COVID Model Projections

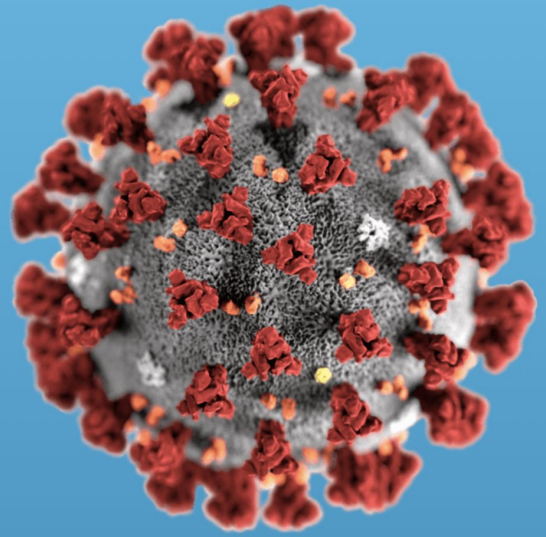
May 14, 2021

BC COVID-19 Modelling Group

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 was convened by Caroline Colijn (SFU) and Dan Coombs (UBC) with support from the Pacific Institute for the Mathematical Sciences.



https://bccovid-19group.ca

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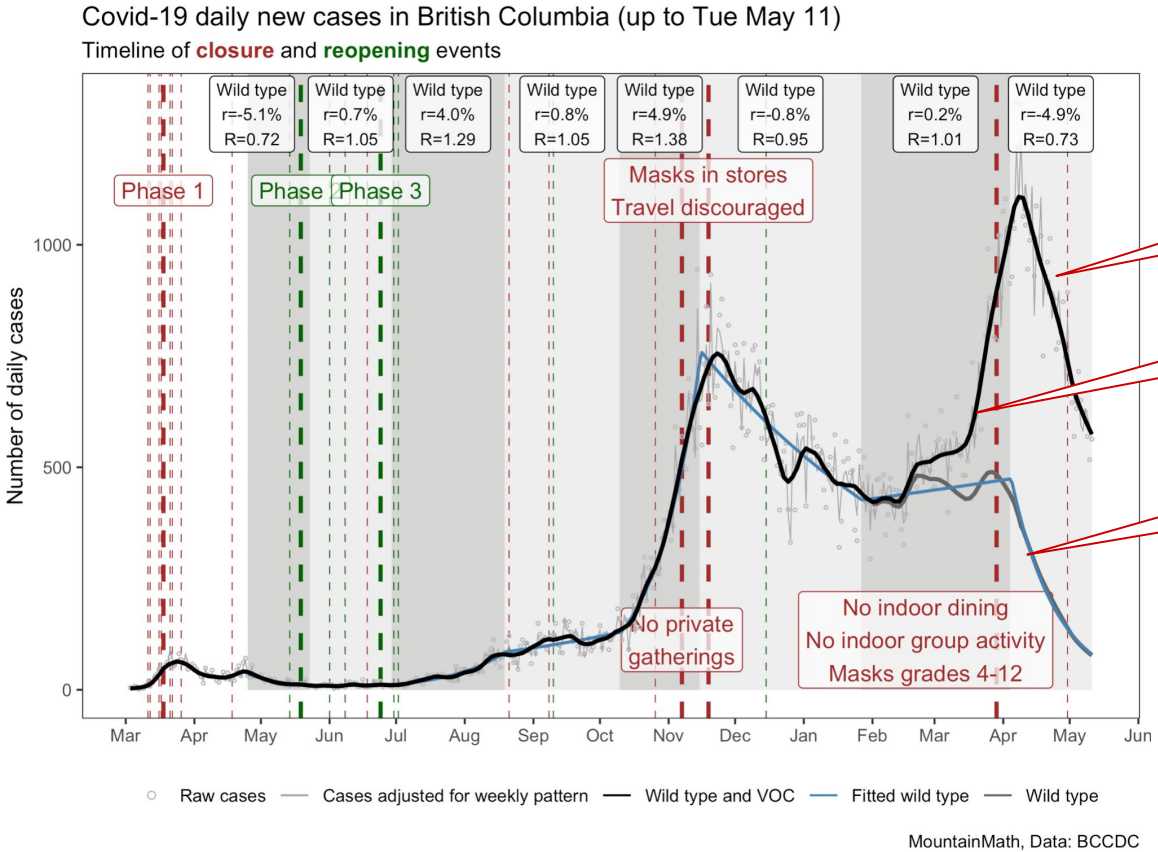
Independent and freely offered advice, using a diversity of modelling approaches.

Bending down the VOC curve

Key messages

- Cases are projected to decline through May
- Hospital and ICU occupancy declining slowly but predicted to remain above 300 and above 100 through May.
- If recent measures are lifted at the end of May (returning to February/March 2021 activities), cases, hospital, and ICU occupancy will grow briefly but then decline by late June as vaccination catches up.
- If recent measures are lifted to last summer's activity levels, we see prolonged periods with high case numbers.
- Recent changes in growth associated with larger impact on VOC than WT.
    - Not due to vaccination
    - Likely due to individual behaviour changes (masks, distancing, restaurant rule)

State of the COVID-19 Pandemic in BC



April 2021: BC has bent down the COVID-19 curve

March 2021: Steep rise in COVID-19 cases

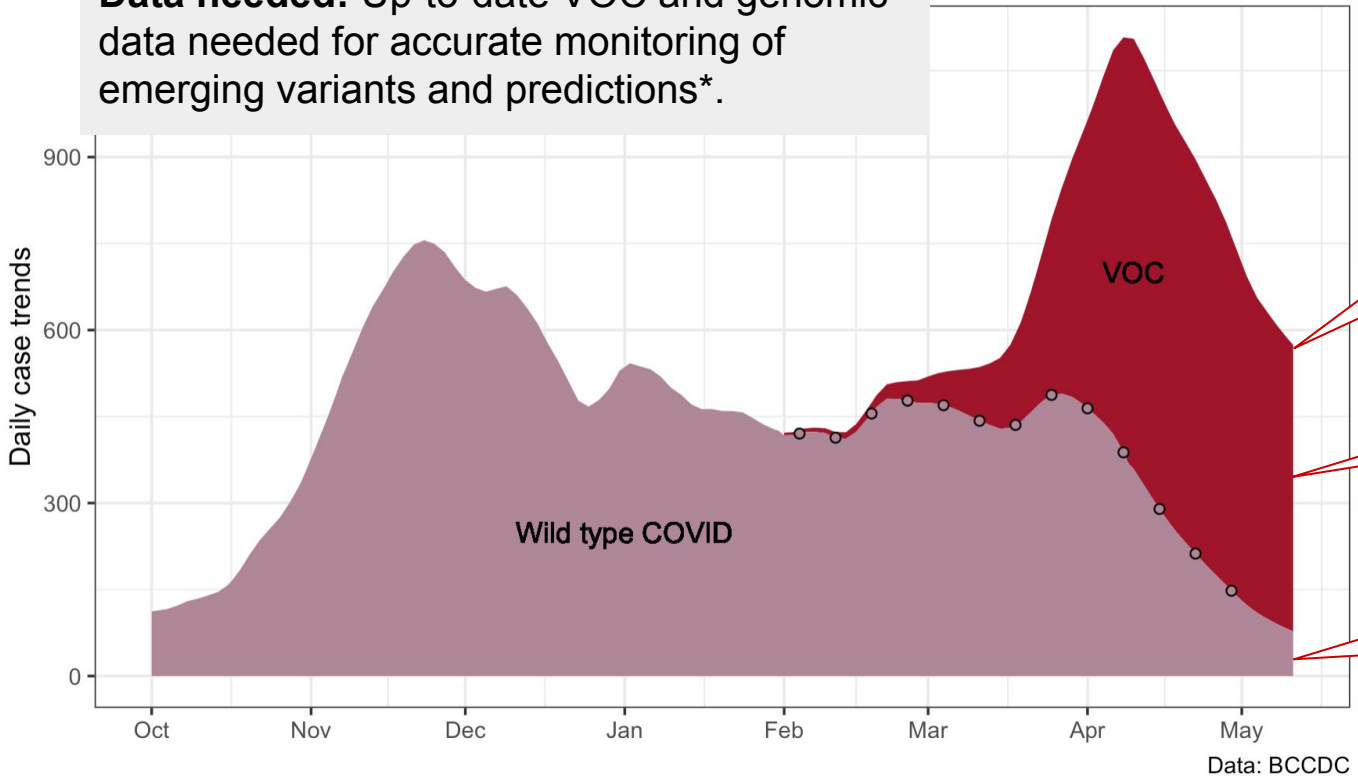
Much of the recent decline appears driven by fast declines in non-variant cases

Recent measures work:
Change reflects a combination of individual actions, vaccination campaigns in hotspots, and increased restrictions (e.g, no indoor dining).

