COVID-19: PHAC Modelling Group Report

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5 SPECIAL REPORT

5.1 ASSESSMENT OF POTENTIAL COVID-19 TRAJECTORIES IN ONTARIO AND QUANTIFICATION OF THE EVOLUTION OF THE INFECTIOUS POPULATION OVER TIME

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Key points

- This analysis suggest that the peak of the current Omicron wave may occur in the coming weeks.
- Simulations show that effective measures, resulting in a reduced level of social contact, may blunt the peak hospitalization rate but will prolong the epidemic.
- For all scenarios studied, results suggest that a resurgence may occur if measures are lifted at the end of January.

Note: Supplemental information on methods and/or results for this report is provided in Annex 6.2.6.

Background

Since its official declaration as a pandemic by the World Health Organization (WHO) on March 11, 2020, Coronavirus Disease 2019 (COVID-19) 336 million cases and 5.6 million deaths have been reported (as of January 19, 2022). Despite the implementation of several rounds of restrictions and non-pharmaceutical interventions (NPIs) and the availability of vaccines, the world has been recently experiencing a further resurgence of cases due to the Omicron (B.1.1.529) variant of concern (VOC)), which was first detected in South Africa in November 2021 [1]. Since then, there has been a rapid increase in transmission in many countries including Canada. Here the Omicron variant has gradually displaced the previous (Delta) VOC, to become the dominant circulating strain [2]. The number of daily cases, effective reproduction number, proportion of tests positive, and subsequently the hospital admissions have all increased more rapidly, and to higher levels than seen to date in Canada. In a recent matched cohort study based in Canada, Ulloa and colleagues found that the risk of being admitted to hospital or dying due to Omicron was 65% lower compared to Delta, as well as the risk of intensive care unit (ICU) admission or death, being lower by 83% [3]. These data are consistent with those from other countries, indicating that Omicron is less virulent than previous VOCs, including Delta, even though its increased transmissibility and immune escape characteristics are anticipated to put a significant strain on the Canadian healthcare system.

In Ontario, modelling released on December 16, 2020 indicated that a reduction of contacts would be needed to reduce strain on the health care system posed by COVID-19 cases. In response, on December 19, 2021 measures in Ontario were put in place, including capacity limits of 50% in a number of indoor public settings [4]. As Omicron became dominant demand for PCR tests surged, and the PCR testing protocol in the province was altered on December 31, 2020 and only individuals belonging to specific groups were recommended for testing [5]. Hence, the stretched testing capacity and subsequent altered testing protocol posed a challenge for updating models with surveillance data in the near-term. After this (effective on January 5, 2022), Ontario entered a modified step 2 of the provincial roadmap to reopening, delaying this until at least January 26, 2022 and moving schools to remote learning until January 17, 2022 [6].

In the dynamic context of the COVID-19 pandemic, data streams and case definitions are altered frequently, which makes grounding models in observable and reliable evidence challenging at times. Also adding to the challenge of modelling projections in the near-term, there is typically a lag time of 1 to 2 weeks in case reporting following transmission events. Hospitalizations and more severe outcomes are lagged further. Using only surveillance data, the extent to which measures impact transmission (e.g., lifting or implementing public health interventions) can be measured only after the fact. This poses a challenge given the need for decision-making in the face of the rapidly spreading Omicron variant. However, models taking account the mechanistic detail of transmission can synthesize available data to provide plausible trajectories under different assumptions.

In the present study, a model is used that is grounded with surveillance data during the period of reliable and consistent case reporting prior to changes in testing. Hypothetical scenarios, of the extent to which recent public health measures have mitigated transmission, are explored to project possible future trajectories of the epidemic in Ontario. These five scenarios explore effects on epidemic trajectories of different assumptions of levels of social contact mixing, modelled as variations in the daily contact rate. Three scenarios are designed to extremes of low and high transmission, and two scenarios investigate activity levels based on previous estimates during the end of the year period in 2020-2021 (December 2020 – January 2021 holiday and end of the year period). The analysis provides estimates of case counts that would have occurred had PCR testing remained consistent, and the evolution of symptomatic and asymptomatic infections over time. In so doing, the study aims to provide model-based insights into possible epidemic trajectories in Ontario, identifying broad trends and possibilities for the timing and size of the peak of infections.

