Real-time modelling of the Covid-19 epidemic: perspectives from British Columbia (I)

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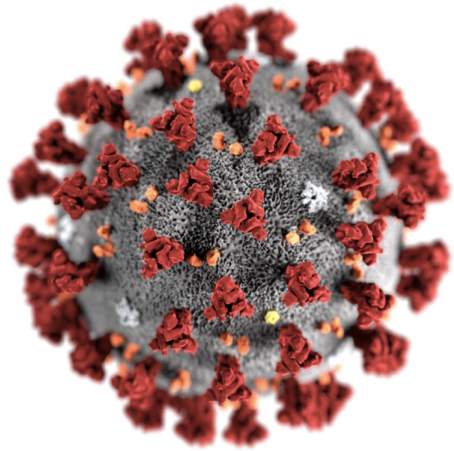
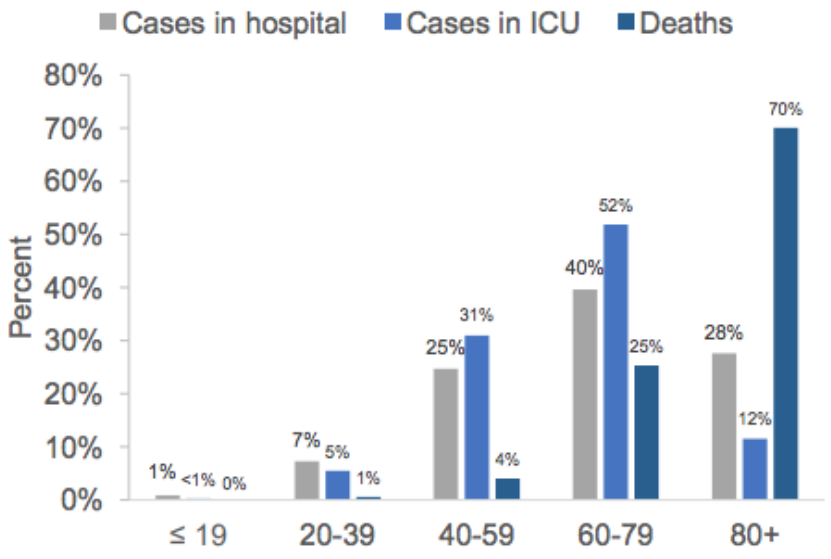
What is COVID19 and where did it come from?

- Corona virus disease 2019 is caused by a coronavirus called Sars-CoV-2
- It's like the first SARS: severe acute respiratory syndrome
- Likely came from wild animal populations (bats)
- Coronaviruses can infect many species
- First detected December 2019 in Wuhan, China



Why is it such a big deal?

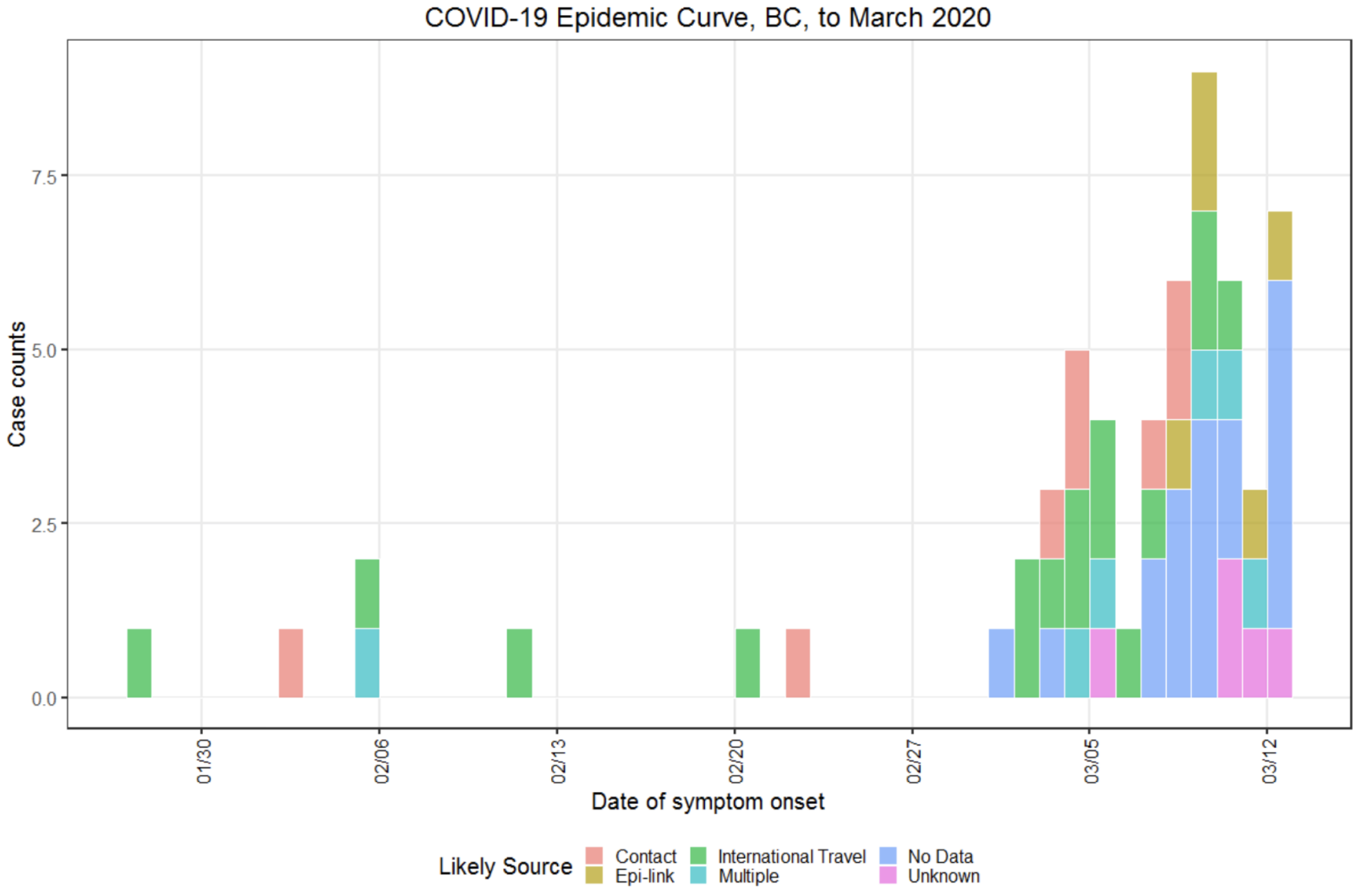
- It can cause severe illness, and not only in the elderly
- Symptoms
  - cough, fever
  - difficulty breathing, pneumonia in both lungs
  - loss of taste, smell, chest pain
- Severe illness:
  - organ failure
  - acute kidney injury
  - heart failure
  - Death



Proportion of COVID-19 cases hospitalized, admitted to ICU and died in Canada by age group, as of 13 May 2020. Source: PHAC

BC EARLY TIMELINE

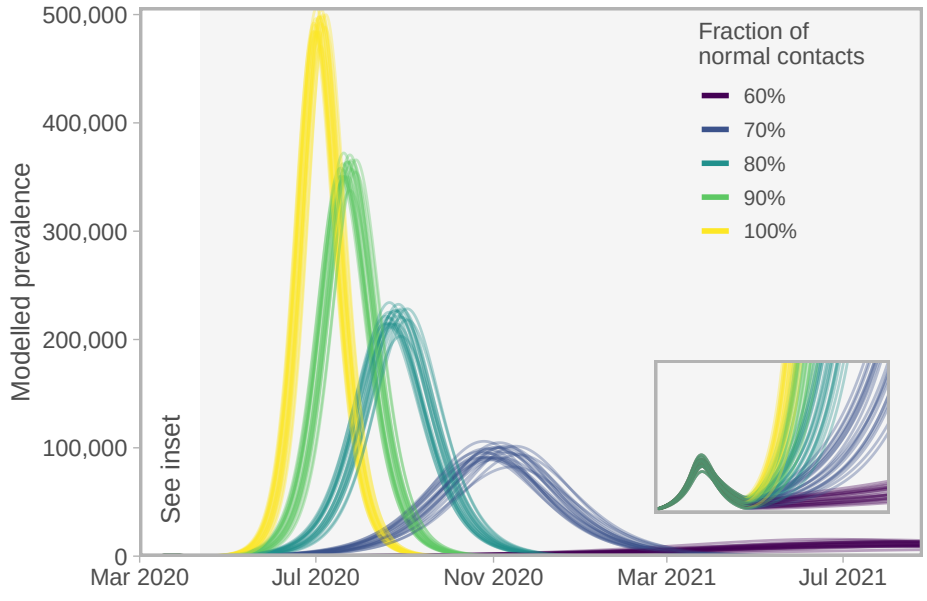
Figure 1: Epidemic curve for COVID-19 confirmed cases in BC, including likely acquisition/exposure, January 1-March 13, 2020



