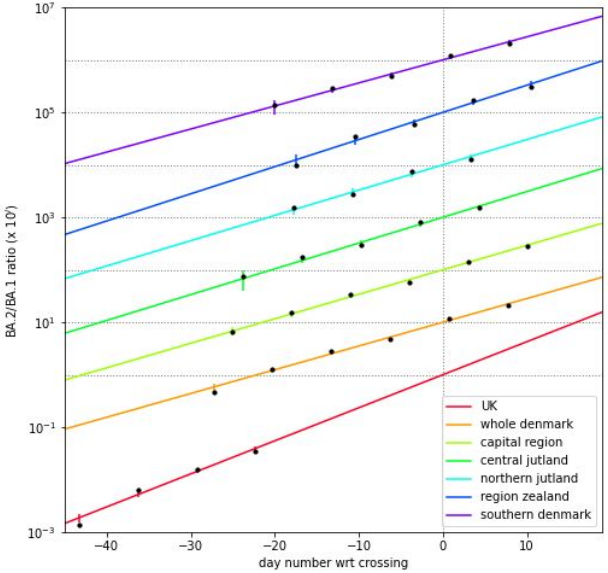
The probability for an omicron case to be type 2 is:

$$p_2(d, s, d_0) = \frac{E[N_2(d)]}{E[N_1(d) + N_2(d)]} = \frac{1}{1 + 1/r(d, s, d_0)}$$

To estimate s, use maximum likelihood. This is a binomial problem, with $n = n_1 + n_2$ trials each day.

$$\ln \mathcal{L}(s, d_0) = c + \sum_d [n_2(d) \ln p_2(d, s, d_0) + n_1(d) \ln(1 - p_2(d, s, d_0))]$$

No analytic solution, so find the estimates and uncertainty numerically.



Data from UK and regions of Denmark analyzed:

- s: selection coefficient
- d0: days after 12/5/2021 when BA.2 becomes the dominant Omicron lineage

68% statistical uncertainties shown

region	s	d0
UK	0.145 ± 0.001	64.3 ± 0.2
whole denmark	0.104 ± 0.001	34.3 ± 0.1
capital region	0.108 ± 0.007	32.0 ± 0.0
central jutland	0.113 ± 0.003	37.8 ± 0.0
northern jutland	0.111 ± 0.002	38.7 ± 0.4
region zealand	0.119 ± 0.004	31.5 ± 0.1
southern denmark	0.101 ± 0.003	34.1 ± 0.2

Selection coefficient of BA.2 wrt BA.1 is consistent across Denmark, and somewhat smaller than in UK.

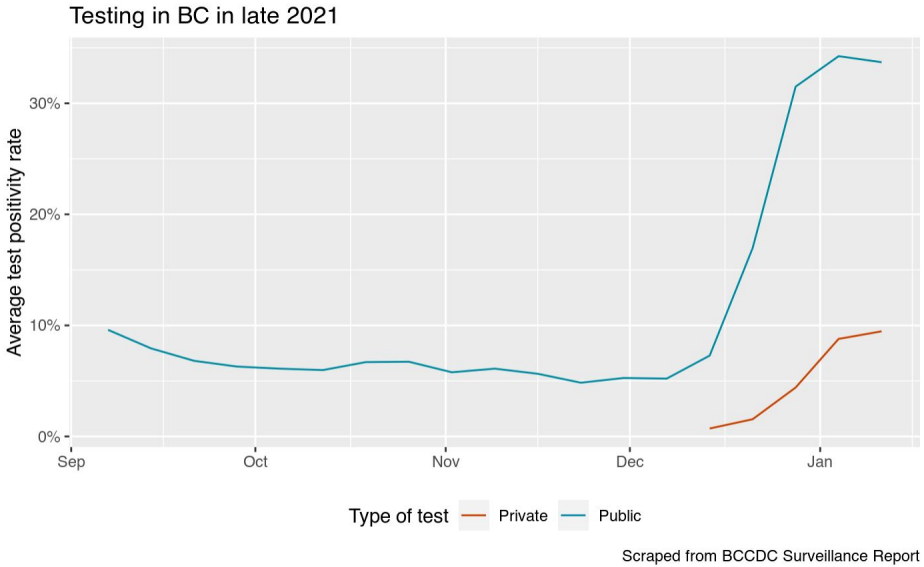
BA.2 will become the dominant Omicron lineage in the UK about 30 days later than in Denmark.

Source: D. Karlen

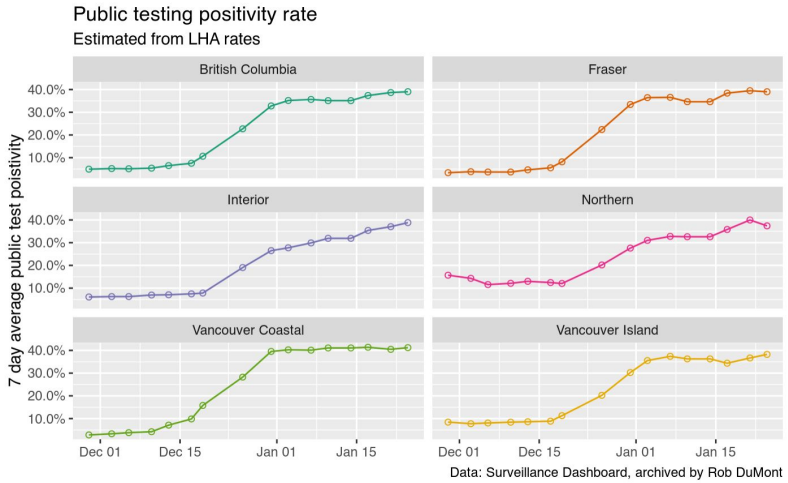
Test positivity

Public testing positivity has remained at very high levels.

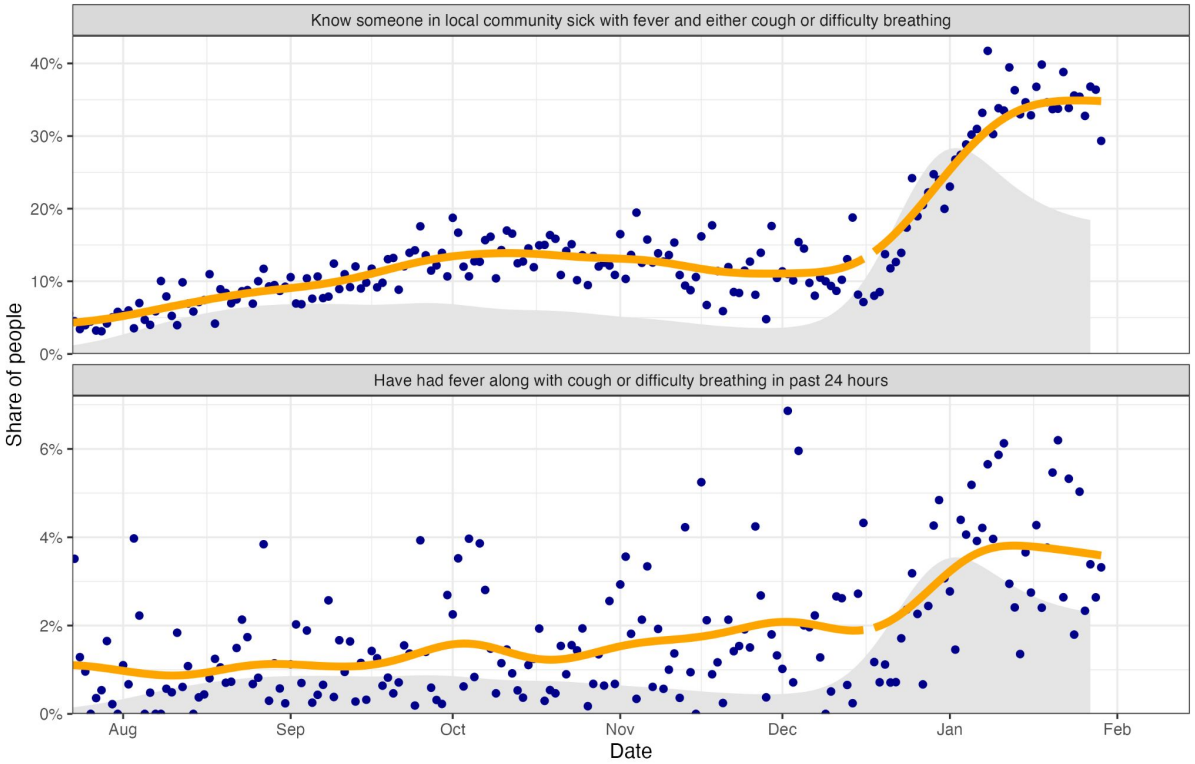
Test positivity of private testing comes with considerable time lag and uncertainty because it has to be manually scraped out of images. It shows an increasing trend suggesting high community prevalence.