Methods

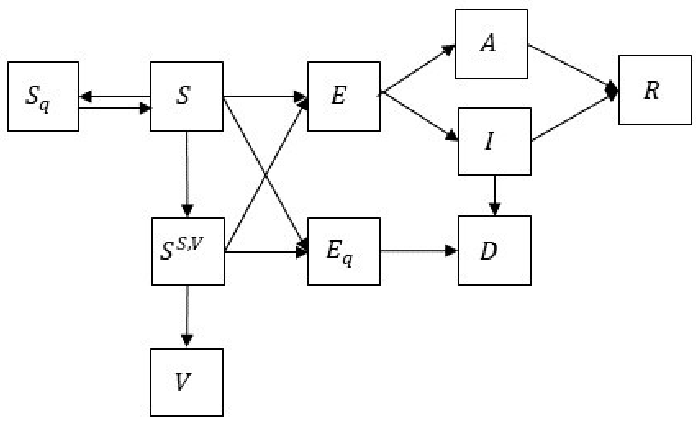
Transmission model

The transmission model, which was formulated in ordinary differential equations, comprises three sub-models. The first sub-model accounted for the ancestral strain of SARS-CoV-2 and has been detailed in [7]. The second sub-model accounted for variant strains Alpha/B.1.1.7 and Delta/B.1.617.2 was adapted from established work [8] and, in combination with the ancestral strain sub-model, fitted to confirmed cases of COVID-19 in Ontario until December 6, 2021. A third sub-model was introduced to account for the Omicron variant and shares the same structure and dynamics as the second sub-model; several parameters and initial conditions have been updated to reflect Omicron-specific features. In the model, the population was stratified into the following compartments: susceptible to infection by SARS-CoV-2 and unvaccinated (S); vaccinated and protection against infection from recent vaccination not yet conferred ($S^{S,V}$); effectively vaccinated (V); latent (E); infectious and symptomatic (I); infectious and asymptomatic (i.e. never develops symptoms), (A); susceptible to infection and quarantined (S_q); exposed and quarantined (E_q); diagnosed (PCR positive) (D). The structure of the latter two submodels accounting for variants is shown in Figure 1, which, in the absence of vaccination, are the same as the structure of the submodel for the ancestral virus [7, 9].

Vaccination was accounted for in terms of primary series and booster doses. The impact of vaccination against infection by multiple variant strains was informed by estimates of vaccine effectiveness against infection by Delta

[10] and Omicron [11]. Time series data of individuals being vaccinated in Ontario were used to parametrize changes in the population vaccinated. Main assumptions for the variant strains were related to relative transmissibility. The Alpha variant was considered as 1.4 times more transmissible than the ancestral strain (modelled as the transmission risk per contact) [12, 13], and Delta was 1.5 times more transmissible than Alpha [14, 15]. The transmissibility of Omicron relative to Delta, in terms of the transmission probability per contact, was assumed to be 3.5 times higher, when accounting for both intrinsic increases in transmissibility and immune escape characteristics [16]. These relative transmissibility estimates were used to inform the search range and initial values for the model fitting procedure, to account for temporal fluctuations in transmission rates. The majority of the model parameters were fixed in time, and several were time-dependent to reflect alterations in social contact mixing, case detection and reporting, and quarantine and isolation. See Annex 6.2.6for further details of the mathematical model and simulation. The fitted model has demonstrated alignment with the observed case data, prior to the alterations in surveillance (Figure A-1 in Annex 6.2.6).

Figure 1. Illustration of the state variables in the transmission dynamics sub-models and their relationships.



Study design

Having aligned the model to observed data, simulations using several scenarios to broadly reflect the possible impact of implementation and then lifting of measures according to the timeline in Table 1.

Table 1. Timeline of possible impact of implementation and then lifting of measures across scenarios.

