Appendix 1 (as supplied by the authors)

Projecting Critical Care Demand for COVID-19 Outbreaks in Canada

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This Appendix provides additional details and simulation outputs in support of the results and conclusions presented in the main text

Model Structure and Description

We developed a computational agent-based model (ABM) for the transmission dynamics of COVID-19 disease in an *in-silico* population (computer environment). The basic structure of the ABM includes a finite collection of agents that represent individuals living in a population; and a virtual environment in which agents are situated and interact. Agents are characterized by time-dependent epidemiological states of susceptible, infected and incubating, infectious and symptomatic with either mild or severe illness, recovered, and dead. We further considered two sub-states of severe and critical illness for (i) non-ICU hospitalization and (ii) ICU admission in which disease-induced death was possible.

In our model, newly infected individuals would develop either mild or severe symptoms. This outcome was age-dependent (1). Individuals between 0 19, and 20-49 years of age had a 20% chance of developing severe symptoms. Individuals between 50 – 64 and 65+ years of age had a higher chance of 60% and 80%, respectively (1).

Model parameters were informed using the latest COVID-19 published estimates. The duration of each epidemiological state in the model was determined by sampling from specific distributions (where available), such as the incubation and hospitalization/ICU period, for each individual in the model when infection occurred. For instance, the incubation period (of each exposed agent) was independently sampled from a LogNormal distribution with a mean of 5.2 days. In our model the infectious period was fixed to 4.6 days. In the absence of estimates for this parameter, we calculated this based on the average estimates of 7.5 days for serial interval (2) and 5.2 days for incubation period using the formulae:

$$\text{infectious period} = 2\times(\text{serial interval} - \text{incubation period})$$

The modelling dynamics is an iterative process in the form of a discrete-time simulation (with 1-day increment in time) where the simulation clock is advanced by the same amount (i.e. 1 day). On each day, the interaction between susceptible and infectious agents is described by an empirically determined contact network (3). Specifically, the daily number of contacts for infectious agents (with any other agent) was sampled from an age-specific negative-binomial distribution (Table A1), and contacts were distributed among different age groups based on a contact matrix (Table A2) for urban and densely populated regions. Disease transmission between susceptible and infectious agents occurred as a result of rejection sampling-based (Bernoulli) trials, where the chance of success is defined by a transmission probability.

The transmission probability was empirically determined through a calibration process. Calibration was based on the average of 500 simulations. For a given transmission probability, simulations were seeded independently with a single individual in the infectious state, and the number of secondary infections were counted. The value of this probability was varied until the target reproduction number (2.0 or 2.5) was produced.

Given the nature of our model (being agent-based), the process of sampling each parameter from its relevant distribution for each individual naturally accounts for the parameter variation (and therefore the sensitivity of the results to these parameters). Most parameters in our model are sampled from their available distributions. For fixed parameters (such as the infectious period), their variation can be accounted for in the calibration process. A detailed list of parameters and their descriptions is provided in Table 1 of the main text.

Contact Matrix

Given that early estimates pertaining to the characteristics of the COVID-19 outbreaks in urban settings, and the lack of contact matrix for rural area, our model is mainly parameterized for disease spread in urban populations. The contact matrix used in our model is derived from a study of social interactions in urban settings (3).

Table A1. Mean and standard deviation of the negative binomial distributions for the daily number of contacts in different age groups (3).

Age group	**Mean (standard deviation) of daily number of contacts**
0-19	15.30 (11.19)
20-49	13.79 (10.50)
50-64	11.26 (9.59)

65+	8.00 (6.96)

Table A2. Proportion of daily contacts for intra- and inter-groups (3). The daily number of contacts (sampled from the negative binomial distribution given in Table A1) for an individual in age group a_i was distributed to different age groups b_j according to the proportions indicated in row a_i. For example, for 15 contacts sampled for an individual in age group a_1 (0-19), we allocated 9 (~0.5712×15) contacts with other individuals in age group b_1; 5 (~0.3214×15) contacts with other individuals in age group b_2, 1 (~0.0722×15) contact with other individuals in age group b_3, and 0 (~0.0353×15) contacts with other individuals in age group b_4. A similar approach was used for all individuals in each age groups to distribute their contacts in the population.