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.

State of the COVID-19 Pandemic in BC

Data needed: Up-to-date VOC and genomic data needed for accurate monitoring of emerging variants and predictions*.



88% variants of concern* (estimate for May 14, 2021)

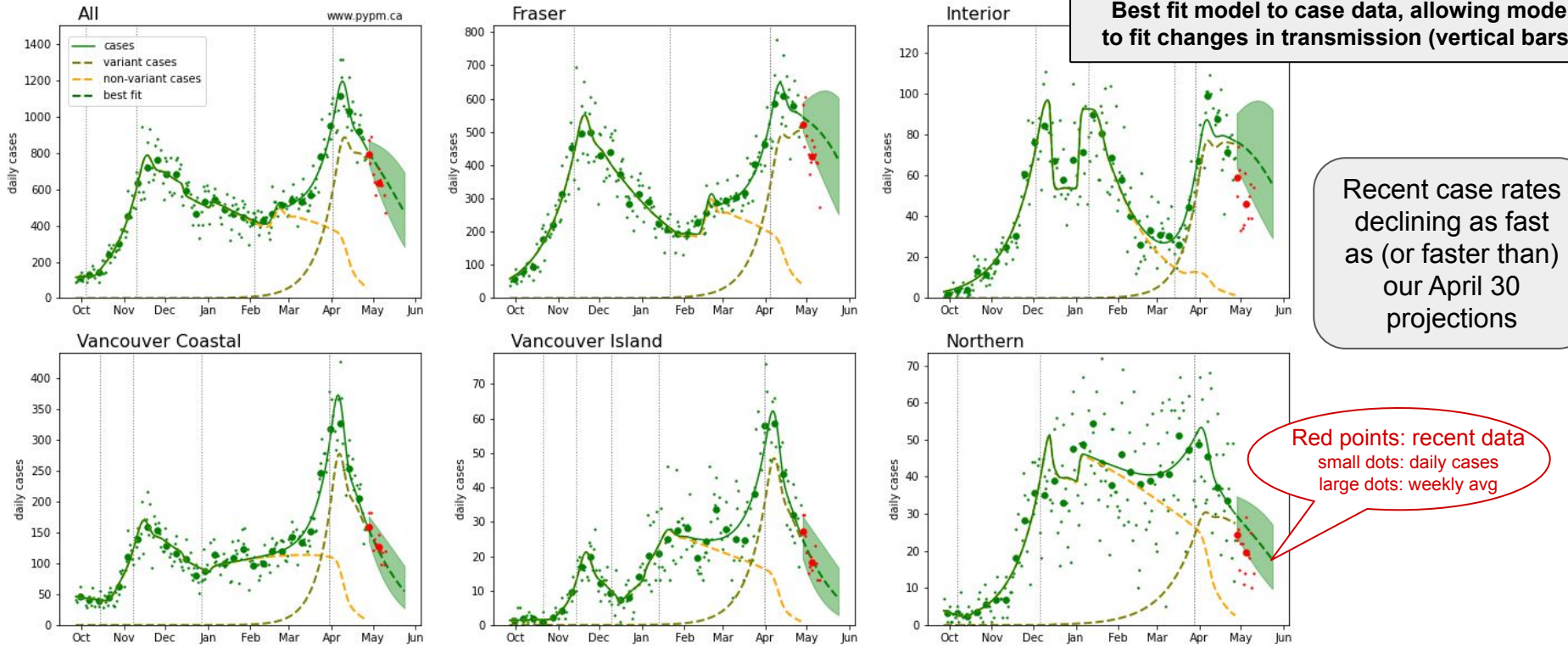
Variant cases roughly constant

Estimated number of non-variant cases has declined rapidly

Source (J. von Bergmann). Case data from BC COVID-19 Database (http://www.bccdc.ca/health-info/diseases-conditions/covid-19/data) and smoothed using STL trend line that removes day-of-the-week effects. VOC data from BCCDC (April 7, 2021). Variant data: http://www.bccdc.ca/health-info/diseases-conditions/covid-19/data#variants

*Accounting for slowdown in variant spread (slide 11).

April 30 model fit to case data by Health Authority



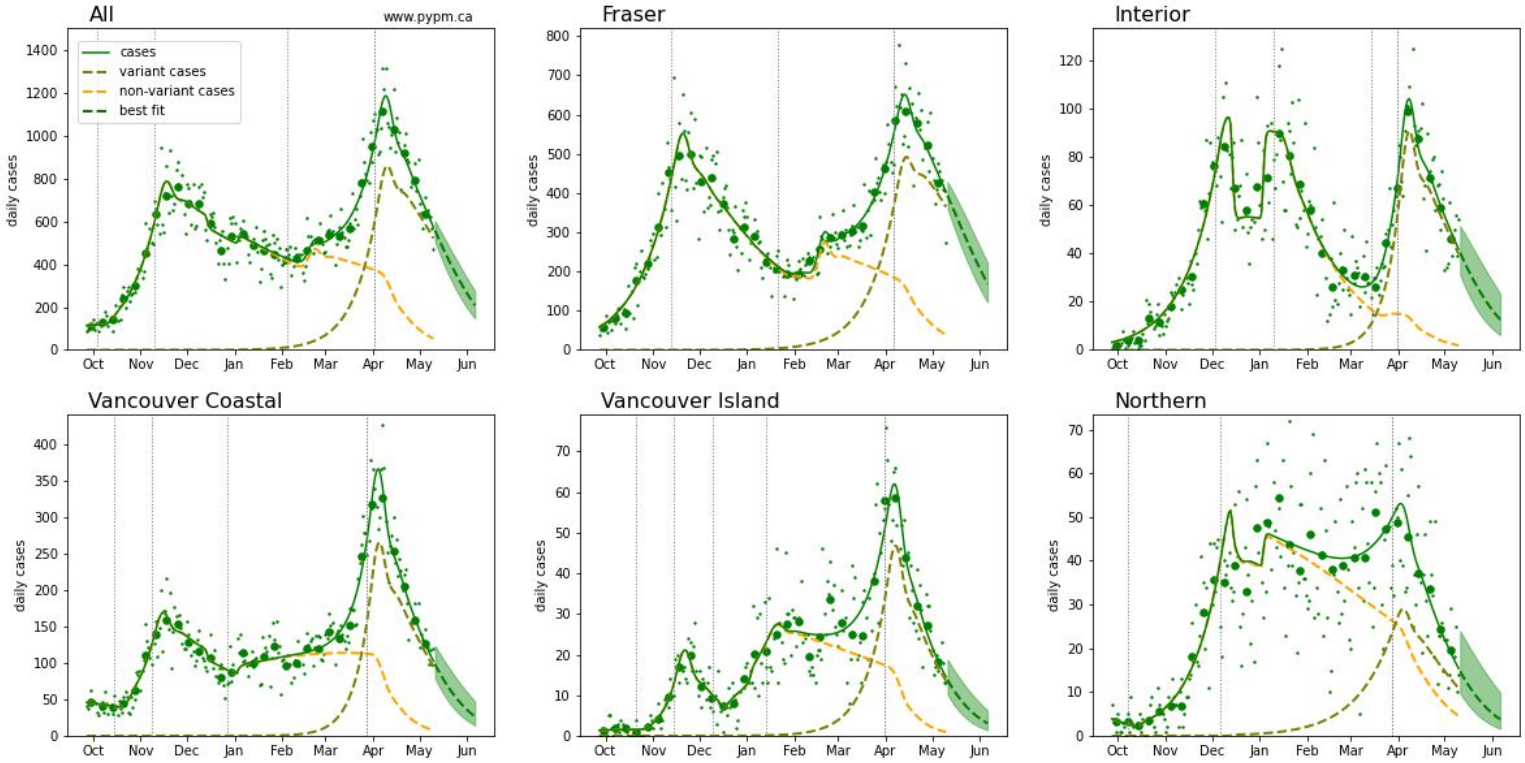
Best fit model to case data, allowing model to fit changes in transmission (vertical bars).

Recent case rates declining as fast as (or faster than) our April 30 projections

Red points: recent data
small dots: daily cases
large dots: weekly avg

Source (D. Karlen). See www.pypm.ca. Assumes homogeneous mixing (no age structure). Assumes vaccination rate of 1st doses continues at 35,000/day (assumes vaccines given to all ages and in proportion to HA populations). Vaccination model benchmarked with data from Israel: see Appendix and link. Model fits to case data projected into May assuming current public health measures. Shaded bands indicate range of trajectories consistent with case data (68% CL).