December 19, 2021	Capacity limits implemented
January 5, 2022	Further measures implemented (modified step 2 of the roadmap to reopen)
January 17, 2022	Resumption of in-person learning for elementary, middle school, high schools
January 27, 2022	Lifting of measures

In five scenarios, the possible effects of the public health measures on the epidemic via impacts on social contact were explored. Scenarios 1 to 3 explored high transmission and low transmission scenarios to give insights into potential extremes of effects:

- *Scenario 1 (sustained high activity, limited impact of measures):* The estimated contact rate from November 24, 2021 to December 6, 2021 (approximately 10.8 contacts per individual per day) was prolonged until January 5, 2022. Measures on January 5, 2022 were assumed to reduce the daily contact rate by 25% until

January 17, at which point mixing was increased following resumption of in-person learning by 1.46 contacts per day per individual [9]. Finally, on January 27, 2022 all measures were lifted and contacts returned to the November 24, 2021 to December 6, 2021 level in addition to mixing in schools.

- *Scenario 2 (effective measures):* The estimated contact rate from November 24, 2021 to December 6, 2021 was prolonged until December 19, 2021. Following the December 19 capacity limits, the daily contact rate was returned to levels midway between those during November 24 to December 6, and those after the end of non-essential workplace closures in May 2020 (a daily contact rate of 6.63, which is a reduction by approximately 40%) until the further measures were implemented on January 5, 2022. The measures effective on January 5, 2022 were assumed to further reduce the daily contact rate by 25% until January 17 2022, at which point contacts increased again following resumption of in-person learning by 1.46 contacts per day per individual [9]. Finally, on January 27, 2022 all measures were lifted and contact mixing returned to the November 24 to December 6 levels in addition to mixing in schools.
- *Scenario 3 (optimistically effective measures):* Identical to scenario 2; however, January 5 measures reduced contacts by 50% instead of 25%. This brought the daily contact level to approximately 3 to 4 contacts per individual per day, indicating an optimistically high effect of measures.

Two additional scenarios were explored, which aimed to capture a potentially more plausible extent of social contacts, compared to Scenarios 1-3. For these, a prior estimate of daily contacts (8.3 contacts per day per individual [8]) was used in Ontario during December 23, 2020 to January 9, 2021.

- *Scenario 4:* The estimated contact rate from November 24, 2021 to December 6, 2021 was prolonged until December 19, 2021. Following December 19, 2021 measures, the contact rate was reduced to 8.3 contacts per day. The measures on January 5, 2022 were assumed to reduce the daily contact rate by 25% until January 17, where contacts were increased following the in-person learning resumption by 1.46 contacts per day per individual [9]. Finally, on January 27, 2022 all measures were lifted and contact returned to the November 24, 2021 to December 6, 2021 level in addition to mixing in schools.
- *Scenario 5:* Identical to above; however, the contact rate following the measures on January 5, 2022 were reduced by 50% (up from 25%).

See Appendix for the detailed contact rates of scenarios 1 – 5. For each Scenario, the fitted model was run to assess the case counts that would have occurred had the PCR testing protocol not been altered and case detection remained consistent following December 31, 2021. Secondly, in light of the alteration to PCR testing (among potentially additional factors), the number of infectious individuals according to the five hypothetical scenarios was assessed.

Results

Scenarios 1, 2 and 3

The model-predicted case counts continued to rise following the January 5, 2022 measures in each scenario (Figure 2). In Scenario 1, in which a weak impact of public health measures was modelled, new cases rose to a peak of approximately 150,000 cases a day in early-mid January (Figure 2). In scenarios modelling a stronger impact of public health measures was modelled (2 and 3), cases rose slower and then resurged after measures are lifted at the end of January. In these scenarios, cases approached a peak, at about 140,000 a day, at the end of the simulation. The decline in model-predicted case counts after the peak is due to a sufficient depletion of individuals susceptible to infection.

The number of symptomatic and asymptomatic infectious individuals followed a similar pattern to the cases (Figure 3).