Scraped from BCCDC Surveillance Report



U of Maryland Global Covid-19 Trends and Impact Survey (UMD CITS)



Data: UMD Global CTIS (survey) and BCCDC (cases)

In the past UMD CTIS Survey data has correlated reasonably well with covid cases in BC. It's a noisy measure, but can help add information in the absence of better data.

The survey is administered on Facebook with a daily sample size of about 300 people in BC (over 200K internationally).

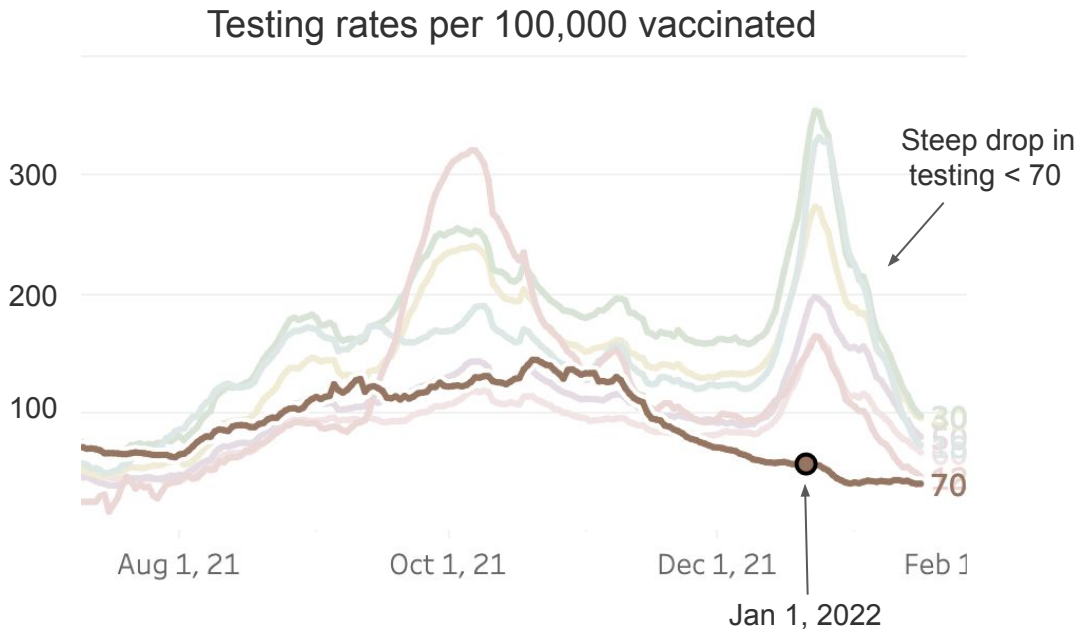
In contrast to the drop in reported cases, the survey suggests a flattening in infections, but not yet a marked decline.

Age-corrected case counts: British Columbia

Official COVID-19 case counts in BC are based on PCR testing.

PCR testing rates have plummeted in the last month among individuals under 70, because BC recommends testing only for those at risk of more severe disease (including unvaccinated adults).

[See testing guidelines here.]



→ Testing rates have been more stable among individuals 70+ (brown curve), providing a more reliable group to track COVID-19 cases over time.

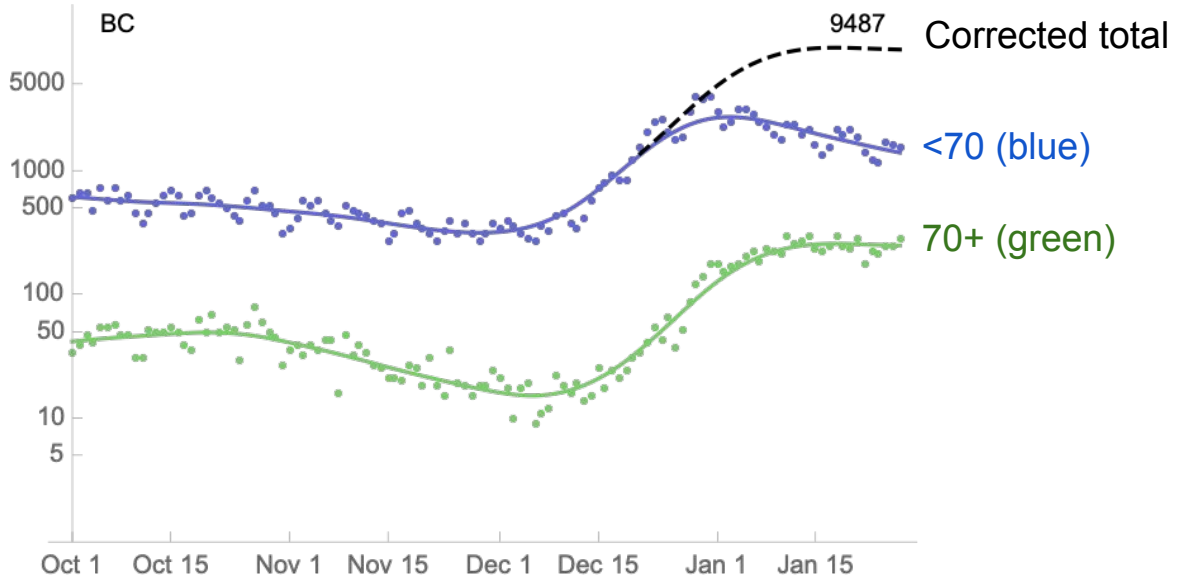
Source: COVID-19 Regional Surveillance Dashboard, "Outcomes by Vax 1" tab, "Testing rate" metric in third graph.

Age-corrected case counts: British Columbia

The black dashed curve gives the expected total number of cases, applying growth in older age cohorts (green) to correct for limited testing in younger groups (blue).

This correction suggests ~9500 cases on January 30 compared to the 1057* reported.

The age distribution is, however, likely to have shifted over the last month, so this total is increasingly unreliable.



→ What can be said reliably is that the most vulnerable age group (70+) continues to suffer very high case counts**, which are not yet declining significantly****.**

Source (S. Otto; BC COVID-19 Modelling Group) 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 BC. *From the daily BC Gov News reports. **Linear regression through log case counts among 70+ from last 14 days of data.