Updated model fit to case data by Health Authority

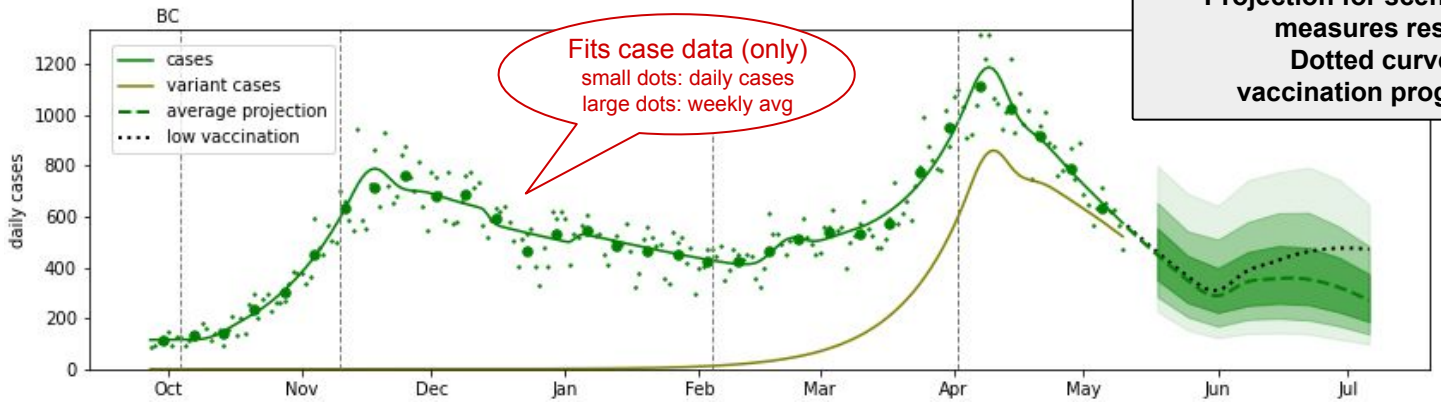


New projections show continued case declines as vaccines rollout.

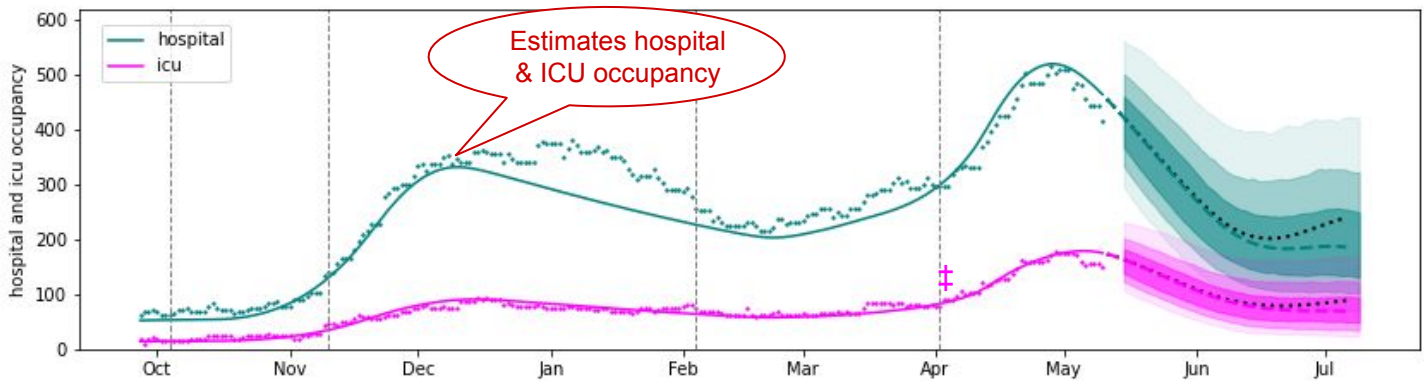
Source (D. Karlen). See www.pypm.ca. These models have no age structure. Assumes vaccination rate of 1st doses grows to 45,000/day on May 17 (given to all ages and in proportion to HA populations until 75% of the population is vaccinated), ultimate 1st dose effectiveness is 90%. Vaccination model benchmarked with data from Israel: see Appendix and link. Assumes current public health measures remain in place. Shaded bands indicate range of trajectories consistent with case data (68% CL).

Model fit with relaxation on May 25

Projection for scenario with circuit breaker measures rescinded on May 25. Dotted curves show impact if vaccination program is less effective*



Projected cases



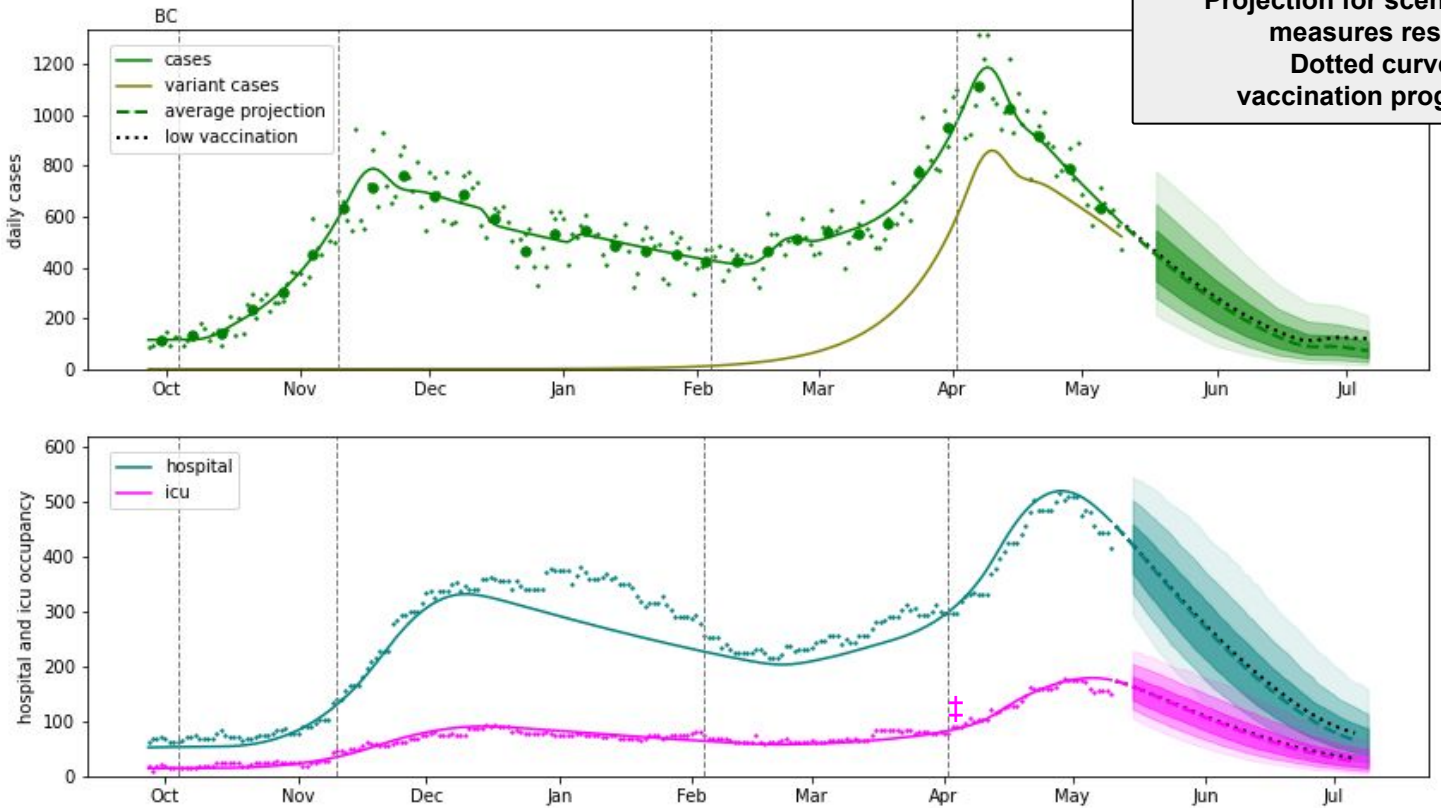
Projected hospital occupancy

Projected ICU occupancy

Source (D. Karlen). See www.pypm.ca. Homogeneous mixing (no age structure). *Nominal versus low vaccination rate assumptions: 45,000/day vs 35,000/day up until 75% vs 65% vaccinated, with 90% vs 80% asymptotic effectiveness of first dose (see Appendix for comparison to real-world effectiveness). Projection is for a scenario rescinding the March 30 measures (the "circuit breaker") on May 25, returning BC to activity levels in early 2021. ‡To match ICU data, the fraction of cases leading to ICU admission is increased by 60% ± 20% in early April. Bands show approximate 50%, 80%, and 95% intervals for nominal vaccination campaign.