Scenarios 4 and 5

For Scenarios 4 and 5, the model-predicted case counts peaked in mid-late January/early February at approximately 120,000 cases a day (Figure 4). When public health measures were modelled as being stronger (Scenario 5), the peak was later. In both scenarios, a resurgence occurred when measures were lifted at the end of January. The numbers of symptomatic and asymptomatic infectious individuals followed a similar pattern (Figure 5).

Discussion

This analysis looks at potential trajectories for the Omicron wave in Ontario, given a range of scenarios from low to high transmission, associated with different modelled impacts of public health measures. Despite the broad range of scenarios, the analysis indicates that the peak of the current wave may occur in the coming weeks. The simulations show that effective measures (more broadly, reduced levels of social contact) prolongs the epidemic. Furthermore, scenarios suggest that a resurgence is possible when measures are lifted on January 27, 2022.

Holidays during this end-of-the-year period may have facilitated relatively high contact rates (e.g., Scenario 1). A decline in model-predicted case counts (Figure 2, yellow band) and infections (Figure 3, yellow band) followed a peak in the highest-contact scenario, due to a decrease in susceptible individuals from infection and vaccination (specifically, third dose administration). Following the lifting of measures on January 27, 2022, a relatively sharp increase in model-predicted infections for both scenarios 2 and 3 considering a moderate reduction in contact rates following December 19, 2022 measures (Figure 3). Scenarios 4 and 5 may be more plausible considering their utilization of historical measurements of social contact mixing in Ontario.

There are a number of limitations in the analysis here. Waning of immunity (vaccine-induced or infection-induced immunity) was not accounted for, and waning immunity may have a substantial impact for predicting infections in a long time frame. The separation of intrinsic transmissibility of Omicron and its immune evasion should also be assessed in future work. Which scenario turns out to be the most realist may be revealed by comparing model outcomes against trends in indicators such as hospitalized cases, cases in ICU, PCR test positivity, wastewater surveillance and absenteeism due to exposure to SARS-CoV-2.

Figure 2. Assessment of case counts predicted by the fitted model assuming consistent PCR testing and case reporting. Assessment based on different assumptions of impact of NPIs to reduce contact rates c were made in addition to assuming no alterations to surveillance and case detection. Scenario 1 is represented by yellow bands. Scenario 2 is represented by blue bands. Scenario 3 is represented by red bands. Note that the y-axis scales in left and right panels differ.