Age-corrected case counts: Health Authority

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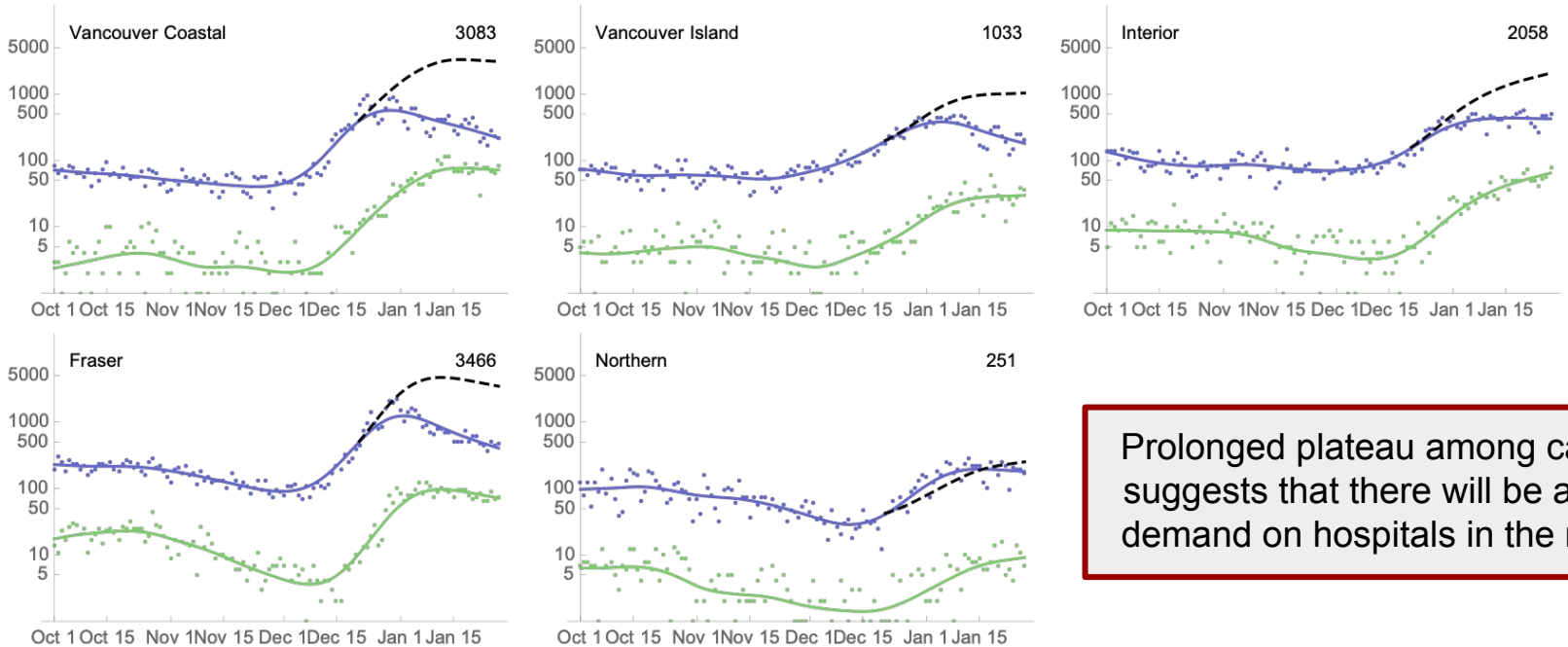
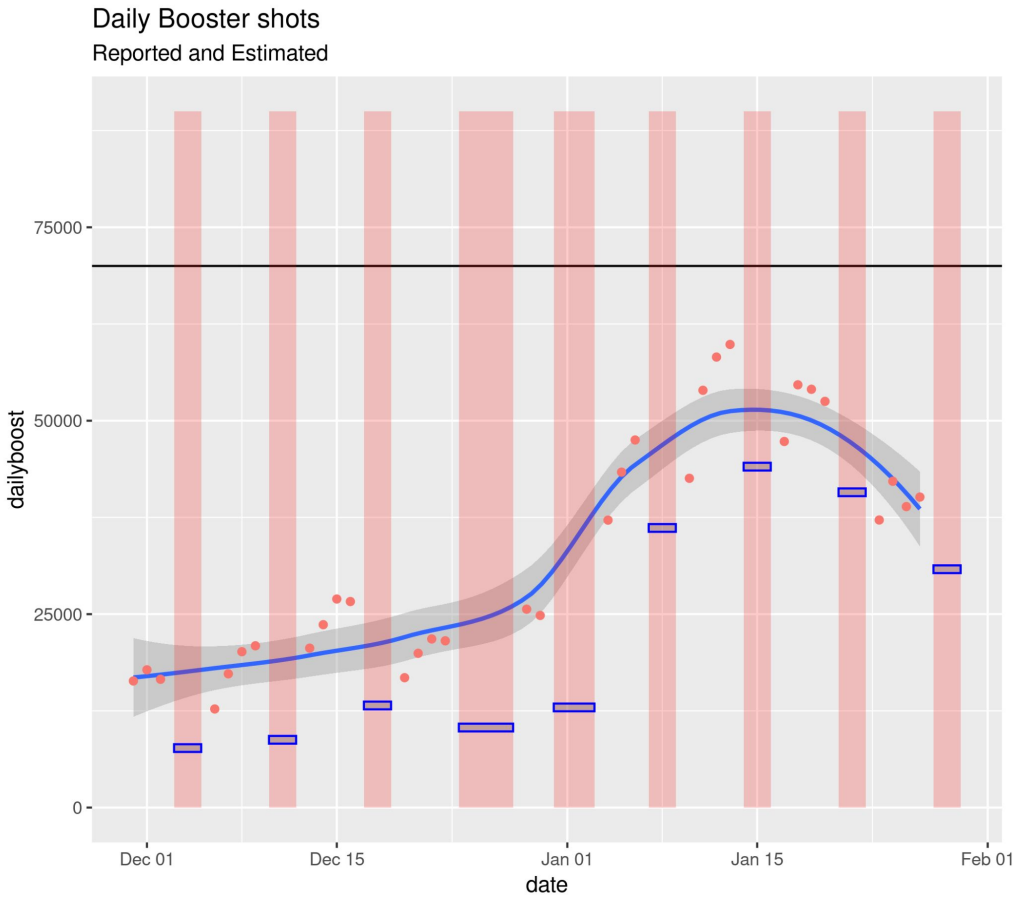


Prolonged plateau among cases in 70+ suggests that there will be a continuing demand on hospitals in the near future.

→ Cases among those 70+ continue to rise significantly* in the Interior Health Authority but have plateaued in most other Health Authorities, showing significant declines only in Fraser Health.

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. *Linear regression through log case counts among 70+ from last 14 days of data.



Data via R Dumont from Daily briefings.
Red dots are reported single-day booster #s.
Blue bars are per day means when boosters delivered are reported for multiple days (total/# of days).
Salmon-coloured bars are periods where there is no single-day data. These are typically weekends and holidays.
Horizontal line is 70K/day, the value assumed in 14 Jan 2022 Epi Modelling.

Boosters provide important protection against severe disease and hospitalization.

BC PHO hospital projections were based on 70K/day boosters.

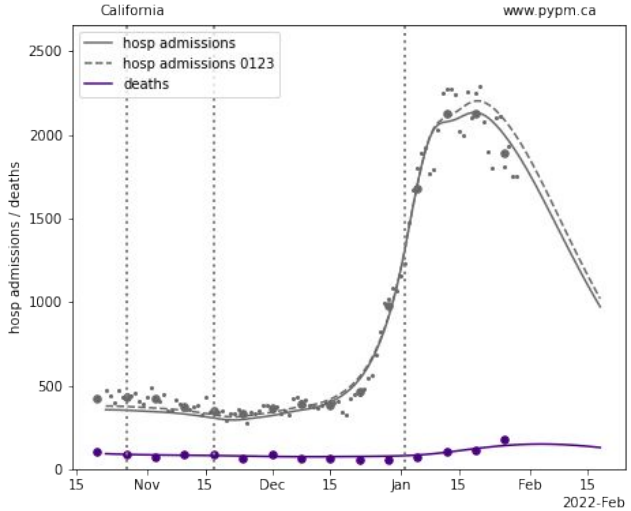
These daily booster data suggest that 10 rarely (6 days) has booster doses exceeded 50K/day since 1 December.

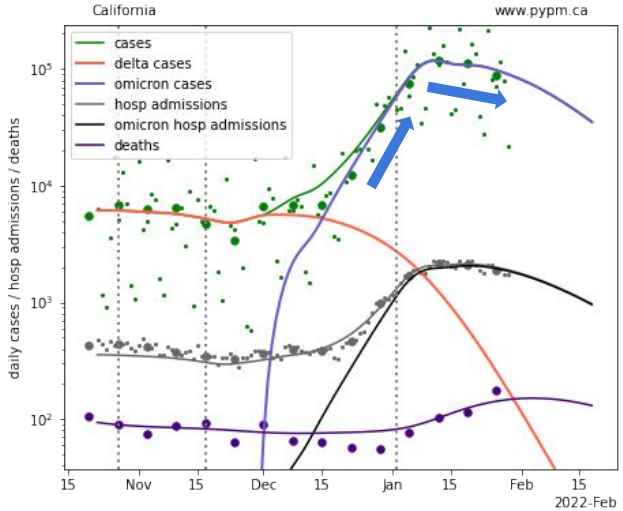
Blue line shows smoothed trend in boosters/day is now < 40K/day.