Model fit with relaxation on June 15

Projection for scenario with circuit breaker measures rescinded on June 15. Dotted curves show impact if vaccination program is less effective*



} Projected cases

} Projected hospital occupancy

} Projected ICU occupancy

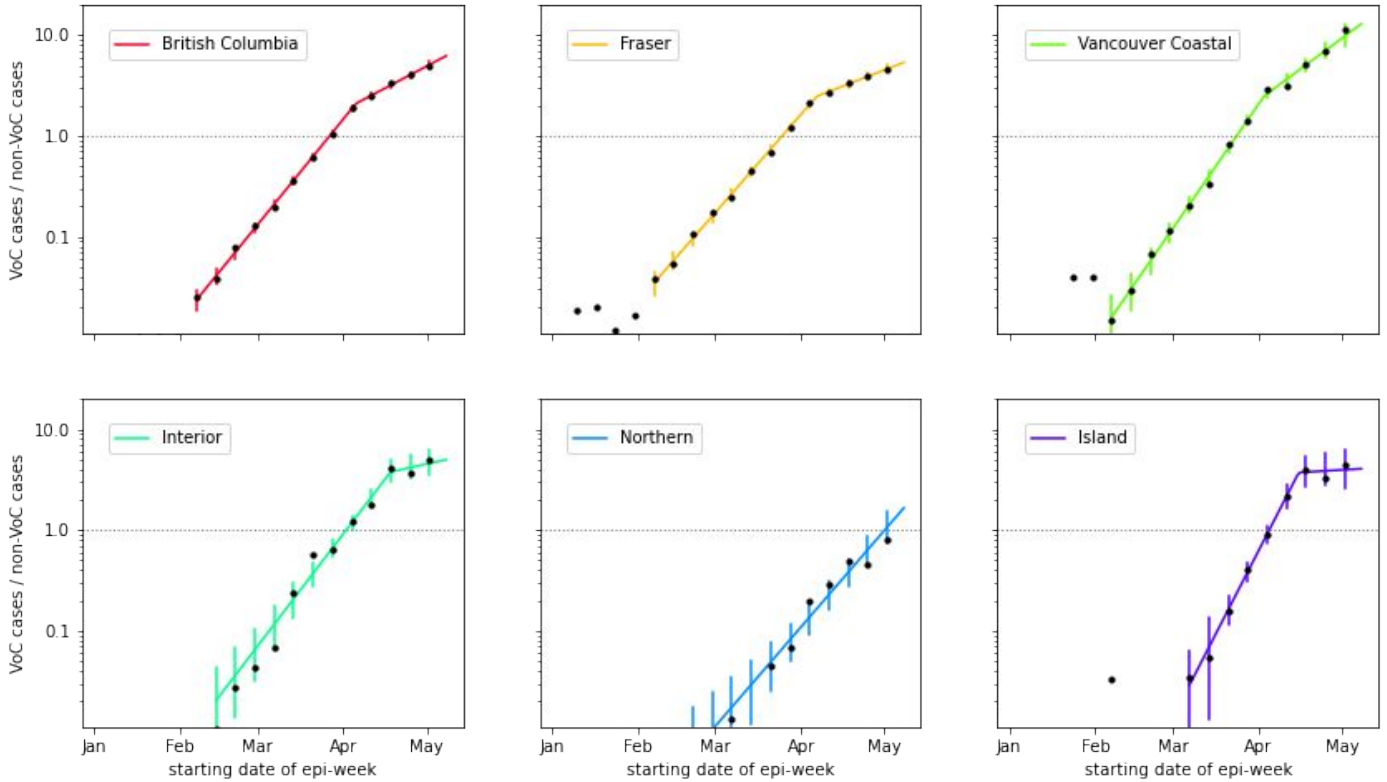
Source (D. Karlen). See www.pypm.ca. Homogeneous mixing (no age structure). *Nominal versus low vaccination rate assumptions: 45,000/day vs 35,000 up until 75% vs 65% vaccinated, 90% vs 80% asymptotic effectiveness of first dose (see Appendix for comparison to real-world effectiveness). Projection is for a scenario rescinding the March 30 measures (the "circuit breaker") on June 15, returning BC to activity levels in early 2021. ‡To match ICU data, the fraction of cases leading to ICU admission is increased by 60% ± 20% in early April. Bands show approximate 50%, 80%, and 95% intervals for nominal vaccination campaign.

Growth advantage of Variants of Concern (VoC) in BC

VoC initially grew 8%/day faster than original strains

Became dominant near April 1 (Northern: May 1)

After “circuit breaker”: advantage reduced to 4%/day faster than original strains:
- measures had greater effect on VoC



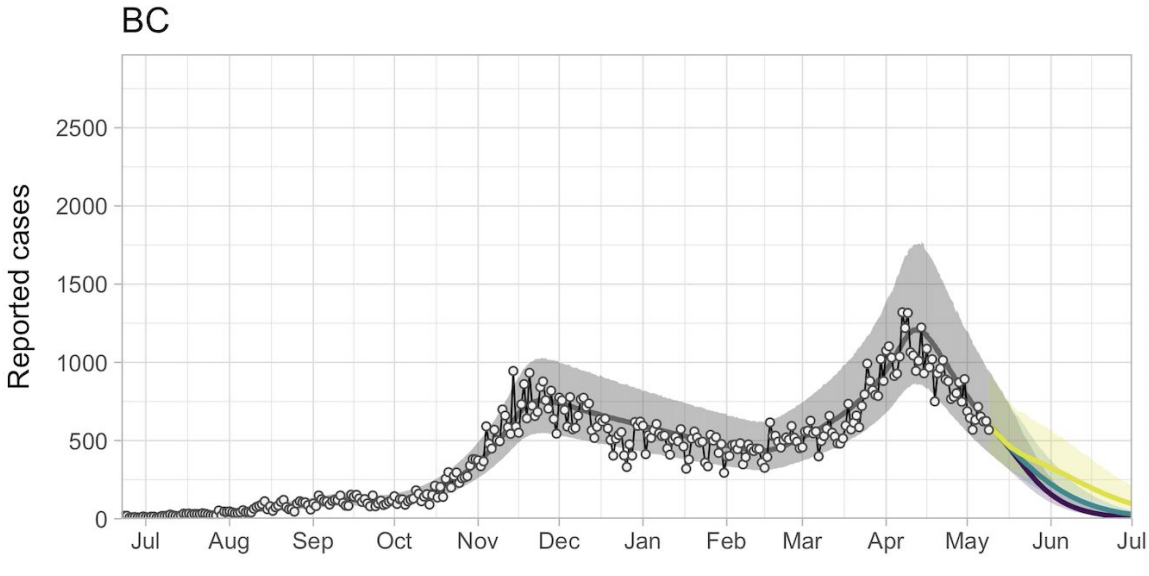
Source (D. Karlen). Fit to weekly VoC and non-VoC case data from BCCDC. Except for Northern HA, a change to the growth advantage is apparent in early April, and fit estimates the change to occur near April 10. There are insufficient data in Interior, Northern, and Island to make accurately estimate the change. For details, see Appendix.

BC incidence projections: contact and slight reopening

Incidence is declining, and vaccinations increasingly contribute to that decline.

Vaccination is incorporated by removing susceptibles at a rate accounting for contact by age, vaccination by age and susceptibility of contacts.

This decline appears robust to a slight increase in contact rates among those distancing (+30% in yellow, -30% in purple).



Yellow: 30% increase in contact*. Green: as now. Purple: 30% decrease in contact.

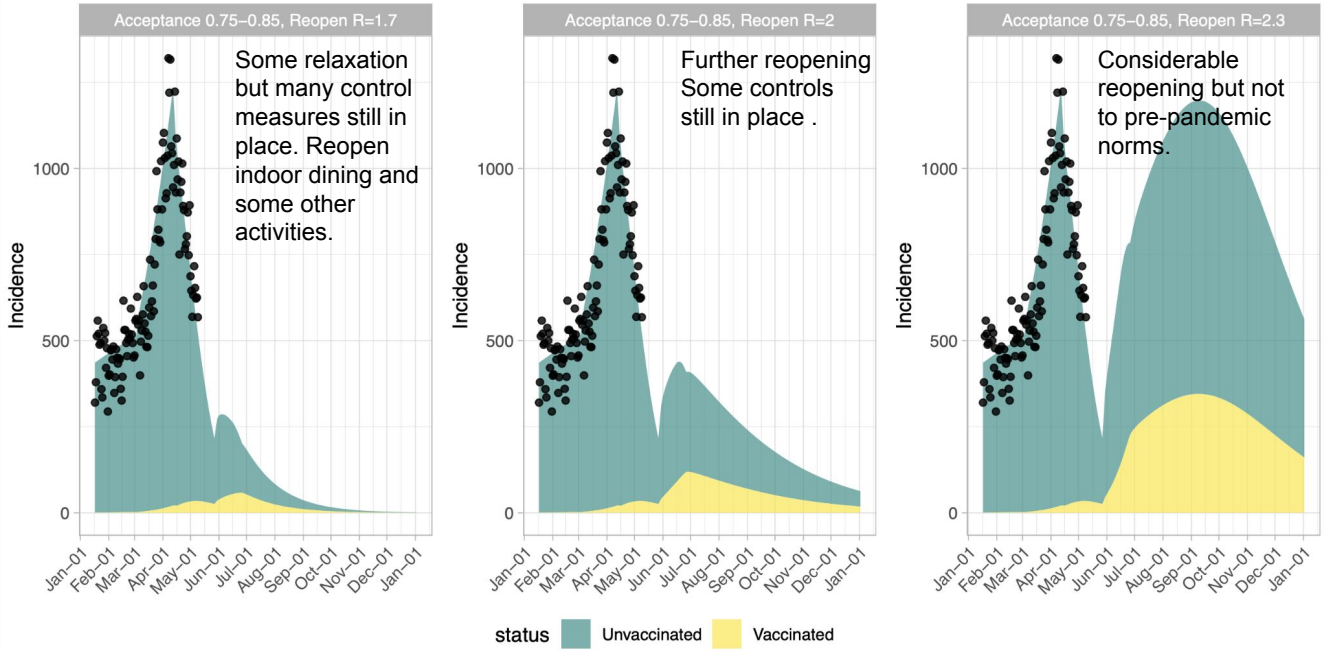
Source (E. Are, C. Colijn). Daily case numbers projected forward, accounting for VOC data from BCCDC (April 7, 2021). These data provide % of cases that were VOC by week (see slide 5). These data were fit by a logistic function to estimate percent VOC by day (see Appendix of April 14 report). Assuming a 40% increase in transmissibility (consistent with the estimated selection *s* in the Appendix of April 14 report), the percent VOC is used to create an overall reproduction number *R* for the virus population. *R* changes in time as the VOC rises in frequency. The social distancing parameter (among others) is estimated to fit the data using the 'covidseir' R package (M. Irvine, S. Anderson). * Measured as *f*, the relative contact rate among those willing and able to distance.