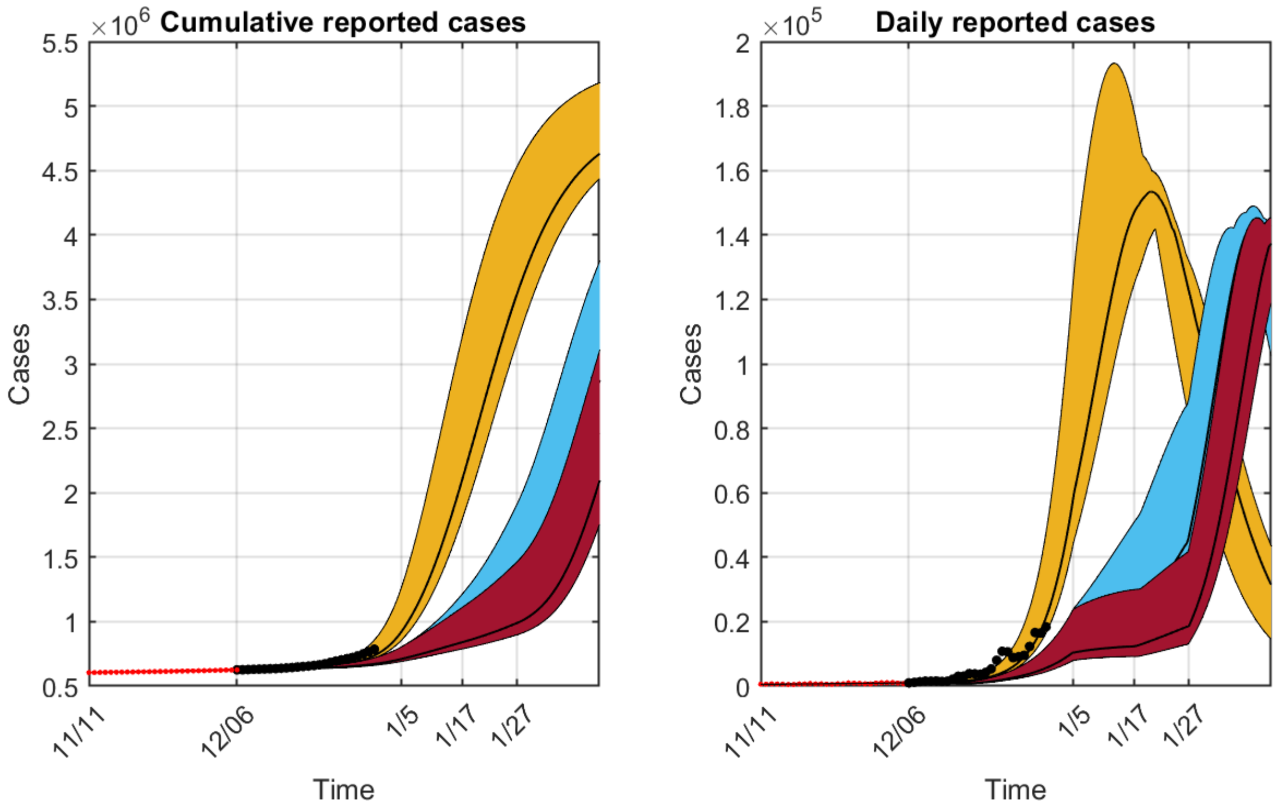


Figure 3. Assessment of symptomatic infectious, asymptomatic infectious and total infectious population under different assumed contact rates. Scenario 1 is represented by yellow bands. Scenario 2 is represented by blue bands. Scenario 3 is represented by red bands. Top left and top right panels have different y-axis scales than the bottom panel.