Clear evidence that Friday-Sunday weekends average cases/day (blue bars) were well below Monday-Thursday (red dots) estimates.

Omicron infection trajectory

- In all US states, growth rates for cases and hospital admissions reduced significantly near the start of 2022. **As a result, hospital demands have been significantly lower than earlier projections**.



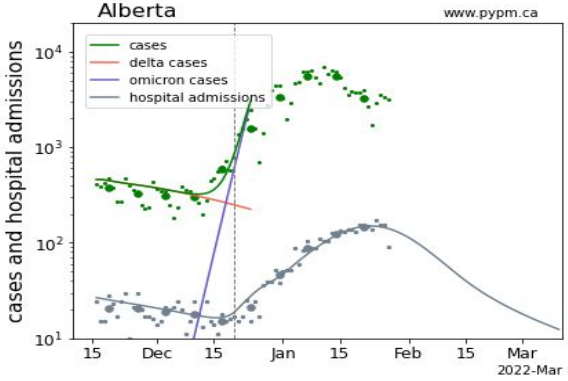


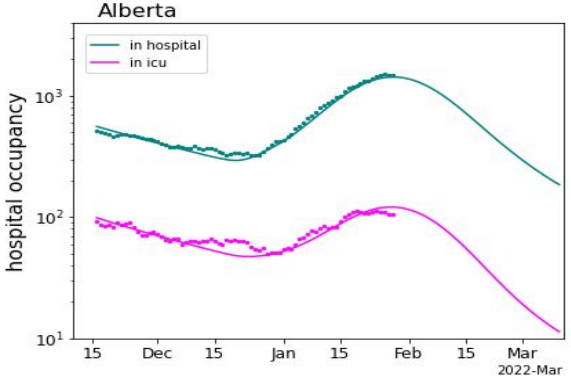
- The left plot shows the rapid rise in hospital admissions in California followed by decline. The curves show model fits to these data. The models include a significant reduction in transmission rate near January 1 (vertical dashed line).
  - the dashed curve shows the model fit from previous week: the projected decline was observed
- The right plot shows data in log scale. Exponential growth appears as straight lines.
  - the sudden change in slope is characteristic of a change in transmission rate
  - the smooth downward bending is characteristic of growing population immunity (the herd effect)

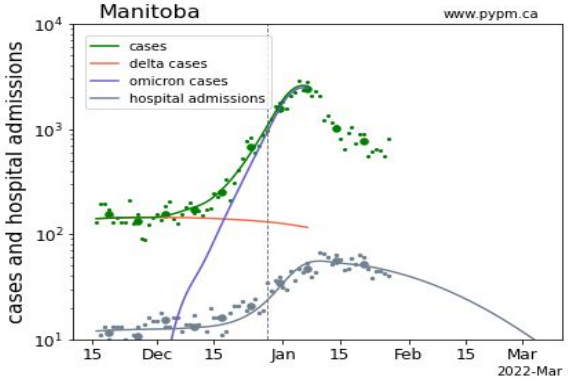
Source (D. Karlen). See www.pypm.ca. The larger dots show weekly averages.

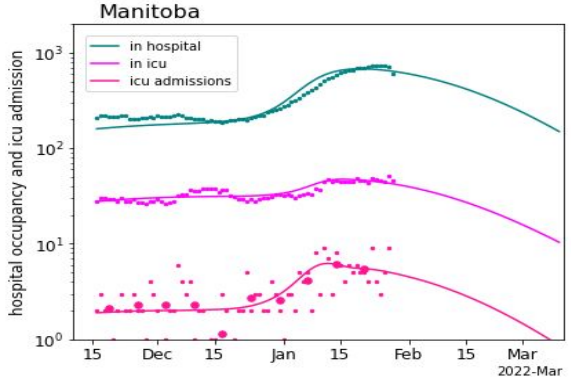
Omicron infection trajectory in Canada

- A similar drop in growth rate is also seen in Canadian provinces.





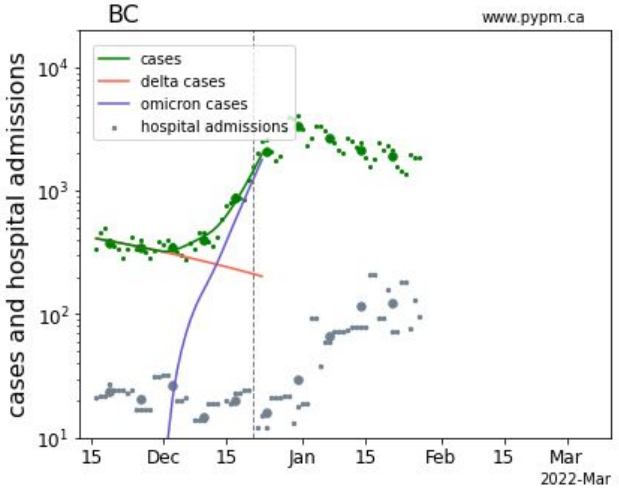


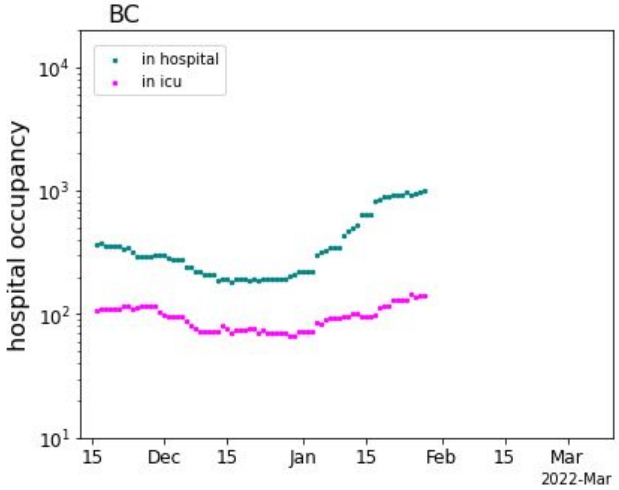


- As a result of changes to testing policy and testing capacity limits, cases can no longer be used in Canada to track the infection trajectory.
- Omicron growth rates can be monitored in provinces that provide reliable hospital admission data, in place of case data (left plots).
- With admission data to estimate Omicron growth rates, projections for hospital and ICU occupancy can be made (right plots).

Omicron infection trajectory in BC

- Without reliable data, we cannot make projections for health care demands in BC





- Hospital admission data are posted irregularly and of poor quality (large scatter).
- The province changed its definition for counting COVID hospital admissions in mid-January.
- Hospital occupancy appears to be leveling off.

Age-based model projections with Omicron

The following slides show model projections for the daily number of cases and number in hospital due to Omicron, using BC data for vaccination status and hospitalization rates by age. Updates:

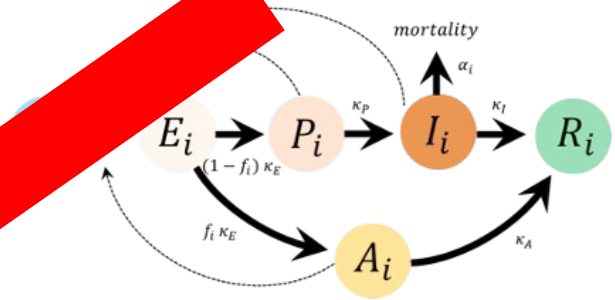
- **Vaccines:** Vaccine status of BC population updated to that on January 14, 2
(allowing time for their immunity to build), including % of boosters by age
- **Severity**: Risk of hospitalization per case is lower for Omicron (esti
76% as severe among unvaccinated by Ferguson et al. and 33
ere by UK Technical Briefing). A range is explored.

Remaining parameters as in previous report:

- **VE$_{infection}$**: Vaccine Effectiveness against infecti
0% for unboosted individuals and 75% for boosted individuals
nical Briefing 33).
- **P$_{severe}$** (Hazard Ratio): Omicron is 34%
e among vaccinated relative to unvaccinated infected individuals
et al.)