Age and essential worker vaccination model: reopening around May 25 in a singly-vaccinated population

Vaccine uptake: 75-85% (PHAC), with youth 12+ included, assuming that all those eligible have a first dose by June 30.

Vaccine Efficacy:
Against symptoms overall: 0.85
Against infection: 0.7
Against symptoms given infection: 0.5

Efficacy chosen to model a singly-vaccinated population



Source (C. Colijn). Model: Mulberry et al with age and contact structure allowing for essential workers and with VOC increasing R. Incidence (active case numbers) from BCCDC. Assumes an ascertainment fraction of 0.7. Serological data would improve this estimate. Rollout is approximate. Efficacy references: Bernal et al , FDA and Dagan et al

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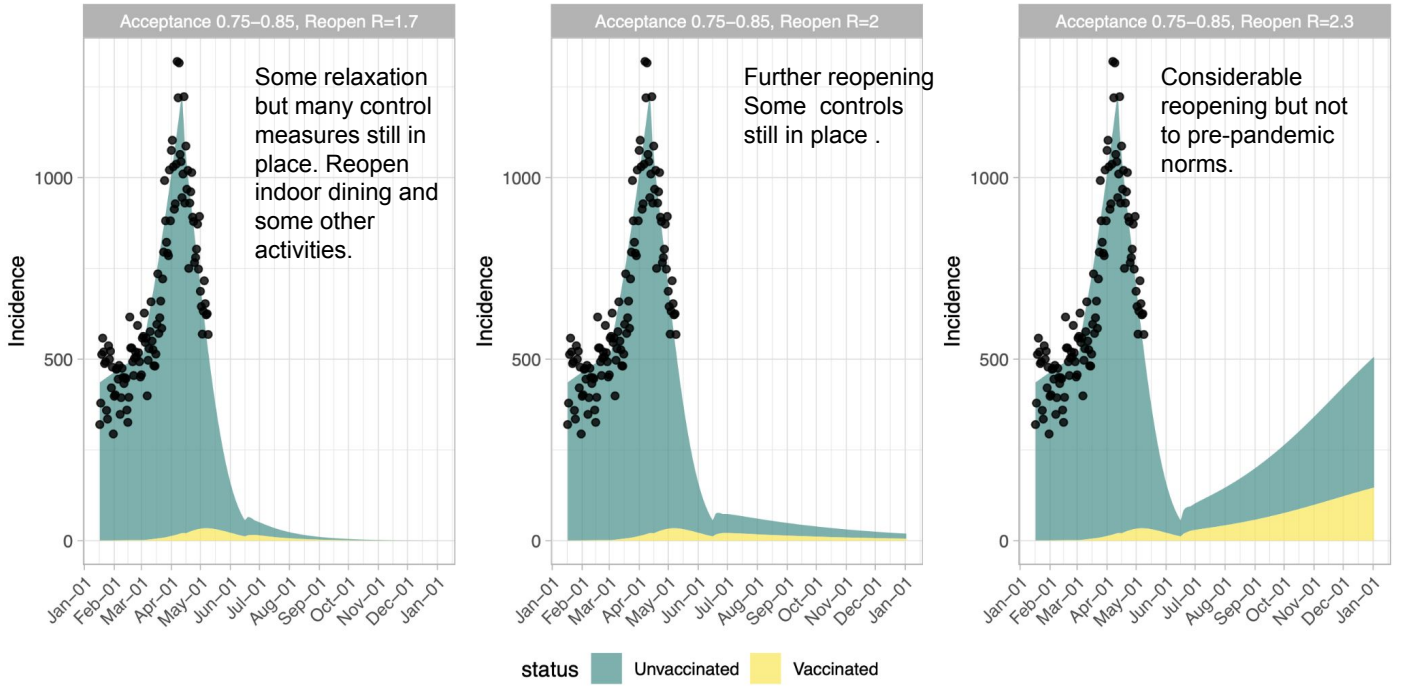

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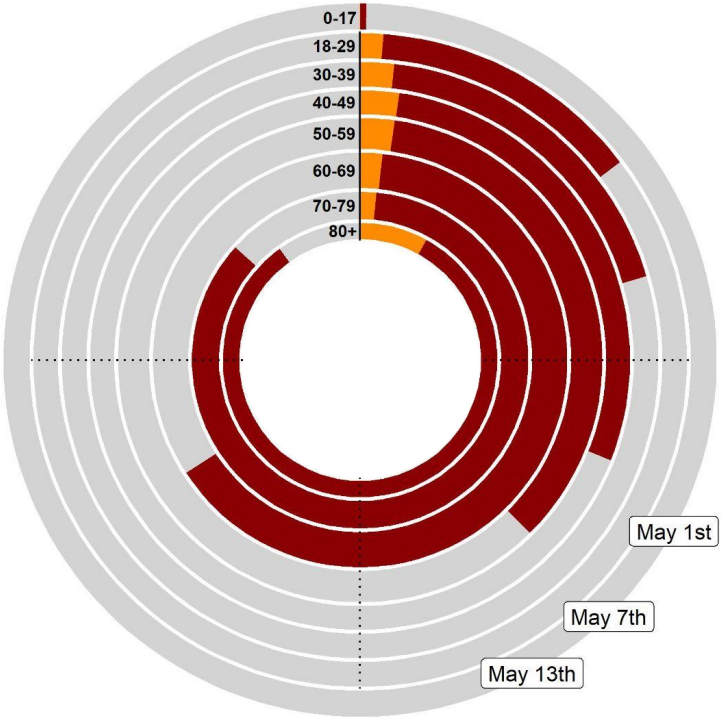
Closing the circle: Vaccination status by age

Last BC data update May 1, 2021

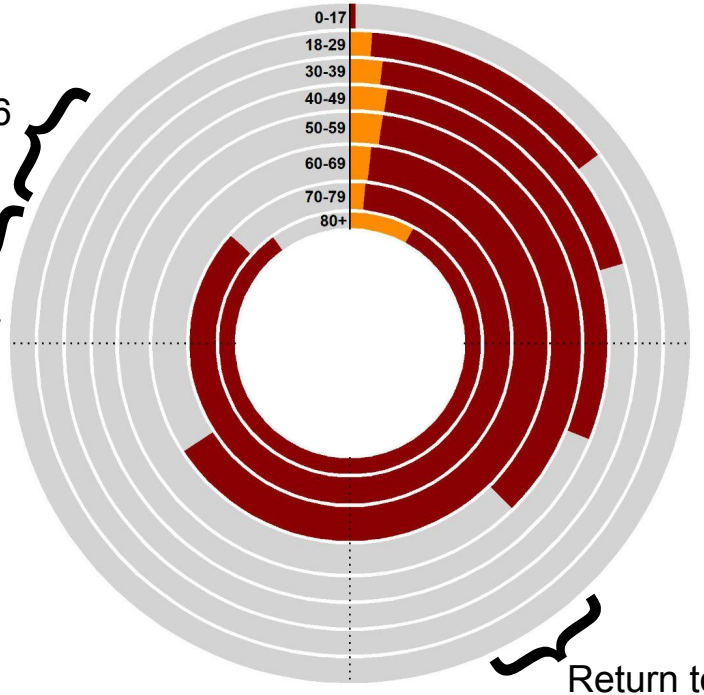


Making progress: Average vaccination levels by date in BC (18+)

Source (B. Wiley). Design by Blake Shaffer (https://blakeshaffer.shinyapps.io/app_vaccines/) BC Vaccination data from https://health-infobase.canada.ca/covid-19/vaccination-coverage/, with the area of each circle segment proportional to BC's population in that age class.