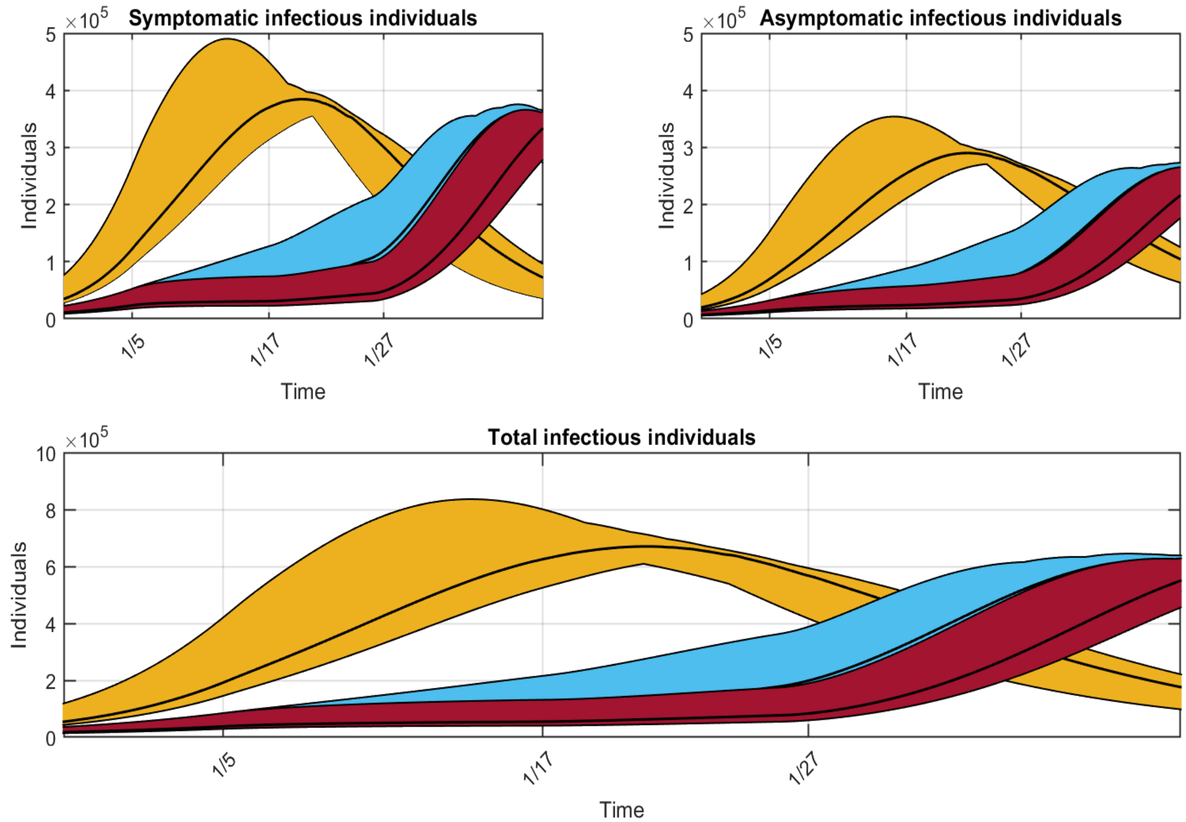


Figure 4. Assessment of case counts predicted by the fitted model with consistent PCR testing and case reporting. Assessment based on different assumptions of impact of NPIs to reduce contact rates c were made and assuming no alterations to surveillance. Dark grey corresponds to scenario 4. Light grey bands correspond to scenario 5. Scales are different between left and right panels.