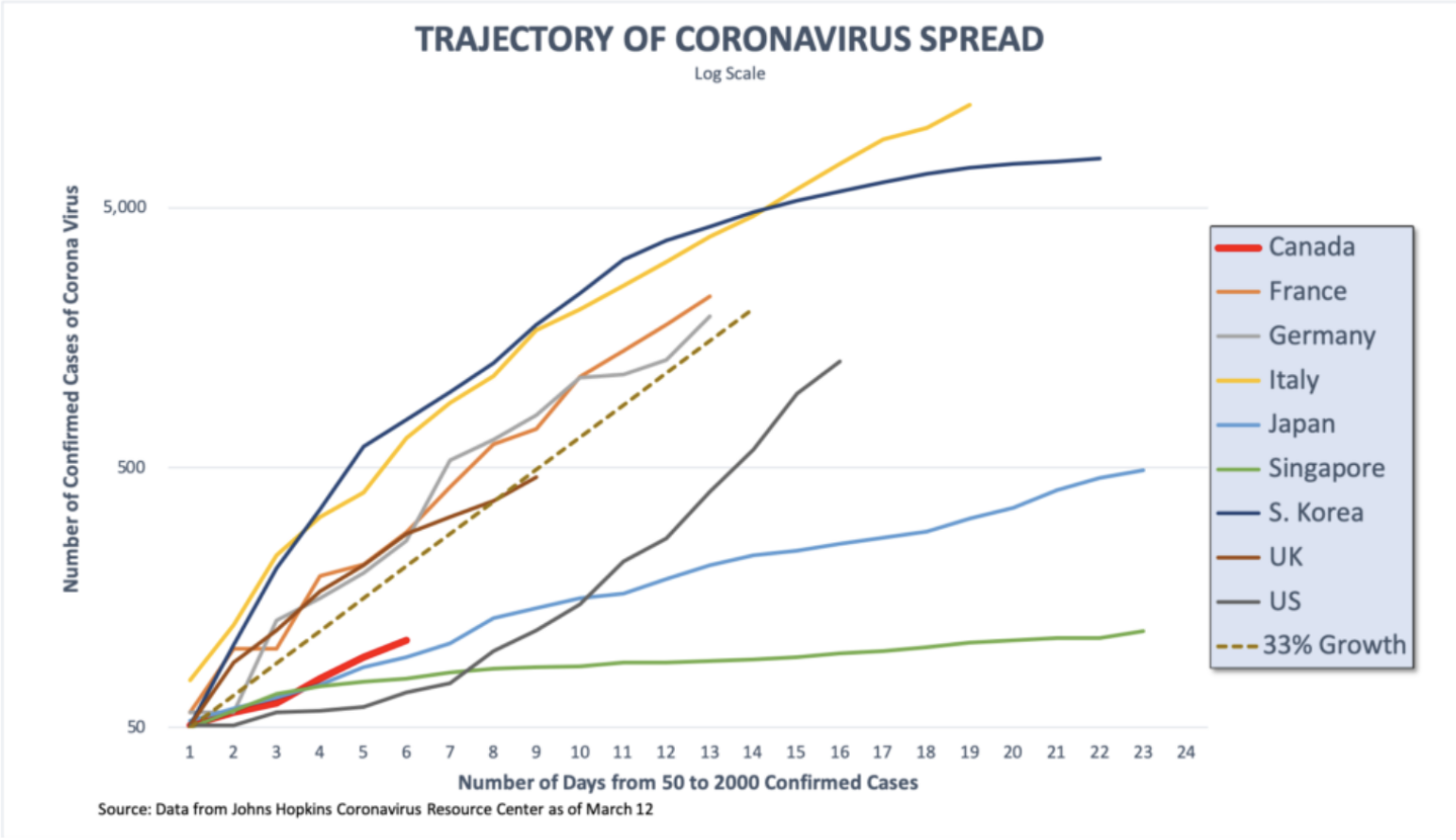
Modelling: early aims

- When will this start to spread in BC?
- How many people might get infected in total?
- What are the best actions to stop transmission?

We were asked to forecast case counts so that BCCDC could forecast hospitalizations and ventilator needs



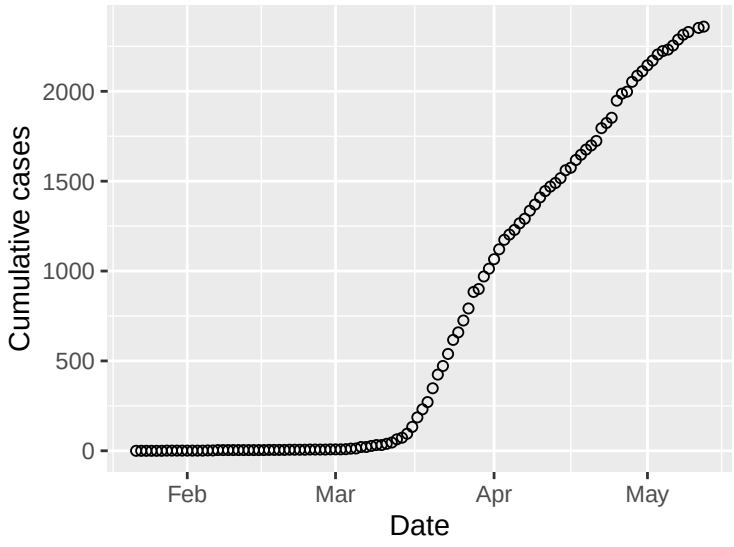
Cumulative counts and bending curves

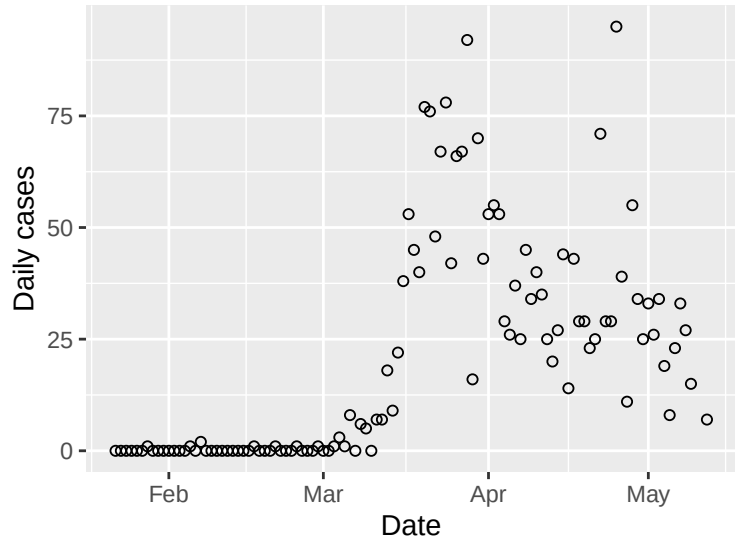


These plots can hide a multitude of modelling sins! READ WITH CAUTION.

Modelling considerations

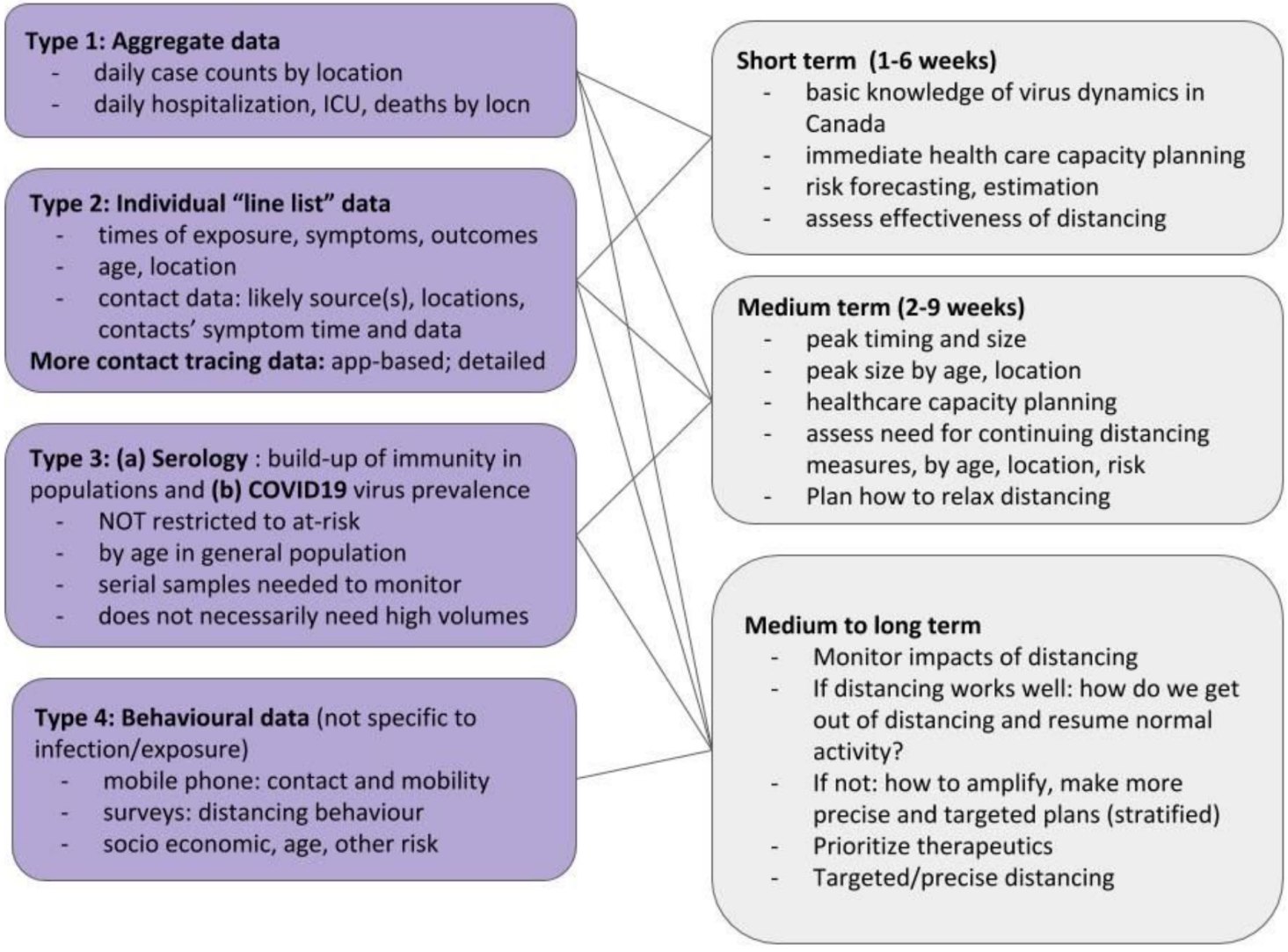
- Basic epidemiology: R_0, duration of infection, exposed class, delay to symptom onset
- When does transmission happen?
- Time to reporting, noise in reporting





