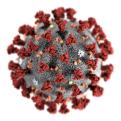
## REAL-TIME MODELLING OF THE COVID-19 EPIDEMIC: PERSPECTIVES FROM BRITISH COLUMBIA (I)

Caroline Colijn

<sup>1</sup>Department of Mathematics Simon Fraser University

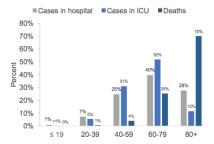
#### WHAT IS COVID19 AND WHERE DID IT COME FROM?

- 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?

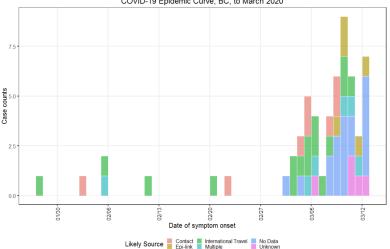
- It can cause severe illness, and not only in the elderly
- Symptoms
  - cough, fever
  - difficulty breathing, pneumonia in both lungs
  - Ioss of taste, smell, chest pain
- Severe illness:
  - organ failure
  - acute kidney injury
  - heart failure
  - Death



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

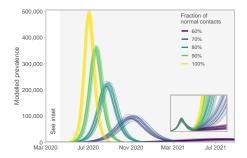


COVID-19 Epidemic Curve, BC, to March 2020

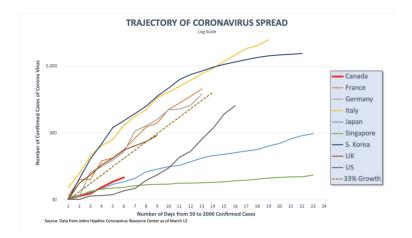
### MODELLING: EARLY AIMS

- 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



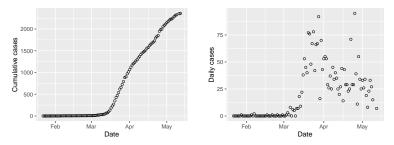
#### CUMULATIVE COUNTS AND BENDING CURVES



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

### MODELLING CONSIDERATIONS

- Basic epidemiology: *R*<sub>0</sub>, 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?

#### Type 1: Aggregate data

- daily case counts by location
- daily hospitalization, ICU, deaths by locn

#### Type 2: Individual "line list" data

- times of exposure, symptoms, outcomes
- age, location
- contact data: likely source(s), locations, contacts' symptom time and data
  More contact tracing data: app-based; detailed

#### Type 3: (a) Serology : build-up of immunity in populations and (b) COVID19 virus prevalence

- NOT restricted to at-risk
- by age in general population
- serial samples needed to monitor
- does not necessarily need high volumes

#### Type 4: Behavioural data (not specific to infection/exposure)

- mobile phone: contact and mobility
- surveys: distancing behaviour
- socio economic, age, other risk

#### Short term (1-6 weeks)

- basic knowledge of virus dynamics in Canada
- immediate health care capacity planning
- risk forecasting, estimation
- assess effectiveness of distancing

#### Medium term (2-9 weeks)

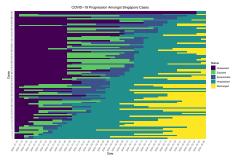
- peak timing and size
- peak size by age, location
- healthcare capacity planning
- assess need for continuing distancing measures, by age, location, risk
- Plan how to relax distancing

#### Medium to long term

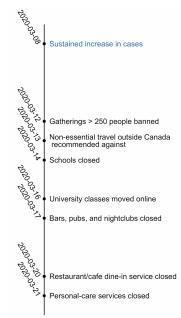
- Monitor impacts of distancing
- If distancing works well: how do we get out of distancing and resume normal activity?
- If not: how to amplify, make more precise and targeted plans (stratified)
- Prioritize therapeutics
- Targeted/precise distancing

## 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

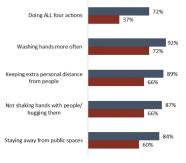


### BACK TO BC'S TIMELINE



## SURVEY, LATE MARCH: IS COVID19 SERIOUS?

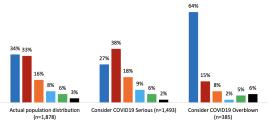
#### COVID-19 precautions being taken



Consider COVID19 Serious (n=1,493)

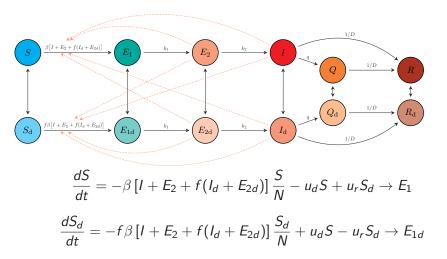
Consider COVID19 Overblown (n=385)