Closing the circle: Vaccination status by age

Last BC data update May 1, 2021



Herd immunity if R_0~5-6

Herd immunity if R_0~4-5

R_0 for variants now in BC is estimated to be ~2.8 to 5.4*, without control measures

Herd immunity: the level of immunity in a population at which a disease starts to decline

→ (1-*f*) $R < 1$ where *f* is level of immunity

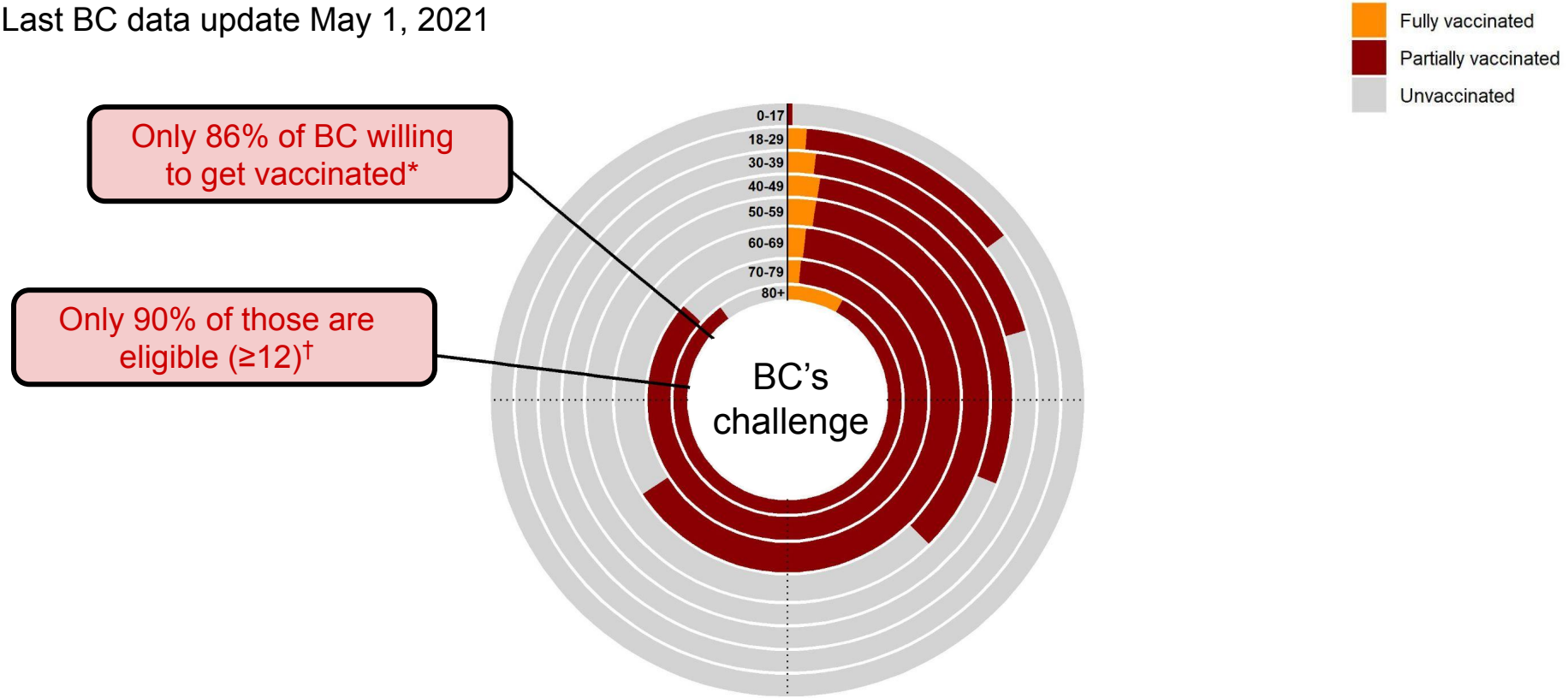
Reproductive number (*R*): number of new cases per case, called R_0 in the absence of any control measures.

Return to Feb/March 2021 activities when R~1.7 for variants now in BC†

Source (B. Wiley). Design by Blake Shaffer (https://blakeshaffer.shinyapps.io/app_vaccines/) *Public Health Ontario: https://www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/2021/02/wwksf-herd-immunity.pdf. †https://bccovid-19group.ca/post/april-2021-report/

Closing the circle: Vaccination status by age

Last BC data update May 1, 2021



Source (B. Wiley). Design by Blake Shaffer. *Angus Reid (April 26, 2021): https://angusreid.org/vaccine-astrazeneca-johnson/. †BCCDC (April 24, 2021) Epi-week 16 Situation Report. ‡NACI "Recommendations on the use of COVID-19 vaccines" (May 3, 2021), Efficacy against symptoms >14 days after one dose (>21 days for Astrazeneca) but before two doses; Pfizer: 92.3% [95%CI: 69-98%]; Moderna: 92.1% [95%CI: 68.8-91.1%]; AstraZeneca: 71.3% [95%CI: 49.0-83.8%].

Closing the circle: Vaccination status by age

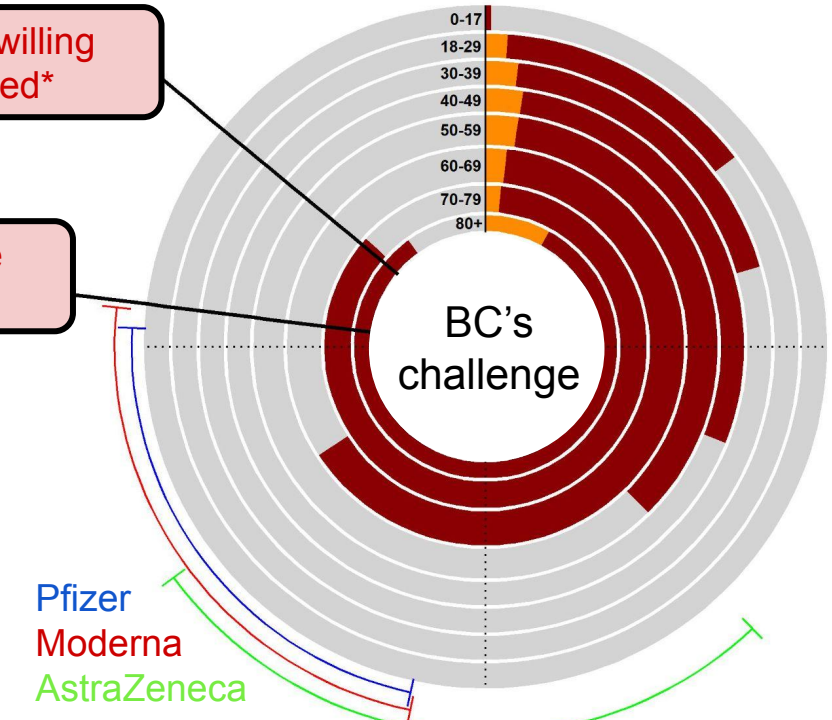
Last BC data update May 1, 2021

Only 86% of BC willing to get vaccinated*

Only 90% of those are eligible (≥12)†

&

First dose only partially effective against symptomatic infection‡



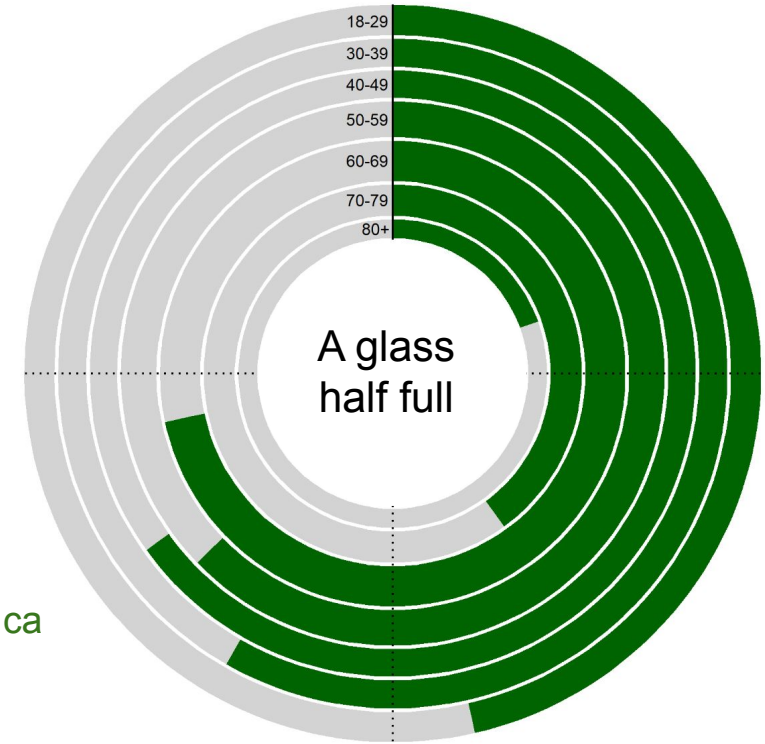
Herd immunity with no control measures will not be achieved until more of BC is fully vaccinated.