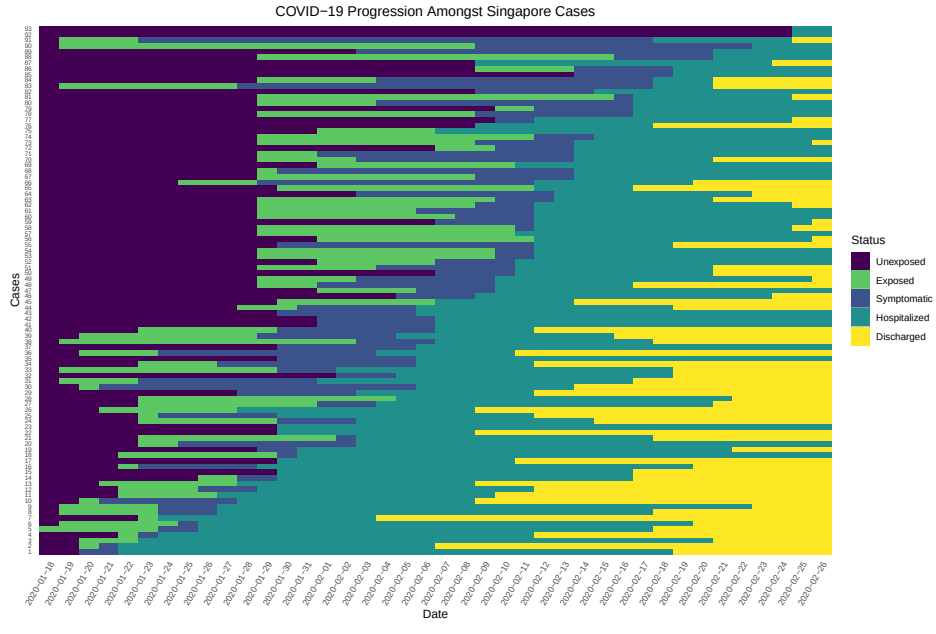
Cumulative counts hide a lot

Where might modellers get their inputs?

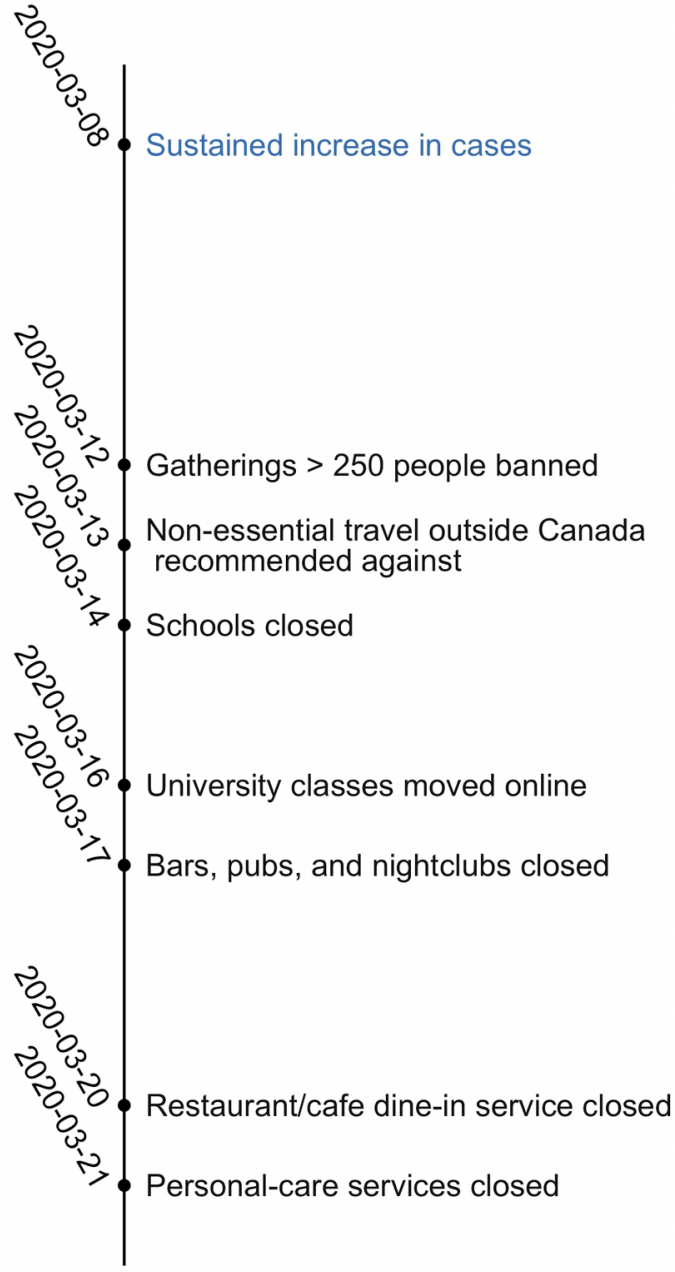


We used Singapore and Tianjin, China for some key inputs

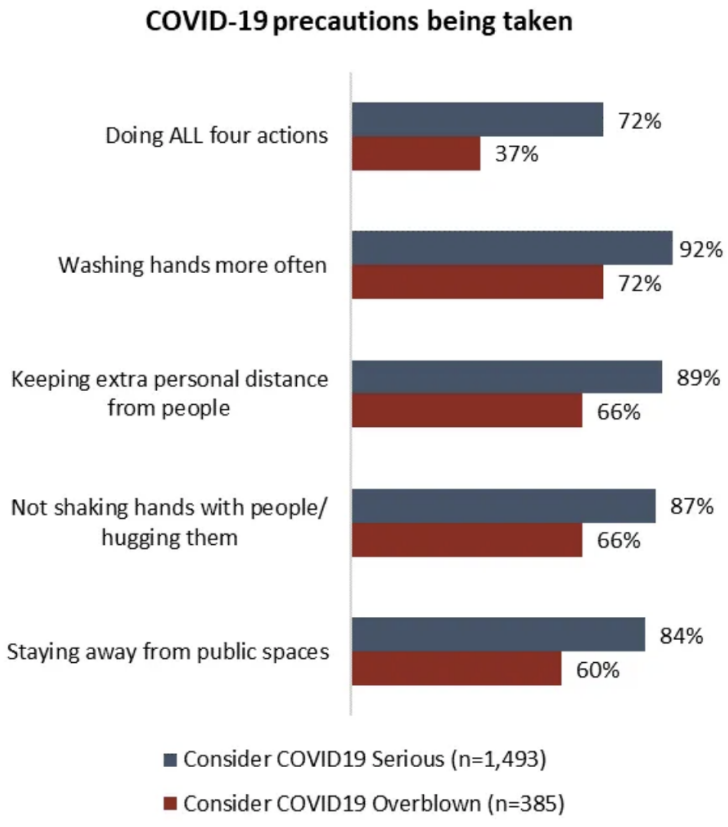
- Time to symptom onset
- Time to infect others: this uses contact tracing data
- Take unknown intermediates into account
- KEY FINDING: transmission before symptom onset