The growth rate of Omicron
to 20% per day, matching case numbers in December. I
stay in hospital was halved to 6 days for Omicron. Slides
~1/4 of all infections in BC were detected (Hamadeh et al.)
testing limits were reached.

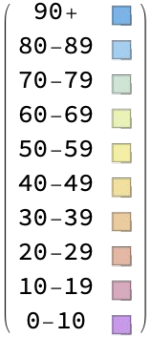
OLD



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, alongside 300 cases and 192 hospitalizations for Delta (not modeled explicitly). Data from Ferguson et al. use their corrected numbers (P_{severe} =26/76, assuming two doses of Pfizer vs unvaccinated, Table 3).

Projected Omicron infections by age

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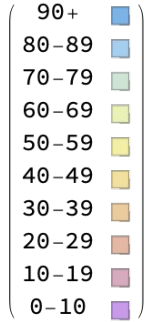
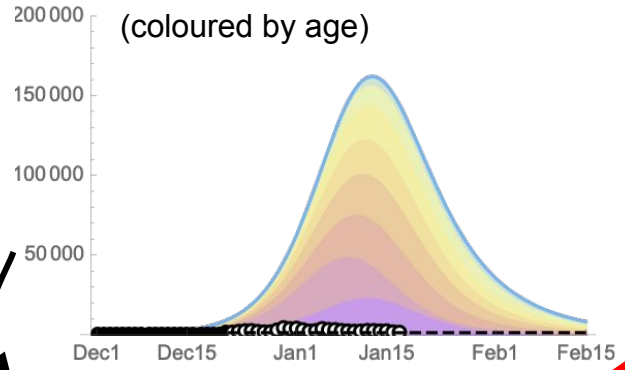
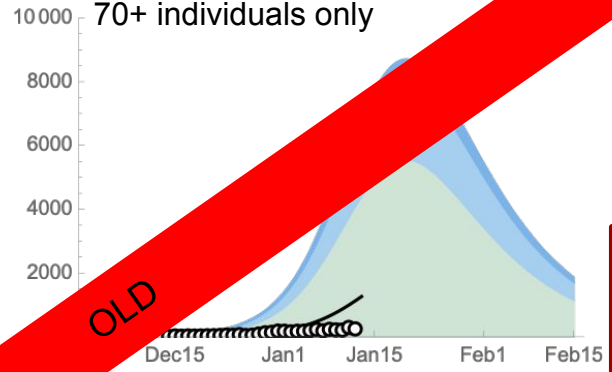
FEW INFECTIONS DETECTED (25%)
Only infections with moderate sympto



Omicron infections
(coloured by age)

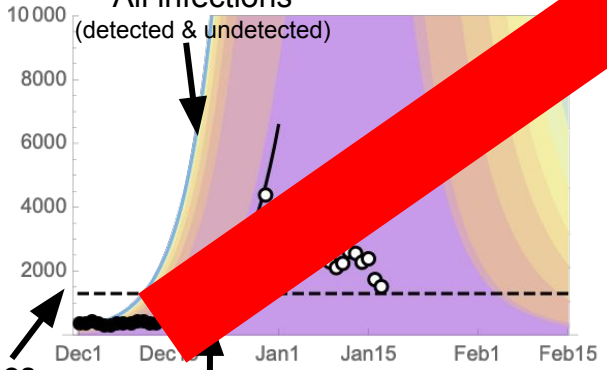


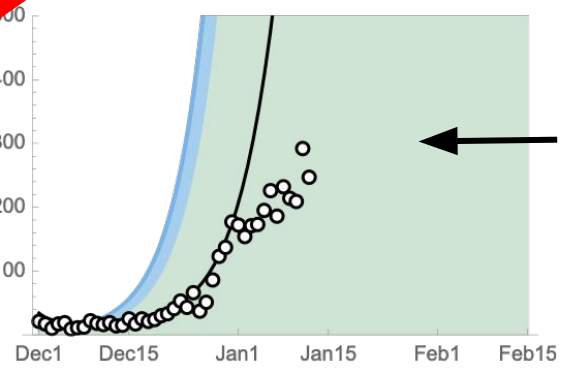
70+ individuals only



Zooming in

All infections
(detected & undetected)





OLD

Max cases
detected in previous waves in BC

Cases detected (black)

Detected cases were used to fit model through December 21 (solid circles); empty circles not used for fitting.

Cases in 70+ should be less affected by testing limits.
Circles show slower growth in this age group than predicted.
Possible explanations:
(1) Older individuals have restricted contacts more and/or (2) Omicron growth slowed following restrictions in late December.

These alternatives are explored in following slides.

Projected Omicron infections by age

(1) Reducing contacts in 70+

FEW INFECTIONS DETECTED (25%)

Only infections with moderate sympto

February 2 2022

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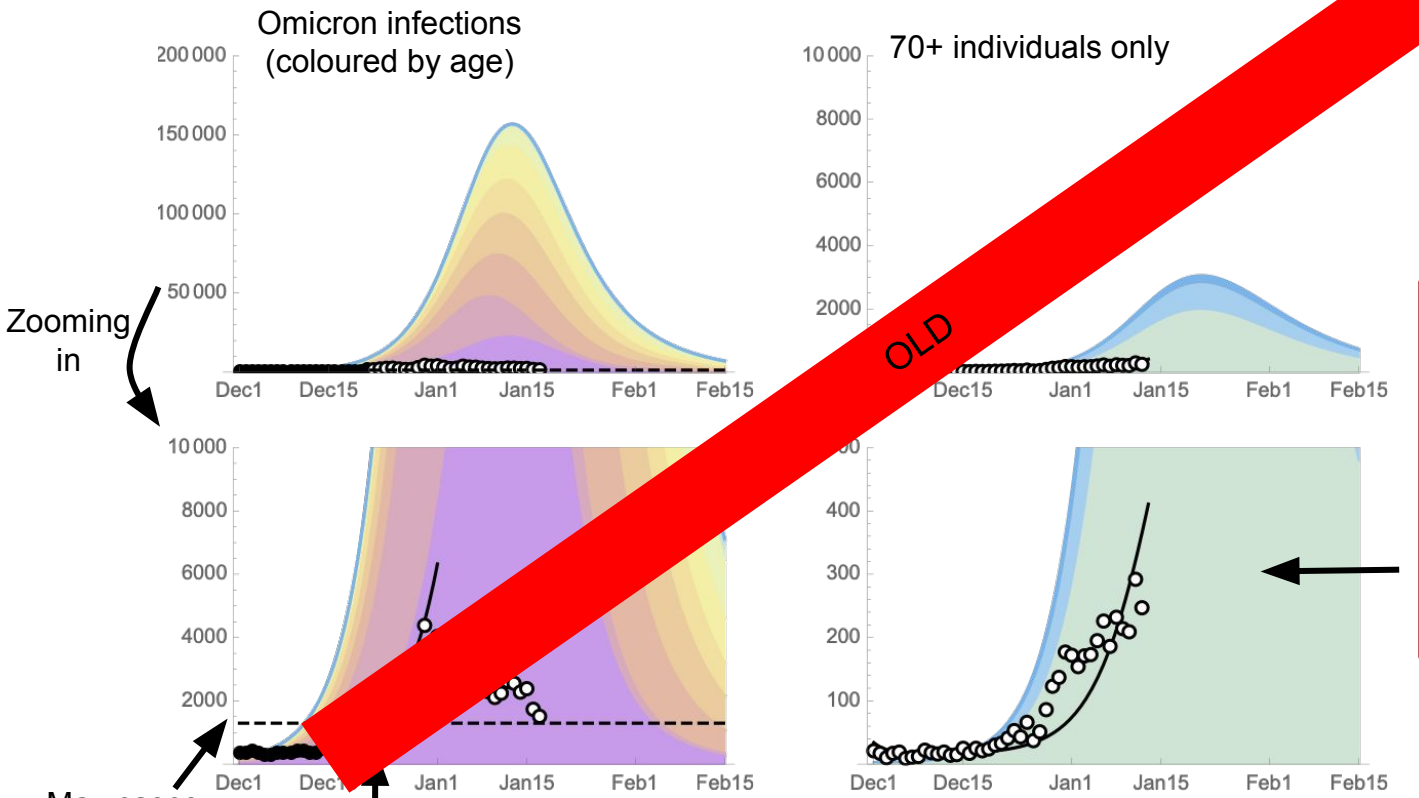

Reducing contacts in 70+

Here, older individuals have restricted contacts 3-times more than younger age cohorts across this period.