Partial relaxation possible sooner.

Source (B. Wiley). Design by Blake Shaffer. *Angus Reid (April 26, 2021): https://angusreid.org/vaccine-astrazeneca-johnson/. †BCCDC (April 24, 2021) Epi-week 16 Situation Report. ‡NACI "Recommendations on the use of COVID-19 vaccines" (May 3, 2021), Efficacy against symptoms >14 days after one dose (>21 days for Astrazeneca) but before two doses; Pfizer: 92.3% [95%CI: 69-98%]; Moderna: 92.1% [95%CI: 68.8-99.1%]; AstraZeneca: 71.3% [95%CI: 49.0-83.8%].

Fraction registered for vaccination in BC

Last BC data update May 9, 2021



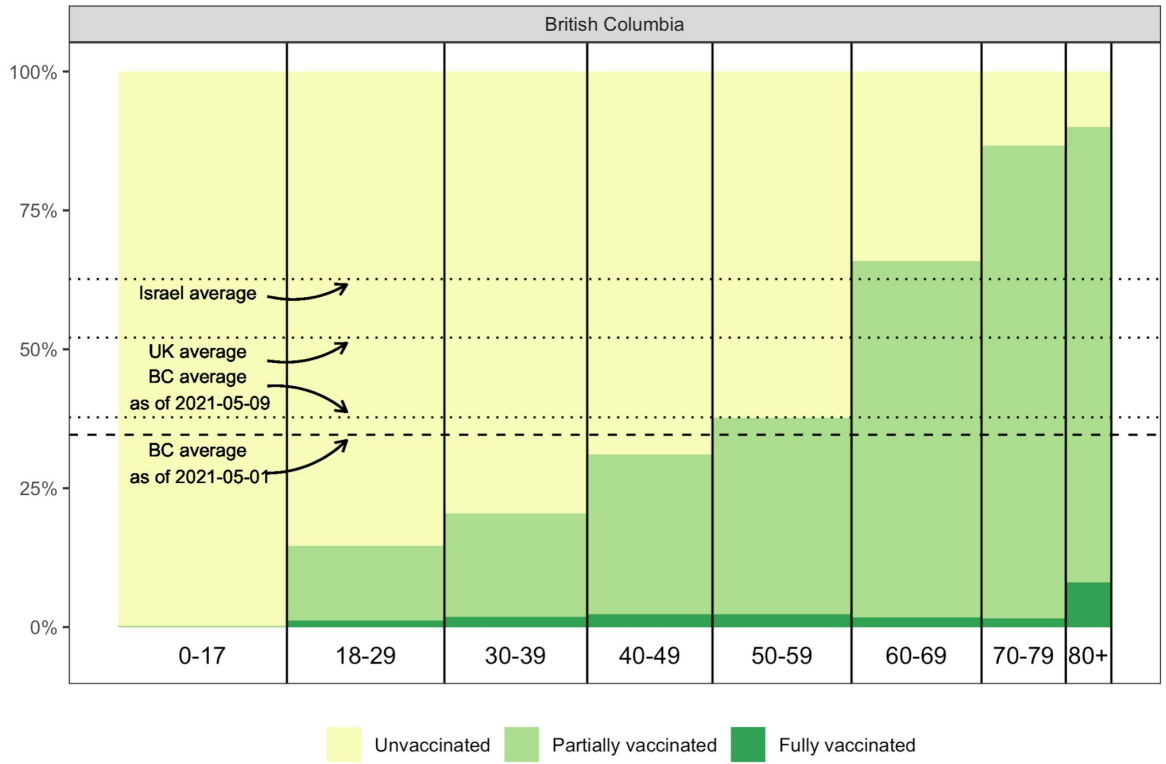
Many more people need to register for vaccinations to ensure the rollout (and our return to normal) is as fast as possible.

http://www.getvaccinated.gov.bc.ca

Source (B. Wiley). Design by Blake Shaffer. https://news.gov.bc.ca/files/5-10-21_vaccine_registration.pdf Many individuals in the older age groups and in targetted communities have been vaccinated without registration, but all adults (18+) are currently being asked to register (http://www.getvaccinated.gov.bc.ca or call 1-833-838-2323).

Vaccination status by age group

Last age-based BC data update May 01



PHAC, StatCan table 17-10-0005

Israel: 62.7% vaccinated (at least one dose). Schools fully reopened on Apr 26 with no restrictions; no restrictions on travel; immunity passports being used for indoor dining, gyms and sports; no restrictions on indoor/outdoor socialization in groups of 50 or less

UK: 52.2% vaccinated (at least one dose). Schools fully open with optional rapid testing available and masks for secondary students; travel is discouraged; indoor dining remains closed; outdoor socializing only, in groups of up to 6.

Countries with high vaccination levels are seeing enough decline in cases to reopen slowly

Source (J. von Bergmann). Vaccination data https://health-infobase.canada.ca/covid-19/vaccination-coverage/
Benchmarks from Israel and UK: https://ourworldindata.org

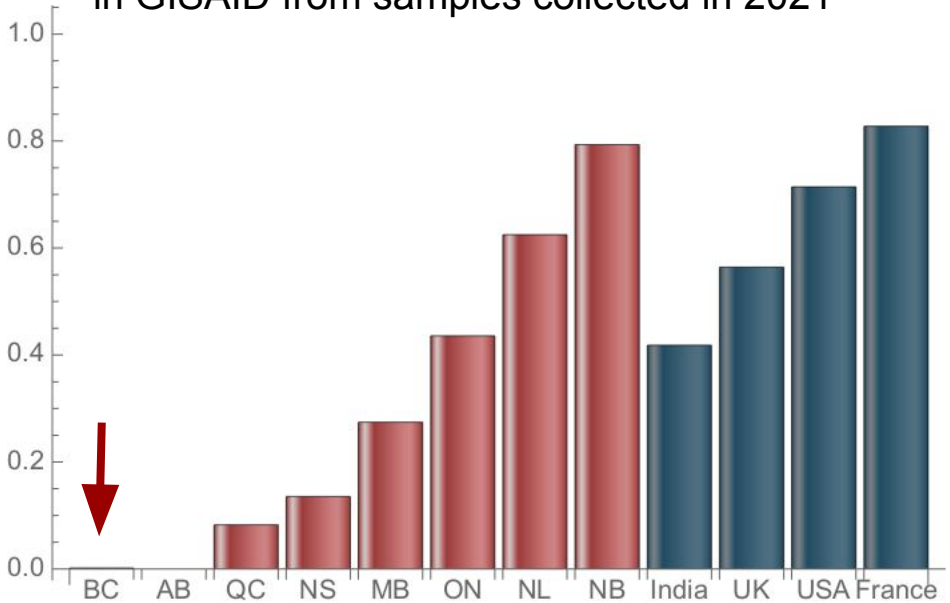
Data gap: Where are the genomes?

BC is a global leader in genomics, yet BC has not publicly shared the thousands of SARS-CoV-2 genomes sequenced in 2021.

These sequences are needed for global analyses to:

- Identify new variants
- Estimate rates of spread
- Assess efficacy of restrictions
- Detect importations

Fraction of SARS-CoV-2 genomes in GISAID from samples collected in 2021



	BC	AB	QC	NS	MB	ON	NL	NB	India	UK	USA	France
2021 samples:	11	0	530	147	369	6879	170	303	5543	228 780	307 515	26 277
All samples:	5876	1676	6425	1086	1344	15 779	272	382	13 245	405 537	430 393	31 743

Source (S. Otto). http://gisaid.org (May 14, 2021)

Further messages

Case numbers projected to decline through May, with hospital and ICU remaining moderate (>300 and >100, respectively).

Partial re-opening to February/March 2021 levels of activity* on May 25 risks slight rise in cases and hospital demand, lower risk if delayed until mid-June.

Re-opening substantially beyond early 2021 activity levels requires higher vaccination uptake, second doses, and/or additional control measures.

Newly shared community-level data on cases and vaccinations will help guide future modelling and local efforts to vaccinate and tackle rising cases. Thanks!