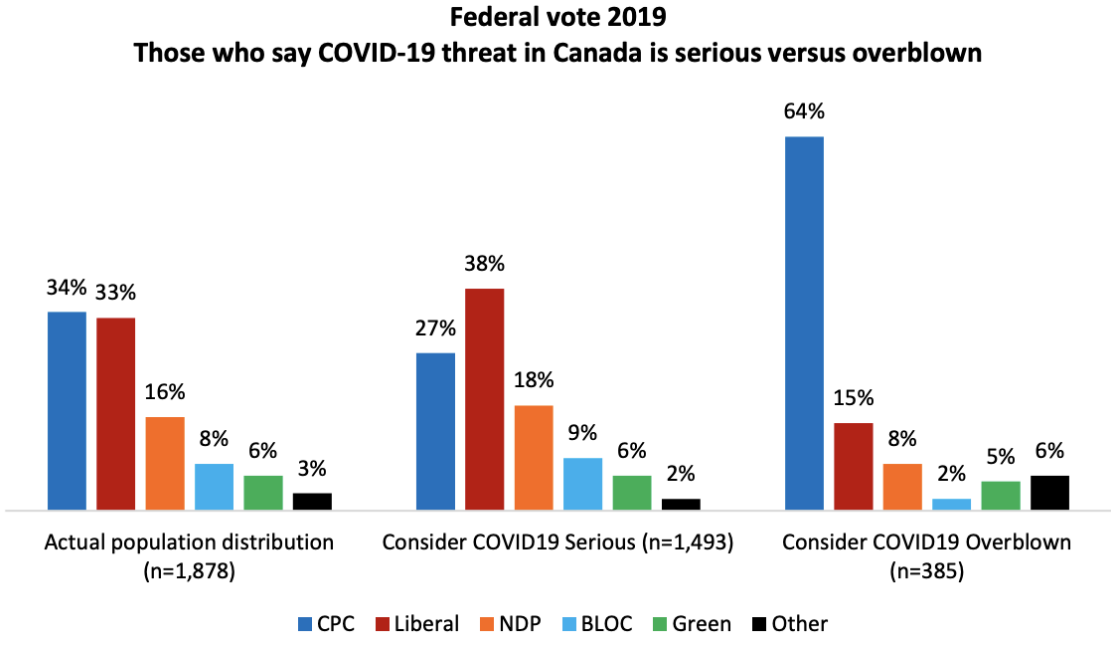


Back to BC's timeline

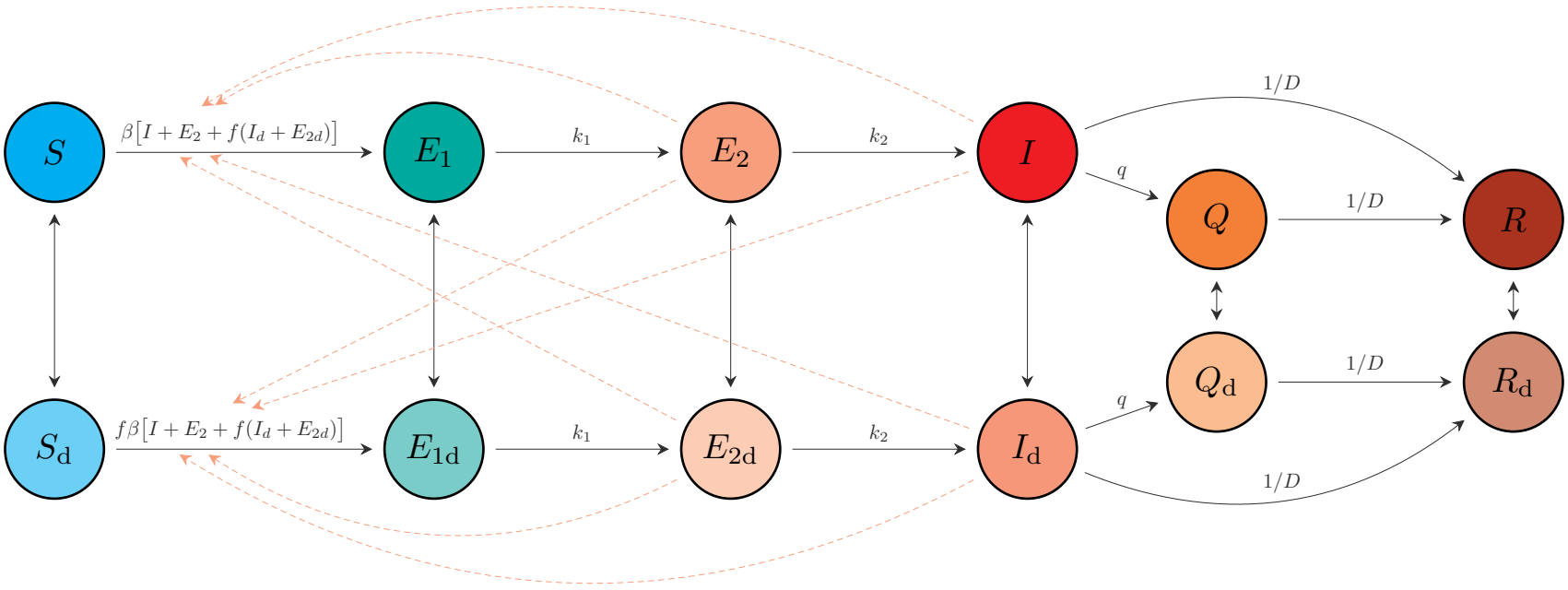


Survey, late March: is COVID19 serious?





A mathematical model with distancing



$$\frac{dS}{dt} = -\beta\left[I + E_2 + f(I_d + E_{2d})\right]\frac{S}{N} - u_d S + u_r S_d \to E_1$$

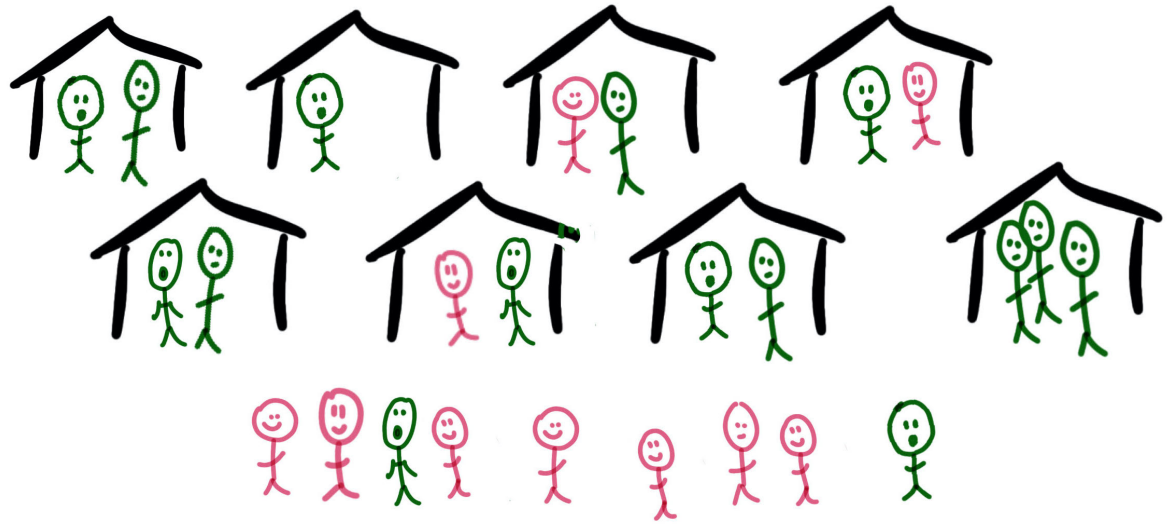
$$\frac{dS_d}{dt} = -f\beta\left[I + E_2 + f(I_d + E_{2d})\right]\frac{S_d}{N} + u_d S - u_r S_d \to E_{1d}$$

Other equations: linear flows between compartments.

Distancing and contact

- Those who are distancing are less likely to go out and contact others.
- When they do go out, they are less likely to see other distancers.
- Contact reduces by f – twice. (f^2 term)

$$\frac{dS_d}{dt} = -f\beta\left[I + E_2 + f(I_d + E_{2d})\right]\frac{S_d}{N} + u_d S - u_r S_d \to E_{1d}$$

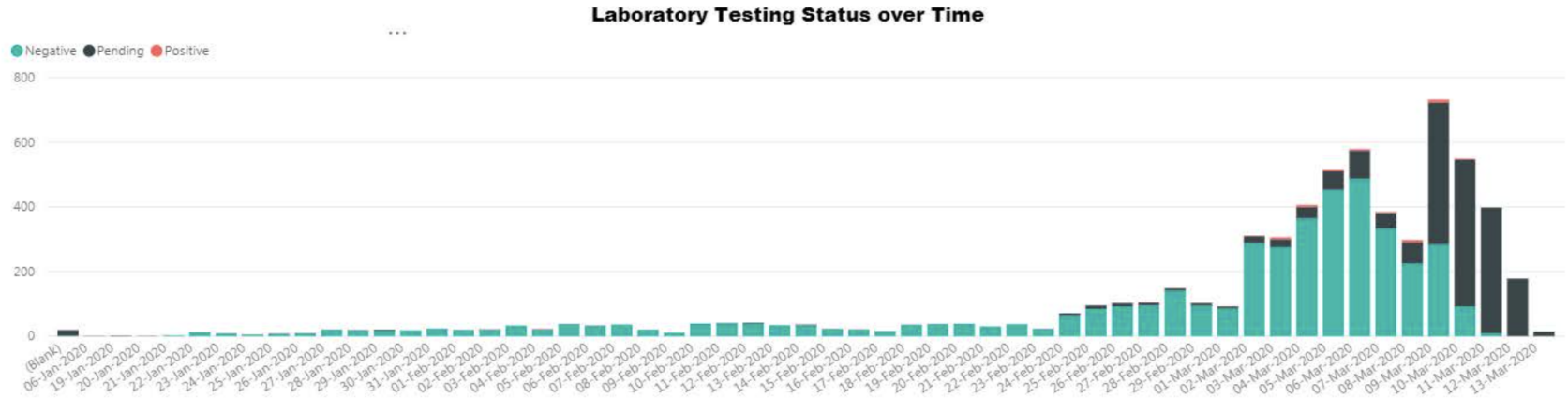


Observation: what do we observe from the model?