Fit doesn't capture shape of slowing growth trajectory.

Detected cases were used to fit model through December 21 (solid circles); empty circles not used for fitting.

Projected Omicron infections by age

(2) Reducing growth rate of Omicron

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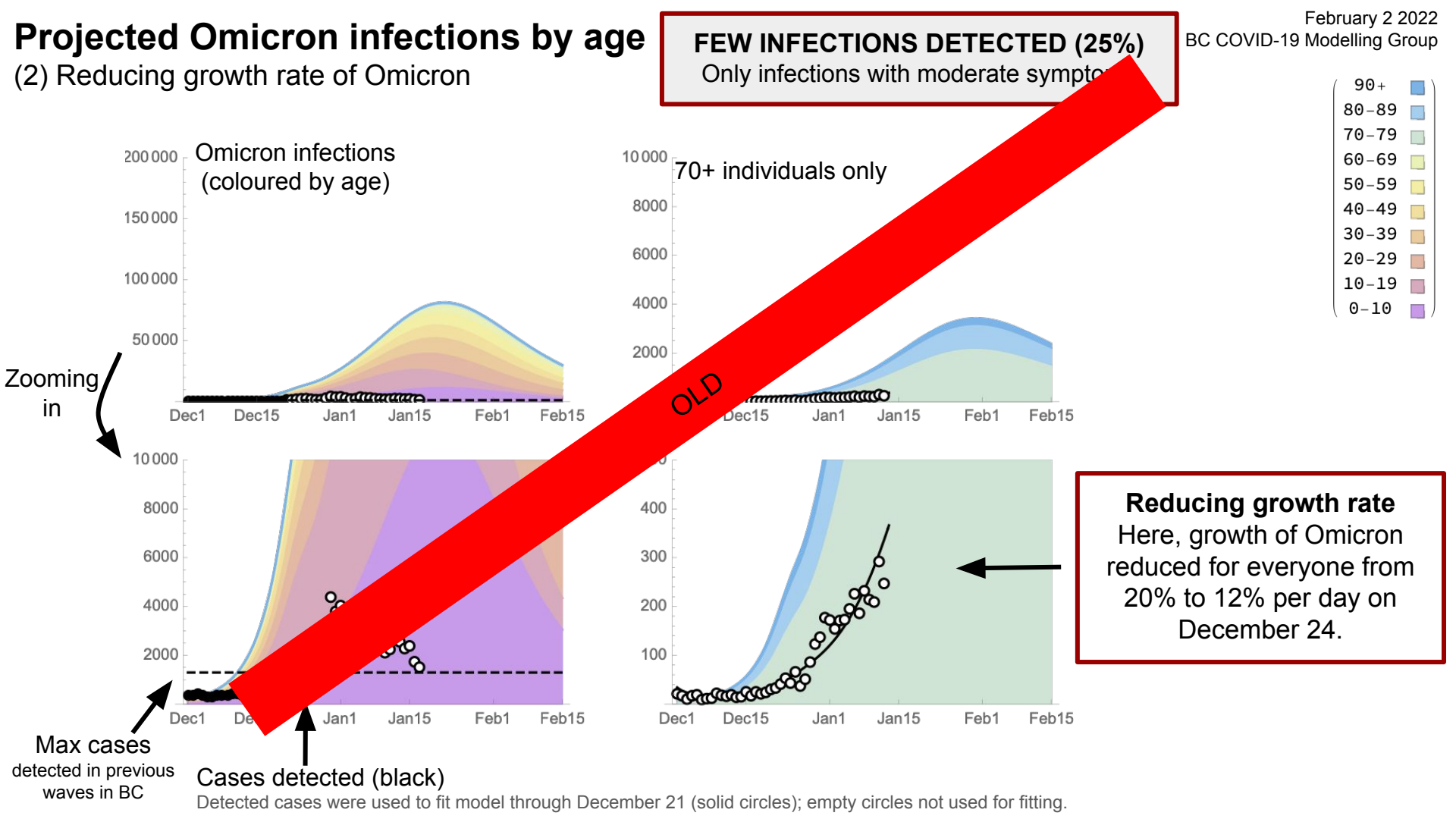
FEW INFECTIONS DETECTED (25%)
Only infections with moderate sympto



Reducing growth rate
Here, growth of Omicron reduced for everyone from 20% to 12% per day on December 24.

Max cases
detected in previous waves in BC

Cases detected (black)

Detected cases were used to fit model through December 21 (solid circles); empty circles not used for fitting.

Projected hospitalizations under two scenarios (REVISED)

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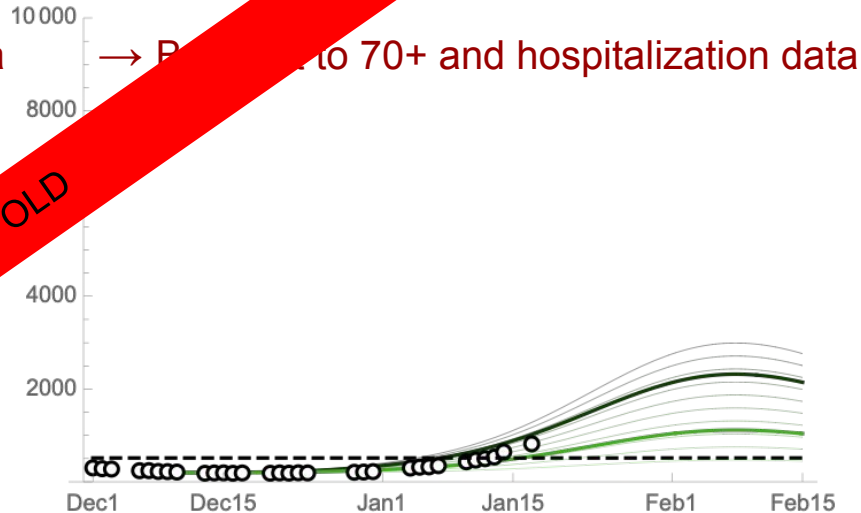
Scenario 1: Reduced contacts in 70+
Fits the hospitalization data only if Omicron severity is reduced relative to UK

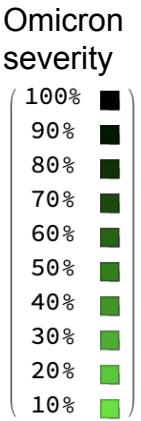
→ Worse fit to 70+ and hospitalization data

Scenario 2: Reduced growth Omicron
Fits the severity data from and predicts a later and shallower peak hospital demand IF lower Omicron growth is maintained