Age group	b_1: 0-19	b_2: 20-49	b_3: 50-64	b_4: 65+
a_1: 0-19	0.5712	0.3214	0.0722	0.0353
a_2: 20-49	0.1830	0.6253	0.1423	0.0494
a_3: 50-64	0.1336	0.4867	0.2723	0.1074
a_4: 65+	0.1290	0.4071	0.2193	0.2446

Results for R_0=2.5

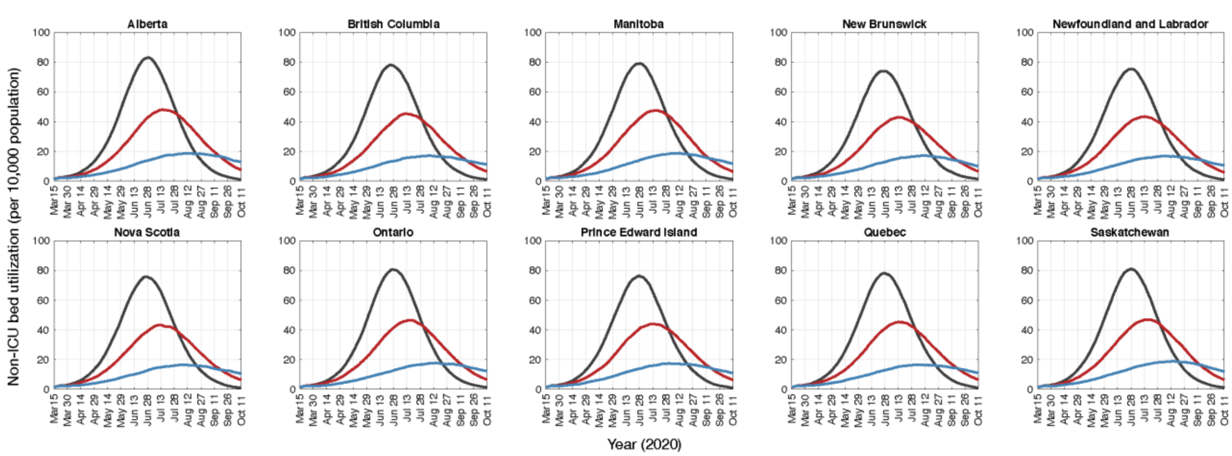

Figure A1. Projected number of non-ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

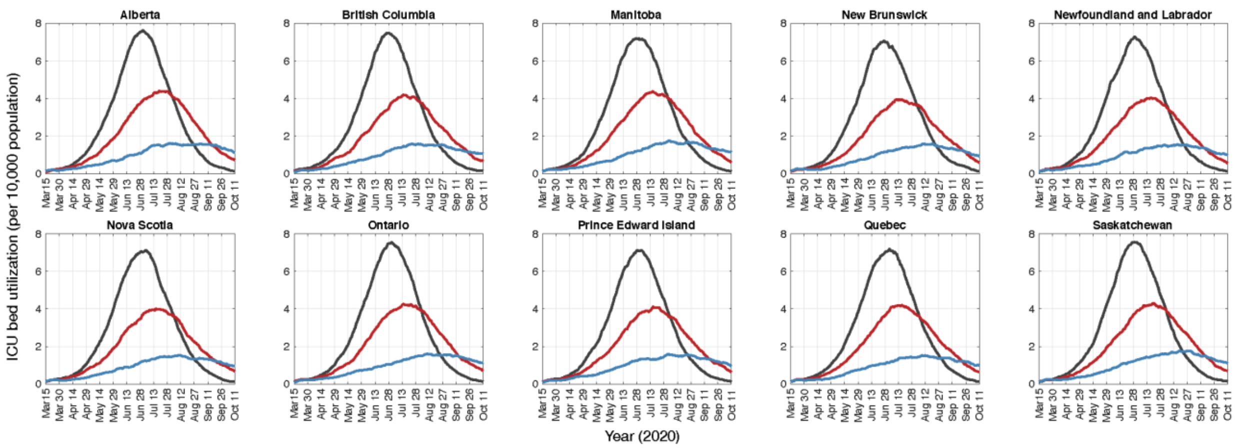

Figure A2. Projected number of ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