- People do not get tested at the moment of exposure.
- Testing rates changed with time
- Exposed $\rightarrow$ symptoms $\rightarrow$ tested $\rightarrow$ reported
- We model noisy and delayed observation:

$$E(\text{cases}(r)) = \text{testing}(r) \int_0^{45} (\text{Symptom onset } r - s) w(s) ds$$

Figure 2: BCCDC public health laboratory testing data by client and health authority, BC, January 1-March 13, 202



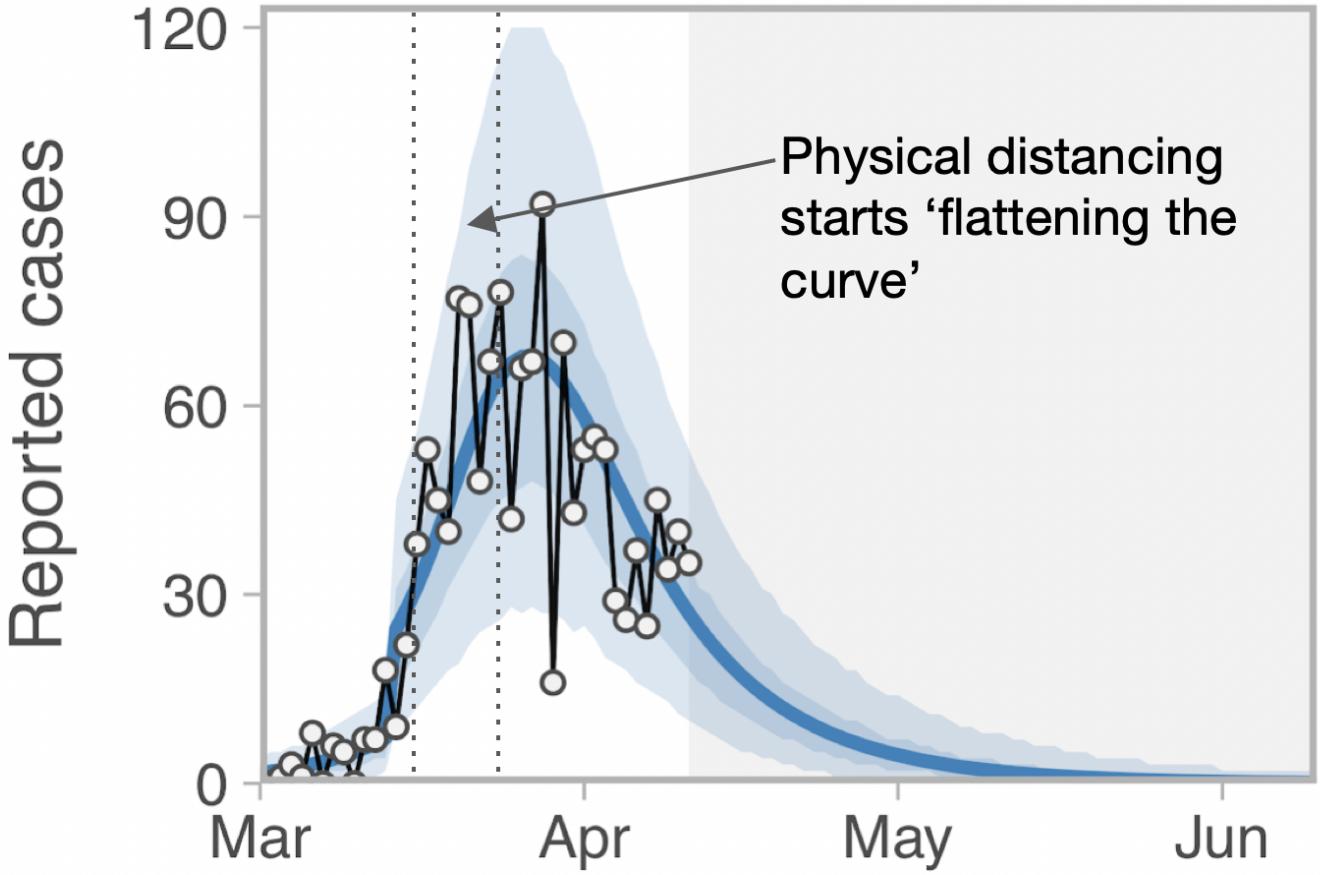
We estimate the impact of distancing

- We model distancing increasing from March 15 to March 22.
- The contact parameter f goes from 1 down to an estimated number f_2.
- The likelihood of a set of parameters is negative binomial. Mean: expected case counts. Dispersion: estimated (ϕ).
- We fit the model using Bayesian inference, with C_r the cases on day r:

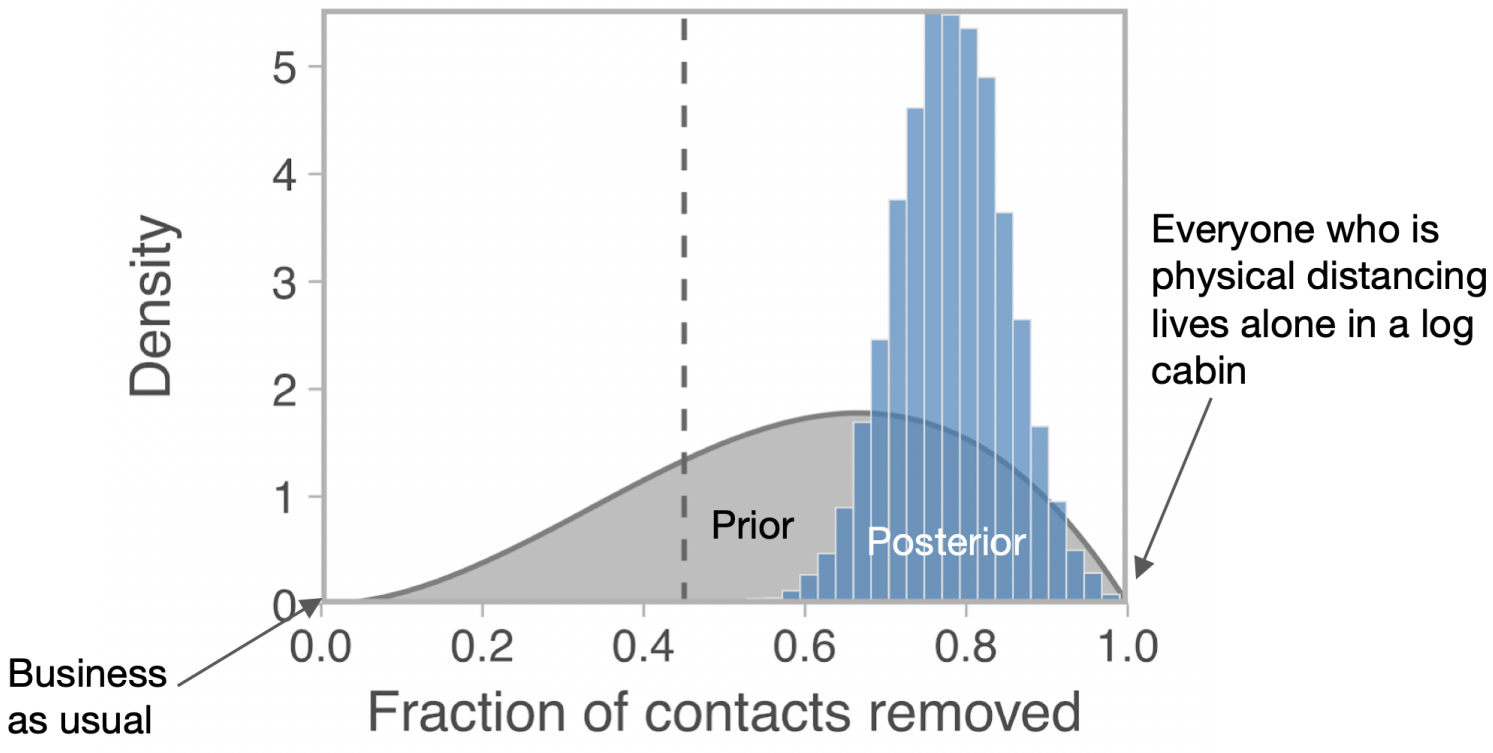
$$\mathrm{P}\left(R_{0\mathrm{b}}, f_2, \phi | \{C_r\}\right) \propto \mathrm{P}\left(\{C_r\} | R_{0\mathrm{b}}, f_2, \phi\right) \mathrm{P}(R_{0\mathrm{b}}) \mathrm{P}(f_2) \mathrm{P}(\phi)$$