Federal vote 2019 Those who say COVID-19 threat in Canada is serious versus overblown



CPC Liberal NDP BLOC Green Other

#### A MATHEMATICAL MODEL WITH DISTANCING



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)

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



# 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:

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

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



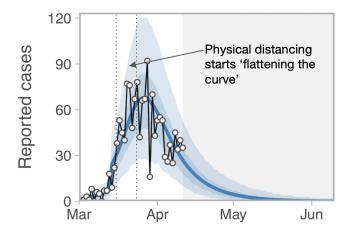
#### We estimate the impact of distancing

- 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 ( $\phi$ ).
- We fit the model using Bayesian inference, with  $C_r$  the cases on day r:

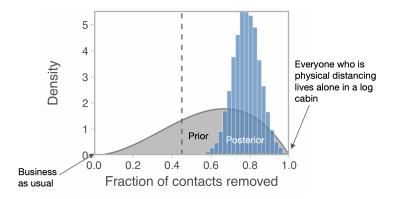
$$\mathsf{P}\left(R_{0\mathrm{b}}, f_2, \phi | \{C_r\}\right) \propto \mathsf{P}\left(\{C_r\} | R_{0\mathrm{b}}, f_2, \phi\right) \mathsf{P}(R_{0\mathrm{b}}) \mathsf{P}(f_2) \mathsf{P}(\phi)$$

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

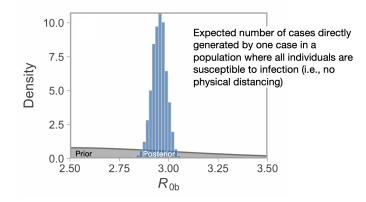
#### RESULT: THE FIT IS GOOD



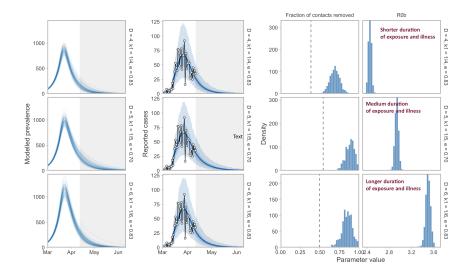
#### POSTERIOR DISTANCING IMPACT IS STRONG



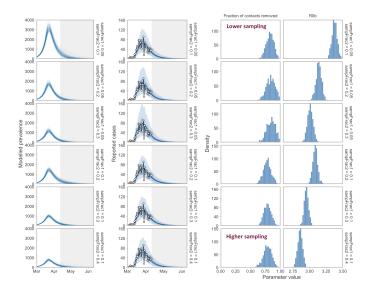
# Posterior reproductive number is 3 ... or is it?



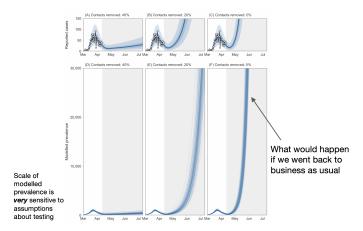
#### DISTANCING IS ROBUST, $R_0$ ISN'T



#### DISTANCING IS ROBUST, PREVALENCE ISN'T

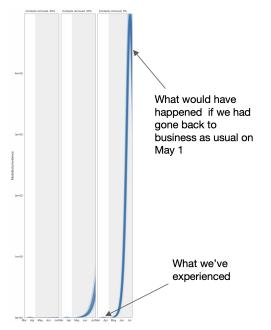


#### WHAT HAPPENS IF WE STOP DISTANCING?

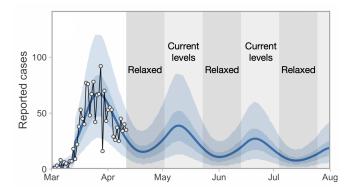


We do not think there is meaningful immunity – declines are due to distancing.

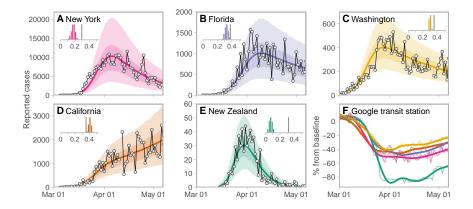
#### WE HAVE NOT SEEN "THE FIRST WAVE"



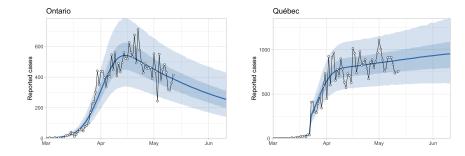
#### **OPTIONS FOR REDUCING DISTANCING**



#### 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