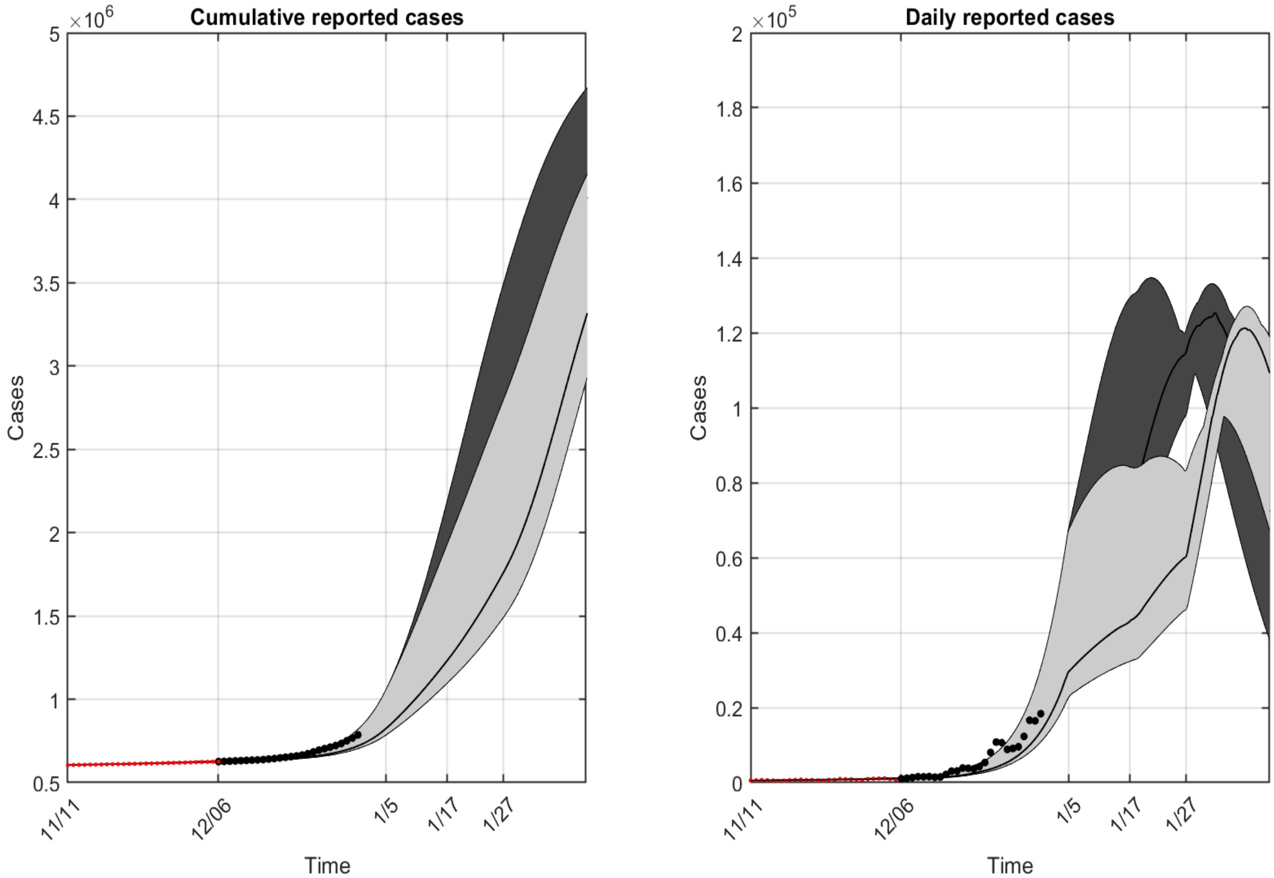
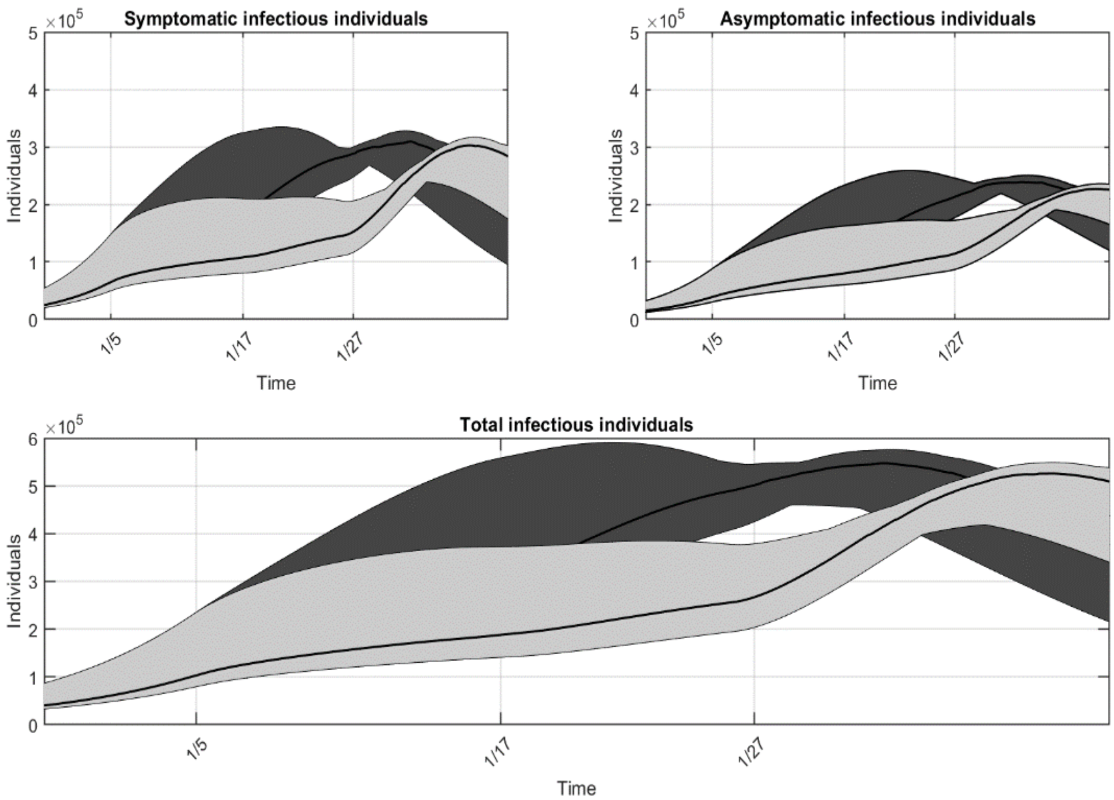


Figure 5. Assessment of symptomatic infectious, asymptomatic infectious and total infectious population under different assumed contact rates. Note that y-axis scales are different between top and bottom panels. Dark grey bands corresponds to scenario 4. Light grey bands correspond to scenario 5.



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