- We have a prior for R_0 and dispersion
- We fix other parameters, then explore.
- And so can you! R package `covidseir`

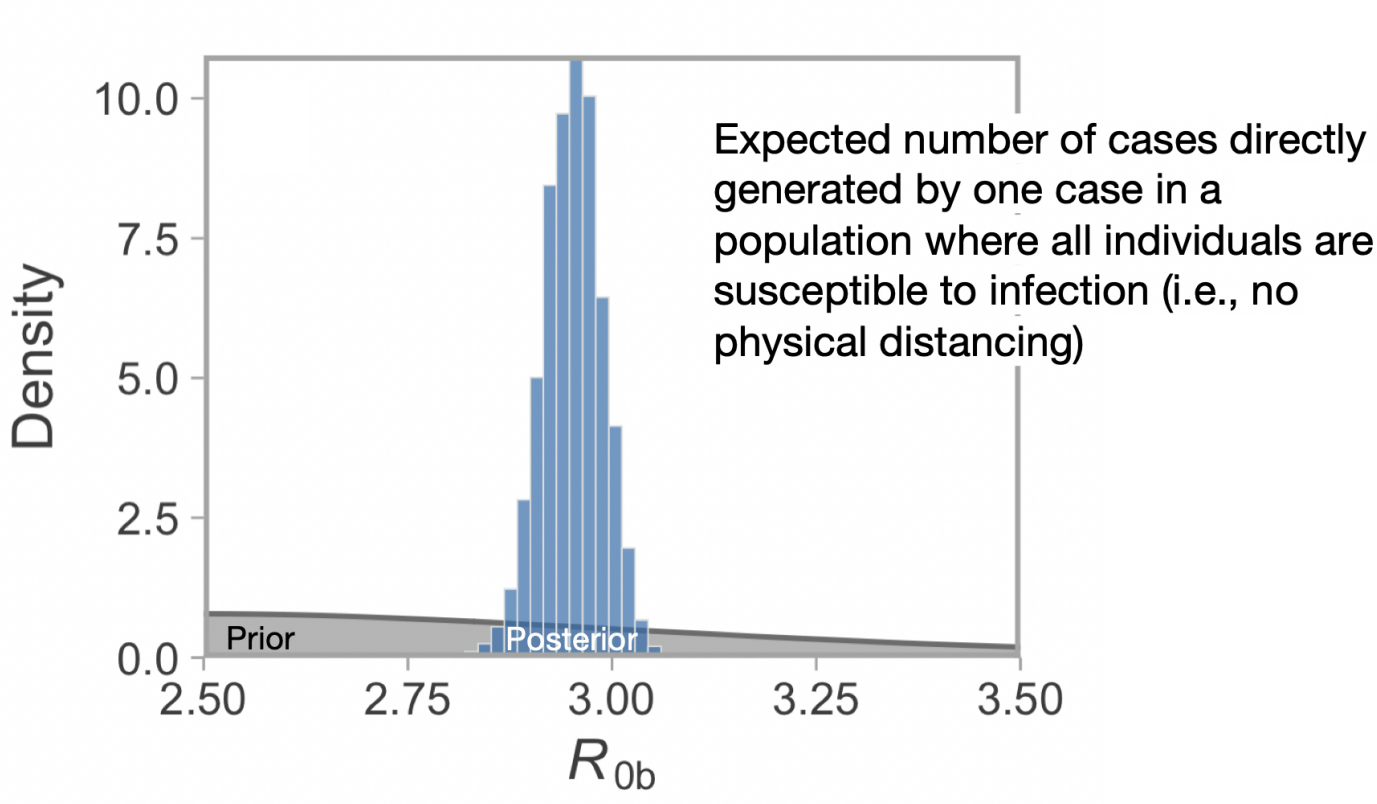
Result: the fit is good



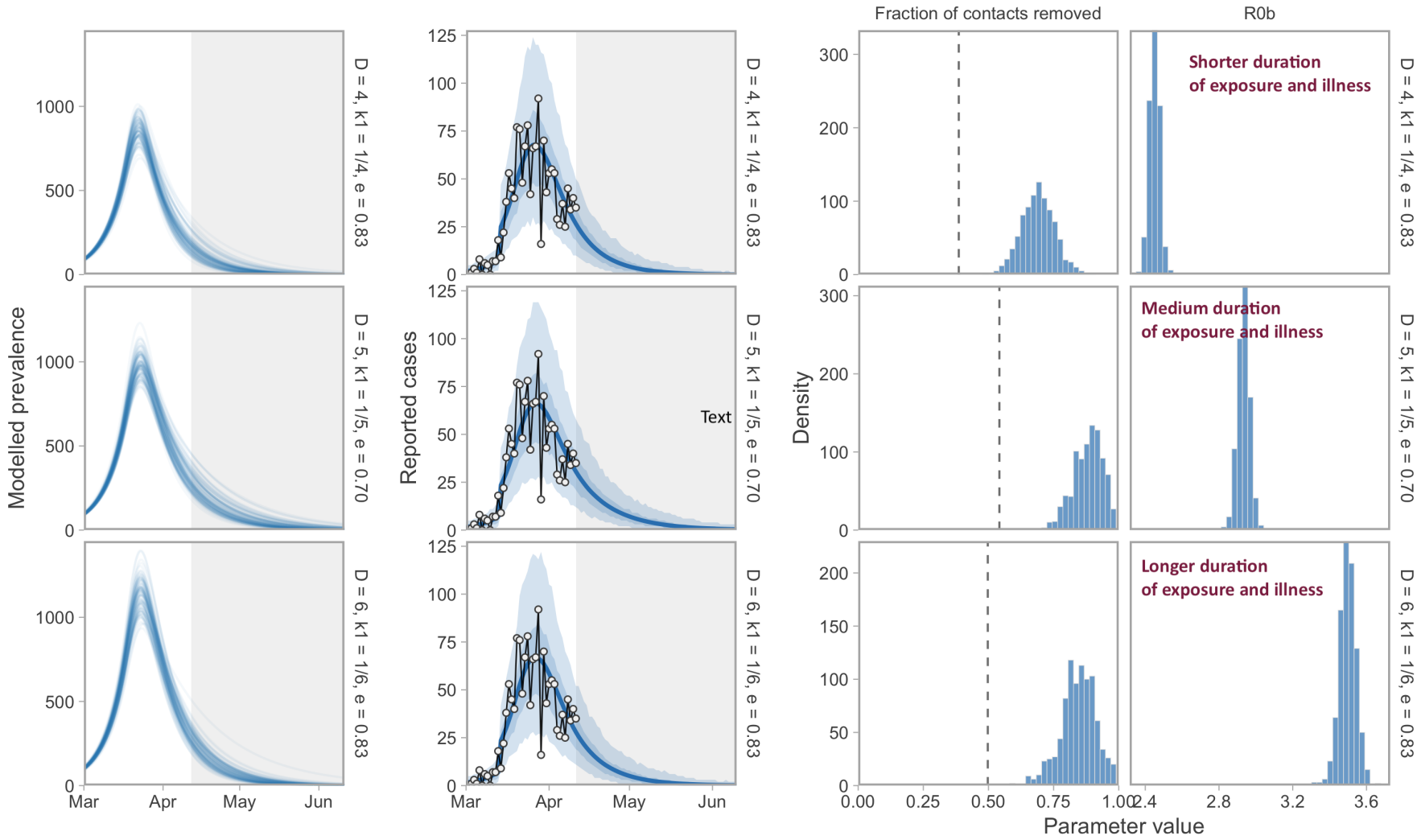
Posterior distancing impact is strong



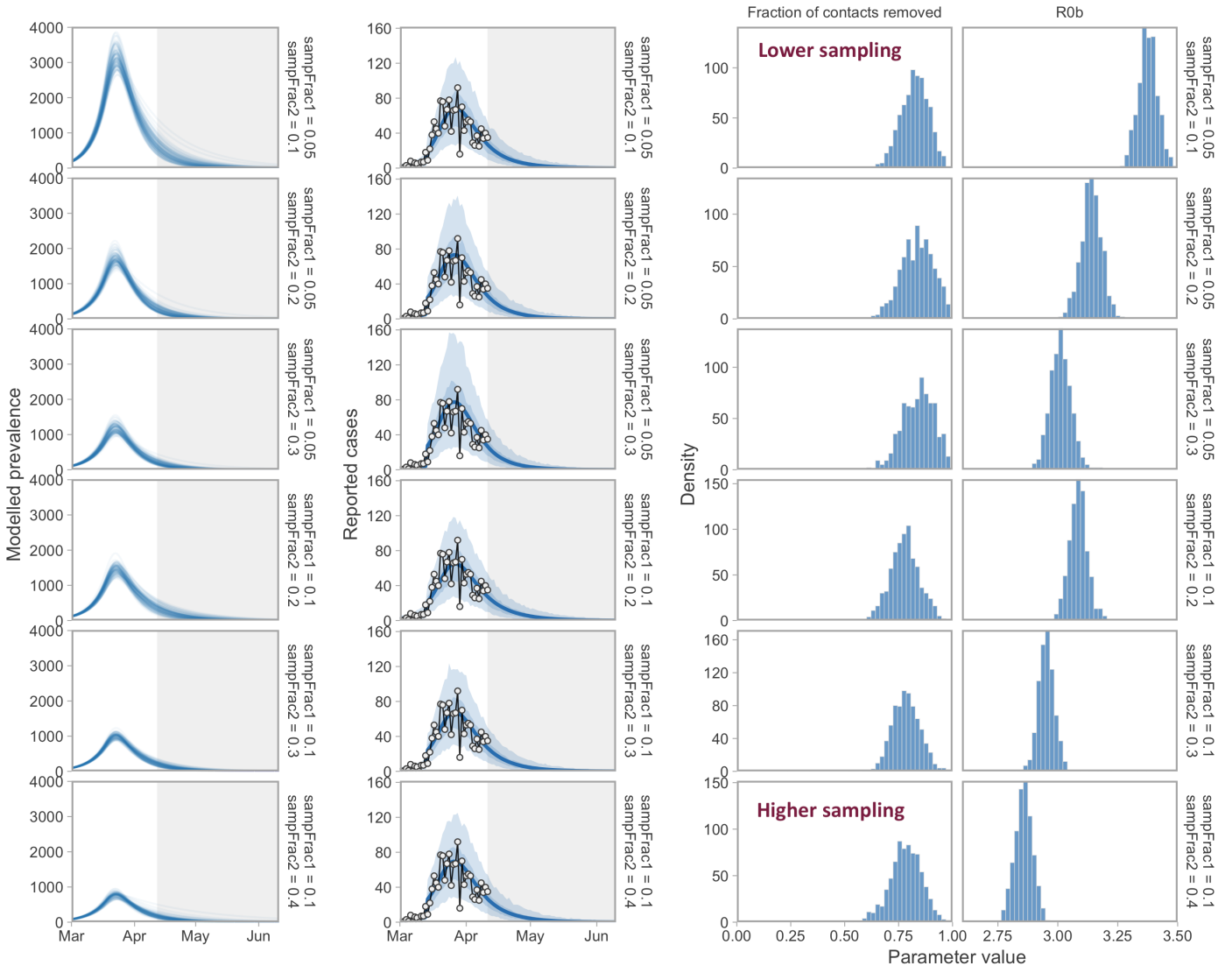
Posterior reproductive number is 3 ... or is it?



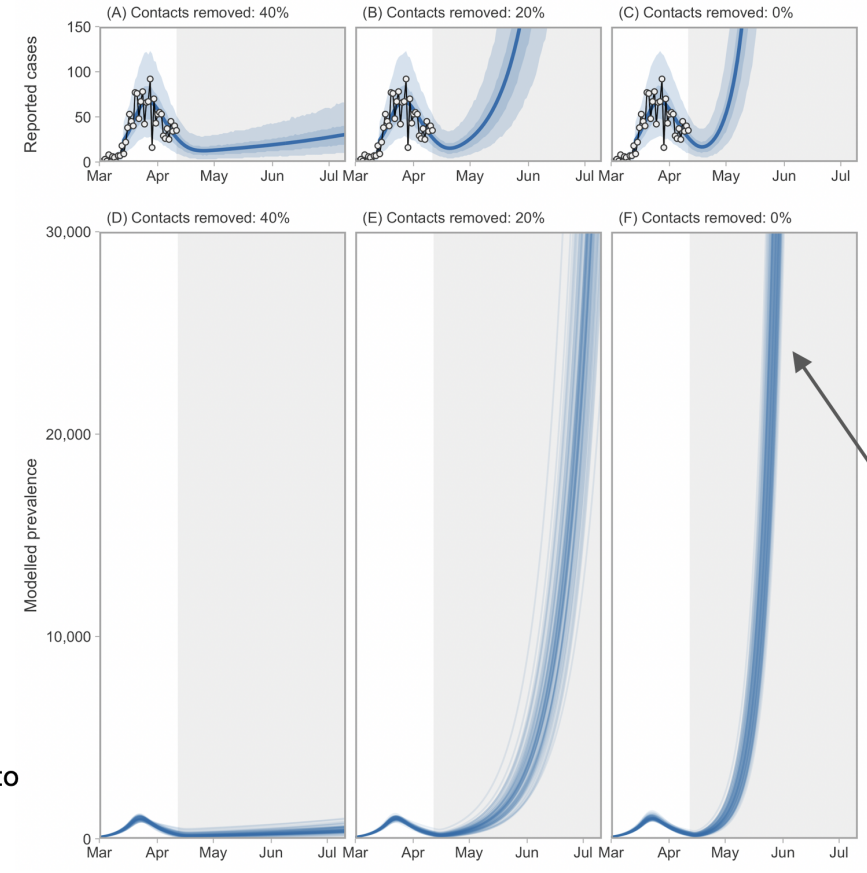
Distancing is robust, R_0 isn't