→ Better fit to 70+ and hospitalization data



OLD

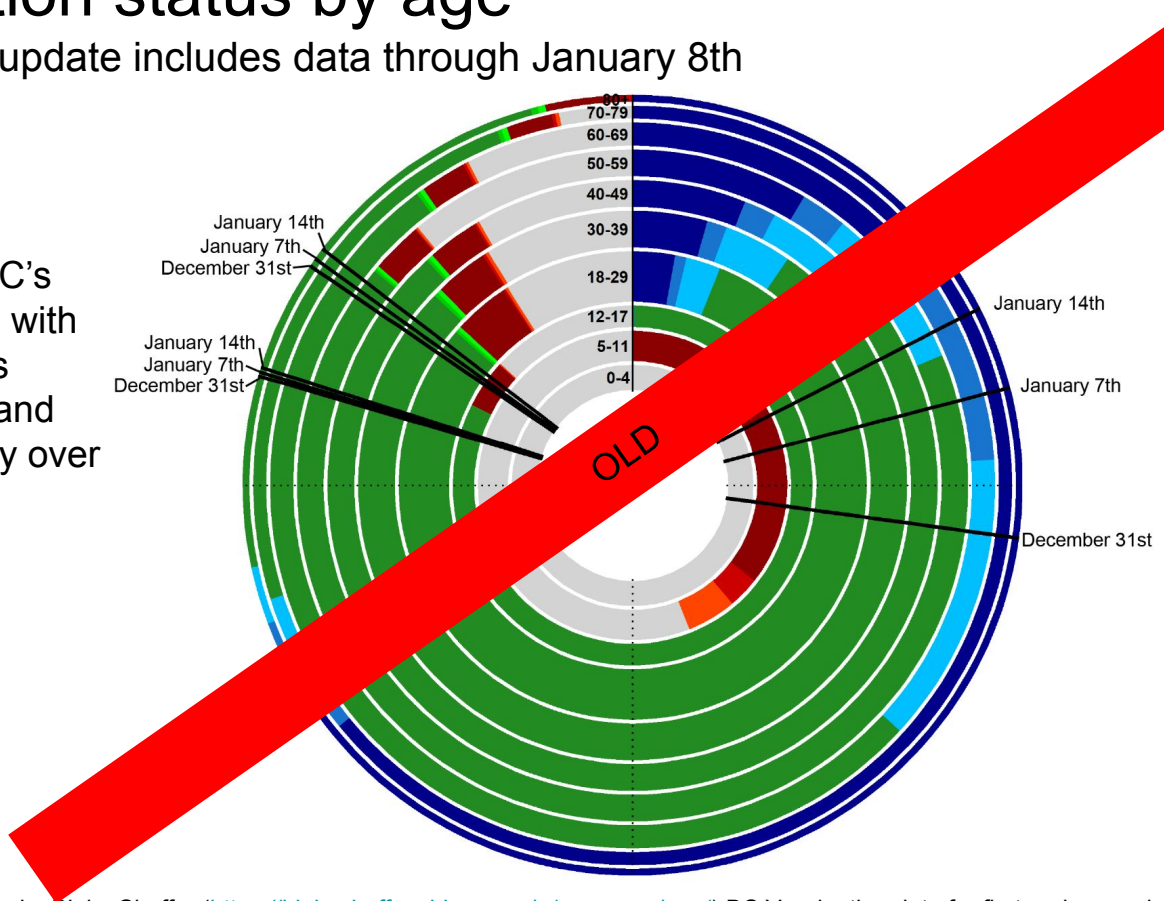


Severity: Varied from 0.1 (light green) to 0.9 (light black) for the risk of hospitalization per case for Omicron relative to previous variants for unvaccinated individuals. Estimated of 76% from Ferguson et al. is thicker black curve; estimate of 33% from UK Technical Briefing is thicker green curve.

Vaccination status by age

January 14th update includes data through January 8th

The fraction of BC's entire population with one or two doses increased **0.5%** and **0.2%** respectively over the past week



Booster Progress

The fraction of BC's entire population with three doses increased **6.2%** over the past week

Single vaccinated before:
- January 8th
- January 1st
- December 25th

Double vaccinated before:
- January 8th
- January 1st
- December 25th

Triple vaccinated before:
- January 8th
- January 1st
- December 25th

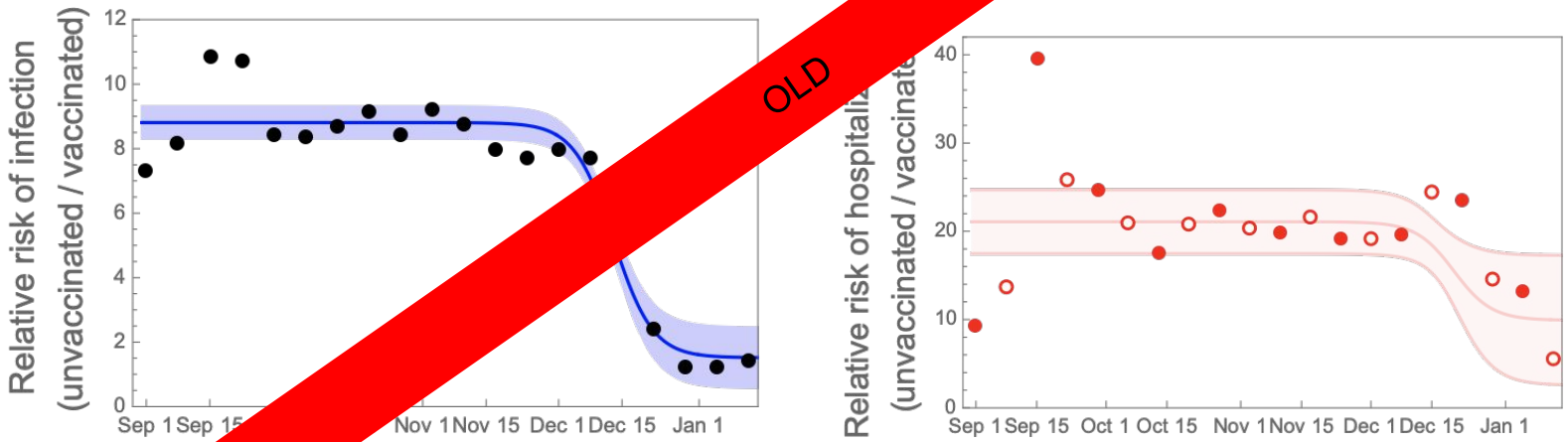
Unvaccinated

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 2022 Population projections for vaccination percentages from BC Stats: https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/population/population-projections

Changing immunity with Omicron

The risk of COVID-19 for an unvaccinated person relative to a fully vaccinated person has decl… with the spread of Omicron in BC. Being unvaccinated increased the relative risk of infection by an average … before Omicron, but this has declined to only 1.5-fold with Omicron (left). The risk of hospitalization has fallen less … -fold before Omicron to 9.9 (right).

[Relative risks are for an average person (age corrected) and do not reflect patterns in s… or given specific types and dates of vaccination.]



Source (S. Otto) Risks for an … accinated person relative to a fully vaccinated person (age corrected) were obtained from the daily BC Gov News reports. Because risk of infection is calculated across the past week, we use data from only one day per week (Wednesday) and fit $a\,(1–p_t) + b\,p_t$, where p_t is the frequency of Omicron (inferred by D. Karlen in Dec 22 report, slide 7). Risk of hospitalization is calculated over the past two weeks of data, so we fit to a model of Omicron frequency seven days ago $a\,(1–p_{t-7}) + b\,p_{t-7}$ to account for the lag in hospitalizations, using data from every other week (analysing solid and hollow points separately) and averaging the results.

Key messages

OLD

State of the Omicron wave in BC:

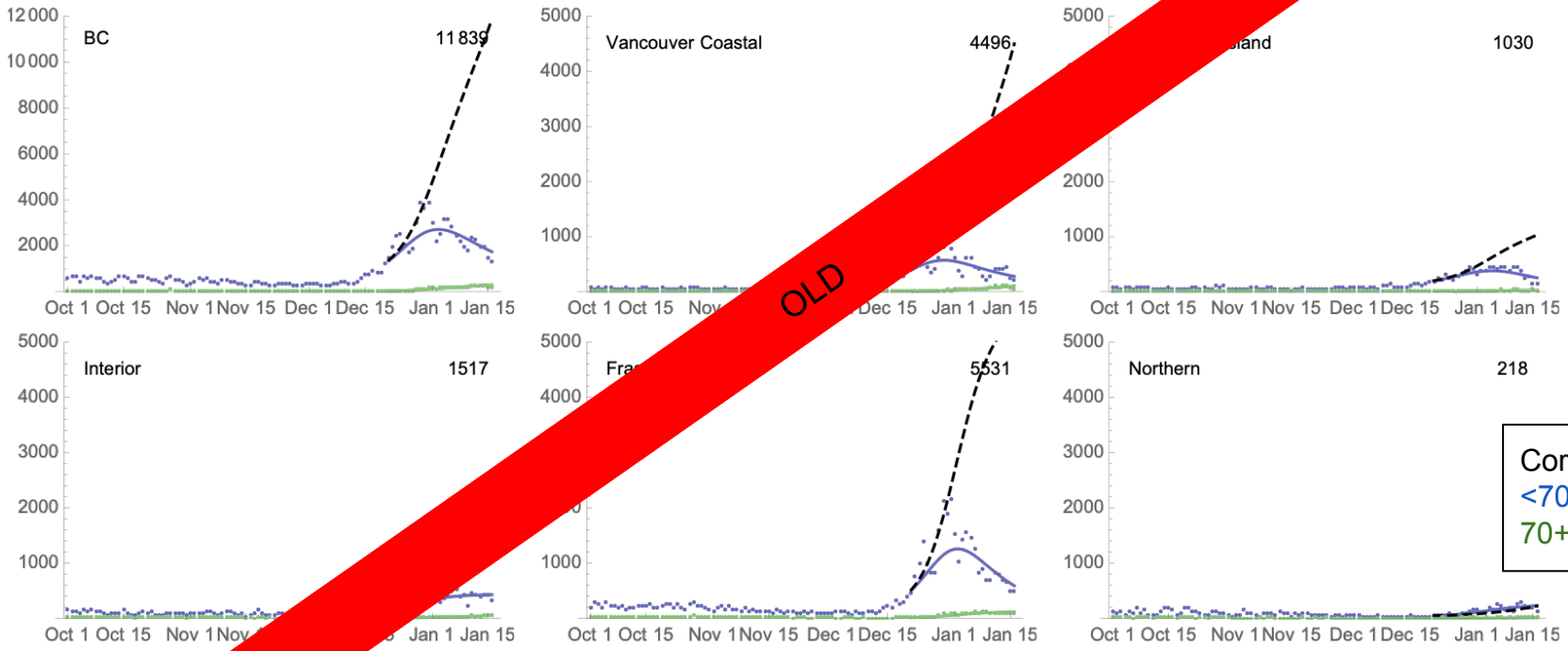
- Cases in individuals >70 in age are continuing to rise across the province. Thi… ortant because hospital demand depends disproportionately on cases in this age class.
- The drop in total cases is restricted to those <70 in age and is therefo… due to shifts in testing policies, with younger and healthy individuals discouraged from testing.
- A model fit to hospitalization data and a model fit to cases for … ver 70 years both indicate that BC has bent the Omicron curve substantially, from roughly 20% daily … infections to 10% daily growth.
- Bending down the curve substantially lowers and del… peak hospital occupancy.
- If current behaviour continues, infections are exp… peak in late January/early February, with hospital occupancy peaking later in February.

Addressing data gaps would help red… certainty:

- Rapid antigen test results would … sess trends in infection rates in BC (not available).
- Wastewater data would als… sess trends in infection rates in BC, but these need to be normalized to account for the total flo… r per day or against another virus (e.g., PMMoV in vegetables). Currently, BC data is not normali… entration in virus per mL).
- Accurate, timel… nsistent daily hospital admission data would allow for better projections of health care demands in t… re.

Appendix: Age-corrected case counts

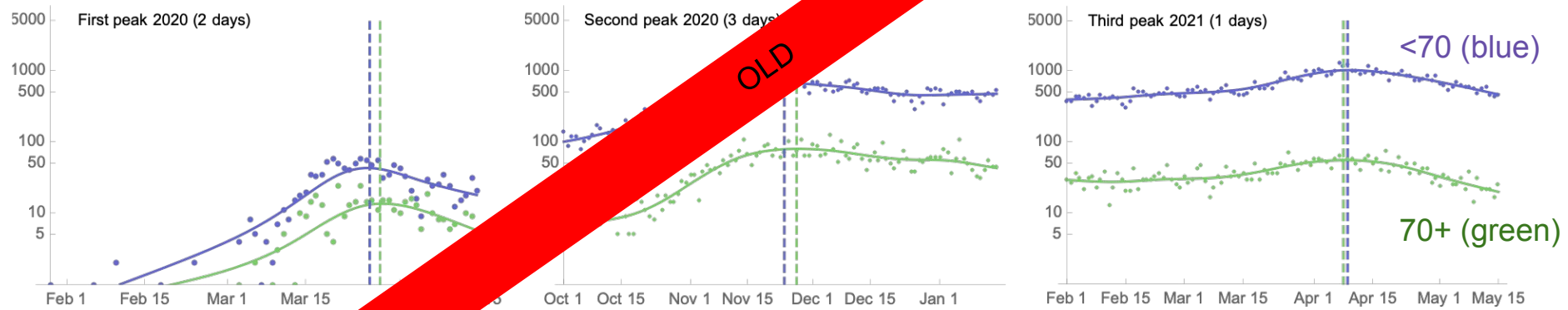
Same data and projections for total case numbers as in main slides but on a linear scale (y-axi



Source (S. Otto; BC COVID-19 Modelling Group) 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), using a curvature penalty of l=3. The fourth (Delta) wave did not have a distinct peak, with similar case counts over a ~two month period before the Omicron wave.

Appendix: Age-corrected case counts

As a check, we compare the peaks of previous waves for [illegible] 70+ (green dashed) and for people <70 (purple dashed). Cubic spline fits a[illegible]ilar in shape and exhibit peaks within 1-3 days of each other for the two ag[illegible]ps.



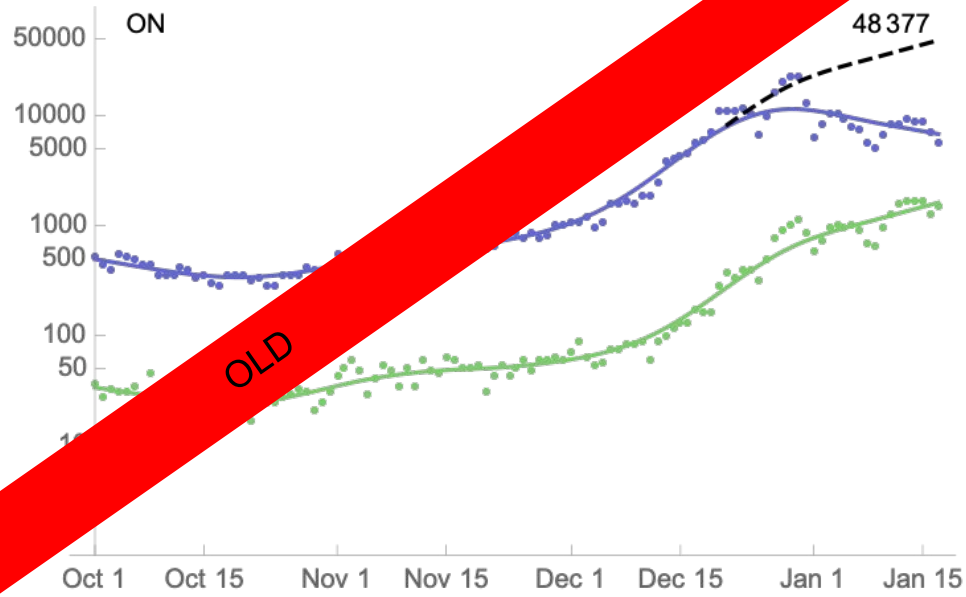
OLD

Source (S. Otto; BC COVID-19 Modelling Group) 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), using a curvature penalty of l=3. The fourth (Delta) wave did not have a distinct peak, with similar case counts over a ~two month period before the Omicron wave.

Age-corrected case counts: Ontario

Similar patterns are found in other provinces, such as Ontario, with case reporting in younger individuals plateauing when testing limits are reached.

Cases in 70+ continue to show growth and have not peaked in ON. Importantly, future hospital demand will largely reflect patterns in this age group.



OLD

→ Using this age co[illegible], the estimated number of cases that would have been detected on January 18 is ~4[illegible] had testing limits not been exceeded, **compared to the 7086** reported.**

Source (S. Otto) *New cases per day in 10-year age groups were downloaded from Ontario Data Catalogue ("Accurate_Episode_Date"). 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. **From Ontario Case Numbers and Spread. As line list information from the Catalogue is continuously updated, recent days are missing many cases. Totals from the last week were thus adjusted to match the reported number of cases (similar results obtained by trimming).