***E.g., restaurant re-openings, “safe six” indoor gatherings with same group**

Data gaps remaining

- Serological survey data has not been released from the most recent surveys. These data are essential for understanding the impact of the disease on different communities and to assess relative infection rates of age groups that are often asymptomatic (youth).
- Severity of each VOC (Hospital/ICU demand and death rates) is needed to better predict near-term impacts of COVID-19 on our communities.
- Crucial genetic data is missing. Only 11 of the thousands COVID-19 (0.1%) genomes sequenced in BC in 2021 have been uploaded to the global GISAID database. This impedes the global effort to learn about which variants matter and how they impact disease.

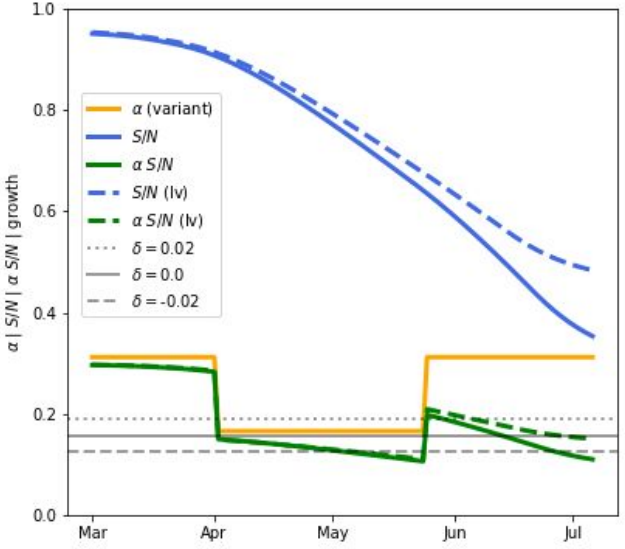
Appendix: Looking under the hood

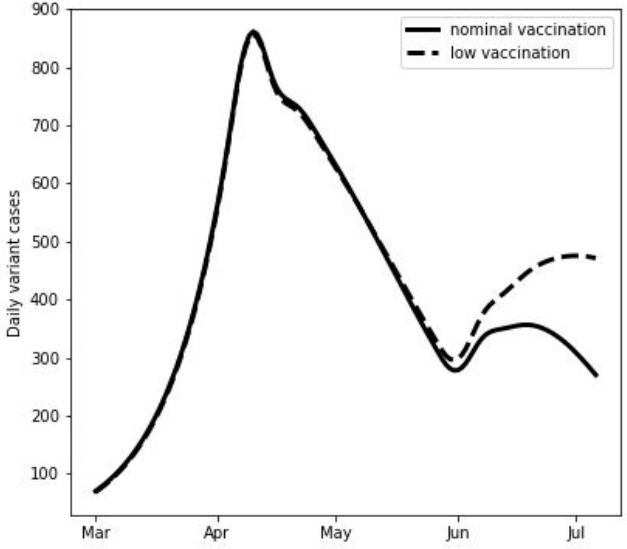
How changes in transmission rate (yellow) and a decline in the number of susceptible individuals (blue) combine to reduce the growth of COVID-19 (green) in pypm model (slide 4)

The daily growth rate (δ) depends on the product of the transmission rate (α) and the susceptible fraction (S/N).

The product is shown by the green curves and the grey horizontal lines show the growth rate for a few values.

In the nominal vaccination scenario, growth becomes negative in mid-June.





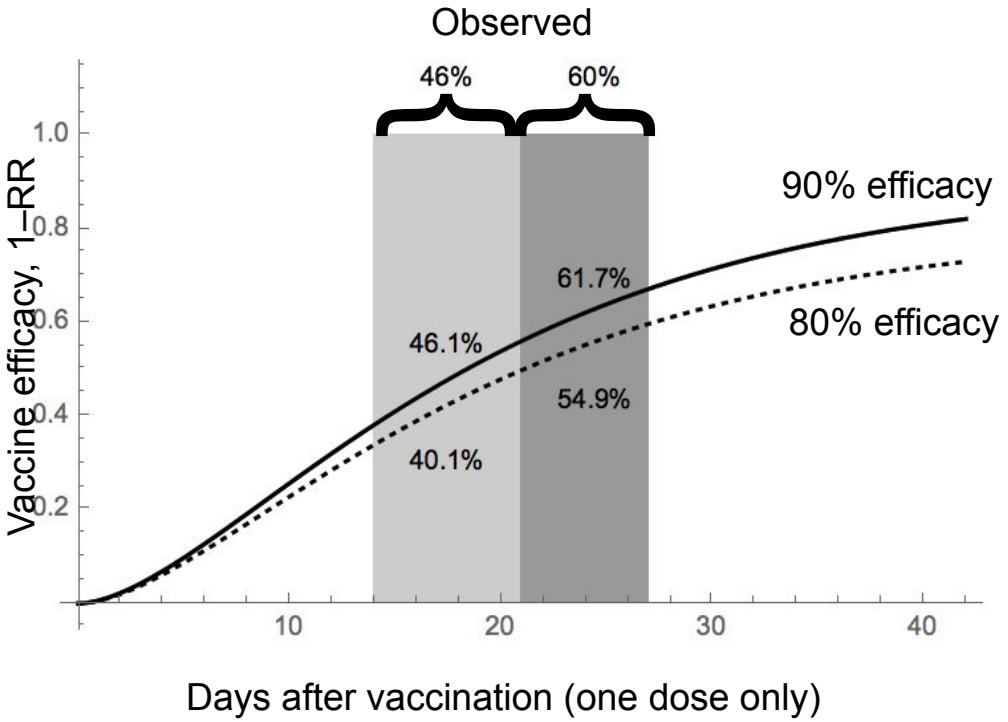
Nominal vaccination scenario: ultimate effectiveness: 90%, 1st dose vaccination rate: 45,000/day until 75% of population vaccinated.

Low vaccination scenario (lv): ultimate effectiveness: 80%, 1st dose vaccination rate: 35,000/day until 65% of population vaccinated.

Appendix: Model assumptions for vaccine efficacy

The pypm model assumes that the efficacy at preventing infection of a single dose rises over time, ultimately reaching 0.9 (solid curve: normative) or 0.8 (dotted: lower efficacy case).

The observed real-world effectiveness of Pfizer from Israel was comparable, preventing 46% of infections between days 14-20 and 60% between days 21-27 (Dagan et al. 2021 NEJM).



Fit for growth advantage

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

$$N(d) = \int_d^{d+m} N_0 e^{rt}\, dt = \frac{N_0}{r} e^{rd}(e^{rm} - 1)$$

For two exponential processes (variant and non-variant), the ratio of the daily cases is given by

$$R(d, s, d_0) = \frac{N_v(d)}{N_{nv}(d)} = a \exp(r_v - r_{nv})d = a \exp(sd) = \exp s(d - d_0)$$

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

In UK, lockdown measures were seen to change the growth advantage. Consider an instantaneous transition on day $d = d_0 + d_1$:

$$r_v(d) = r_n v(d) + s_0 + (s_1 - s_0) H(d - d_0 - d_1)$$

where H is the heavyside function. Imposing continuity for R at the transition date.

For $d \le d_0 + d_1$:

$$R(d, s_0, s_1, d_0, d_1) = \exp s_0(d - d_0)$$

and for $d \ge d_0 + d_1$:

$$R(d, s_0, s_1, d_0, d_1) = \exp s_1(d - d_0 - d_1) \exp s_0 d_1$$

The fraction of cases that are variant are:

$$p_v(d, s_0, s_1, d_0, d_1) = \frac{N_v(d)}{N_{nv}(d) + N_v(d)} = \frac{1}{1 + 1/R(d, s_0, s_1, d_0, d_1)}$$

Use maximum likelihood to estimate parameters and their covariance. This is a binomial problem, with $n = n_v + n_{nv}$ trials each day and n_v identified as variant.

$$\ln \mathcal{L}(s_0, s_1, d_0, d_1) = c + \sum_d [n_v(d) \ln p_v(d, s_0, s_1, d_0, d_1) + n_{nv}(d) \ln(1 - p_v(d, s_0, s_1, d_0, d_1))]$$

Fit results:

region	s0	s1	d0	d1
British Columbia	0.078 ± 0.001	0.034 ± 0.002	Mar 30	9.4 ± 0.8
Fraser	0.073 ± 0.001	0.025 ± 0.003	Mar 28	12.5 ± 0.9
Vancouver Coastal	0.092 ± 0.002	0.047 ± 0.003	Mar 27	10.0 ± 1.2
Interior	0.083 ± 0.003	0.014 ± 0.010	Apr 04	16.0 ± 0.1
Northern	0.073 ± 0.004	-	May 04	-
Island	0.123 ± 0.008	0.004 ± 0.023	Apr 07	10.7 ± 1.7

Growth advantage of Variants of Concern (VoC) in BC

VoC initially grew 8%/day faster than original strains

Became dominant near April 1 (Northern: May 1)

After “circuit breaker”: advantage reduced to 4%/day faster than original strains:
- measures had greater effect on VoC