Distancing is robust, prevalence isn't



What happens if we stop distancing?

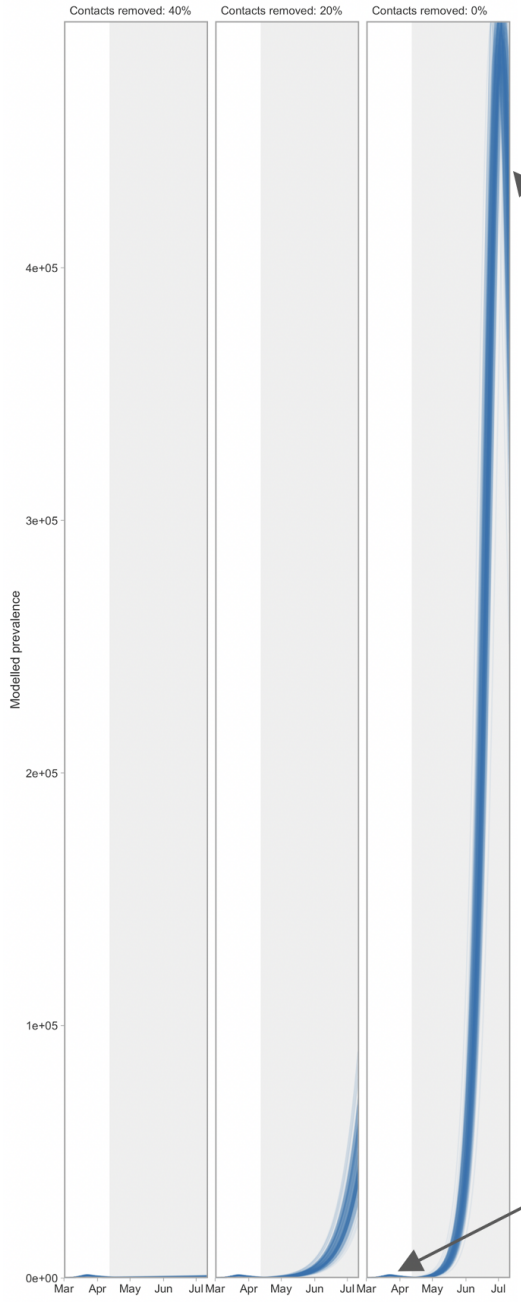


What would happen if we went back to business as usual

Scale of modelled prevalence is ***very*** sensitive to assumptions about testing

We do not think there is meaningful immunity – declines are due to distancing.

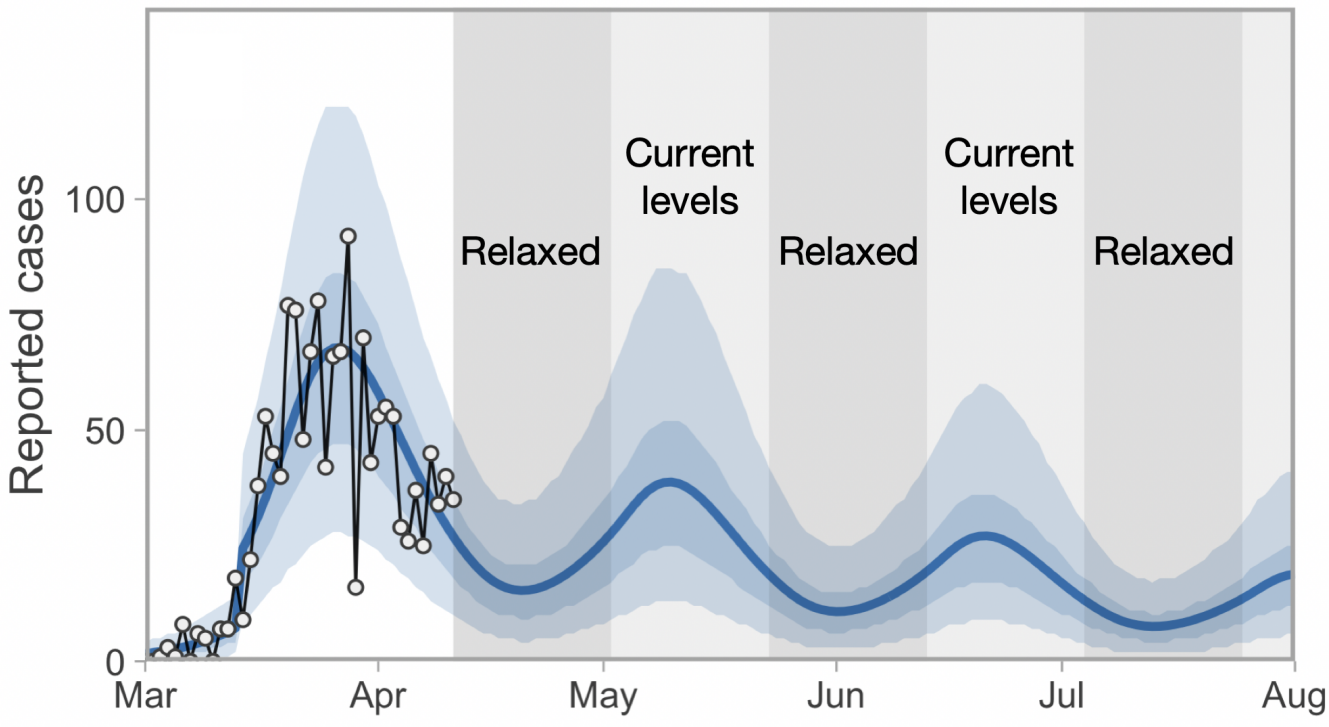
We have not seen "the first wave"



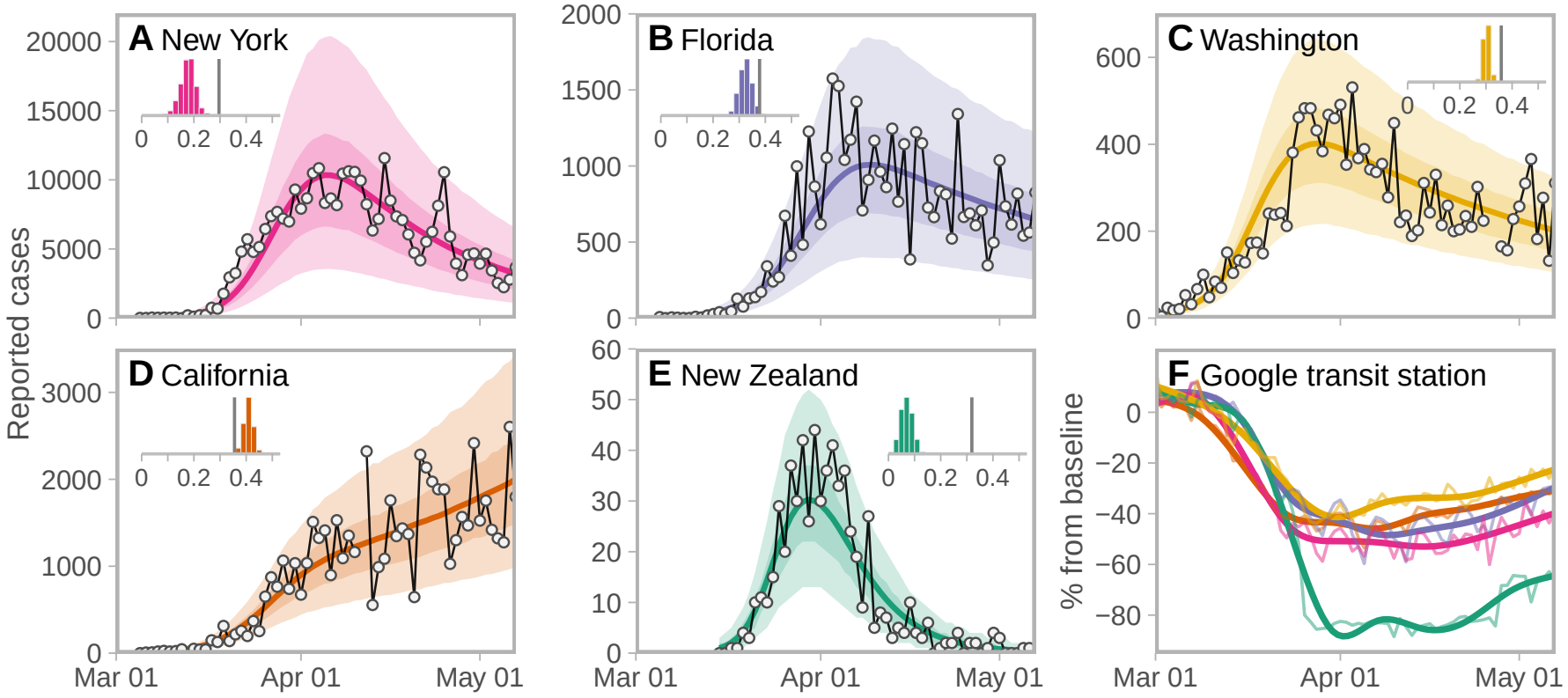
What would have happened if we had gone back to business as usual on May 1

What we've experienced

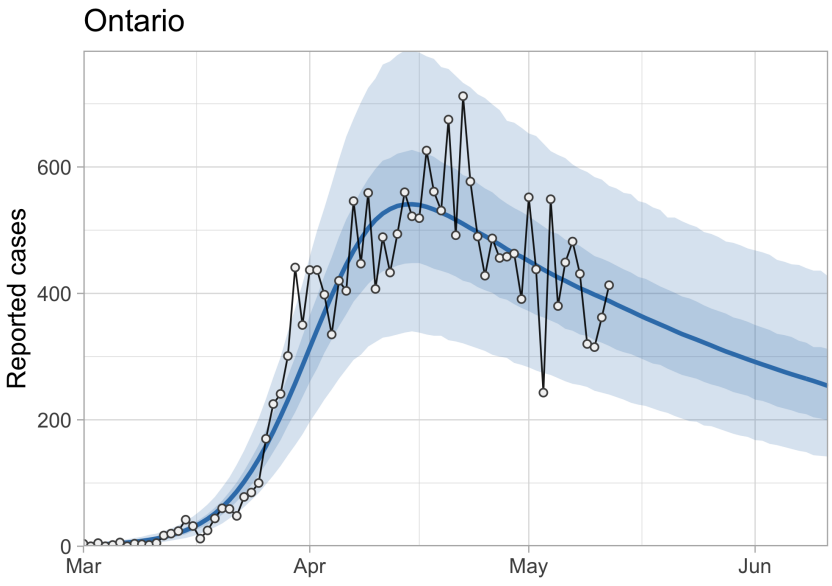
Options for reducing distancing

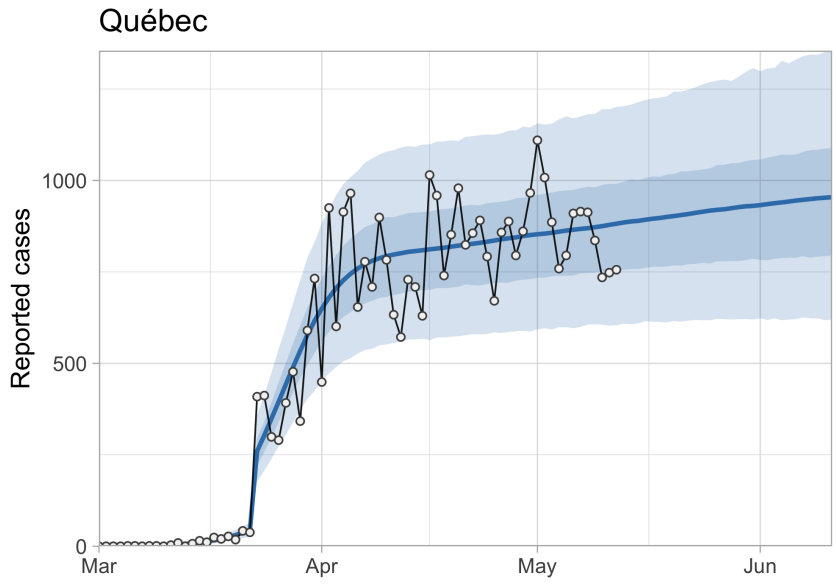


Where do we go from here?



Quebec and Ontario





Next steps for this modelling

- Relate strength of distancing to mobility data
- That way, estimate risk sooner
- Related project: how soon can we detect effect of behavioural change?
- The population isn't well-mixed, or all the same: modelling high-risk settings (meat packing etc), introductions

What we don't know (highlights)

- How many British Columbians have COVID19 today? last week?
- How many have ever had COVID19? In Canada?
  - Serological data: up to 10% in Spain. Likely very low here.
- How infectious are children? What happens if we re-open schools?
- What activities correspond to what level of contact, or contact reduction?
- What do contact patterns in Canada today look like? (by age, by activity level, by geography)

Thank you

- Sean Anderson, Andrew Edwards – Fisheries and Oceans
- Jessica Stockdale, Nicola Mulberry, Dan Coombs
- BCCDC modelling team
- British Columbia Centre for Disease Control
- Genome BC
- Michael Smith Foundation for Health Research

GitHub

seananderson/covidseir

Bayesian SEIR model to estimate physical-distancing effects - seananderson/covidseir