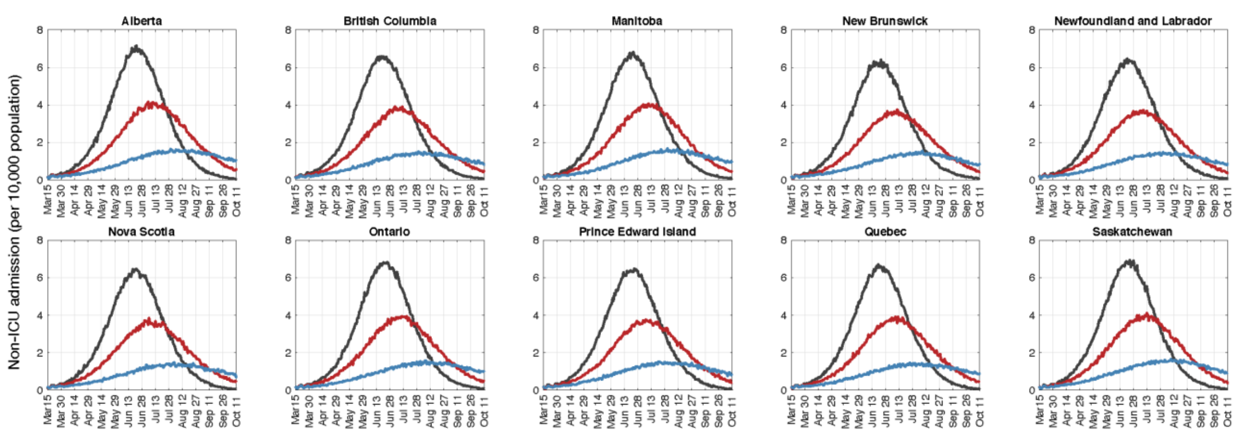

Figure A3. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

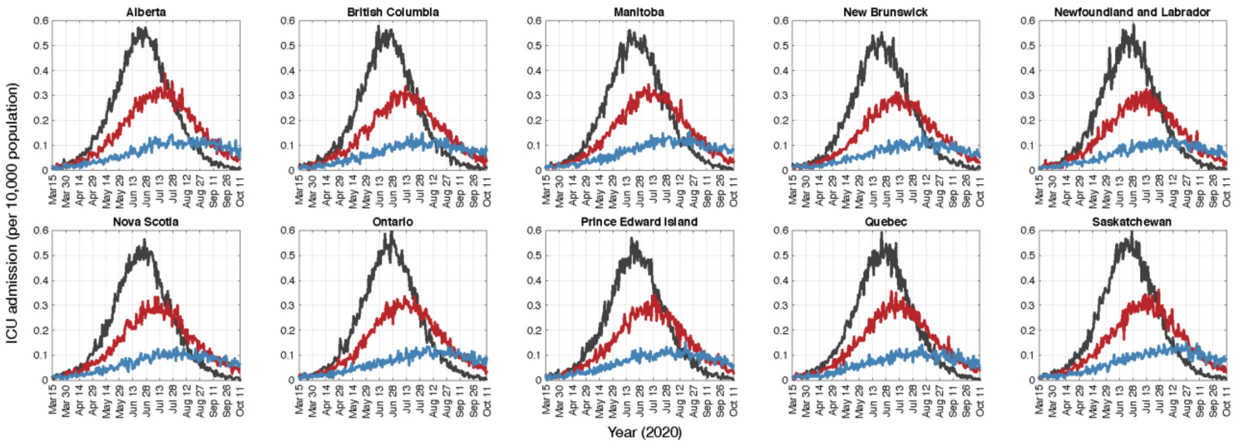

Figure A4. Projected daily incidence (per 10,000 population) of required ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

Results for R_0=2

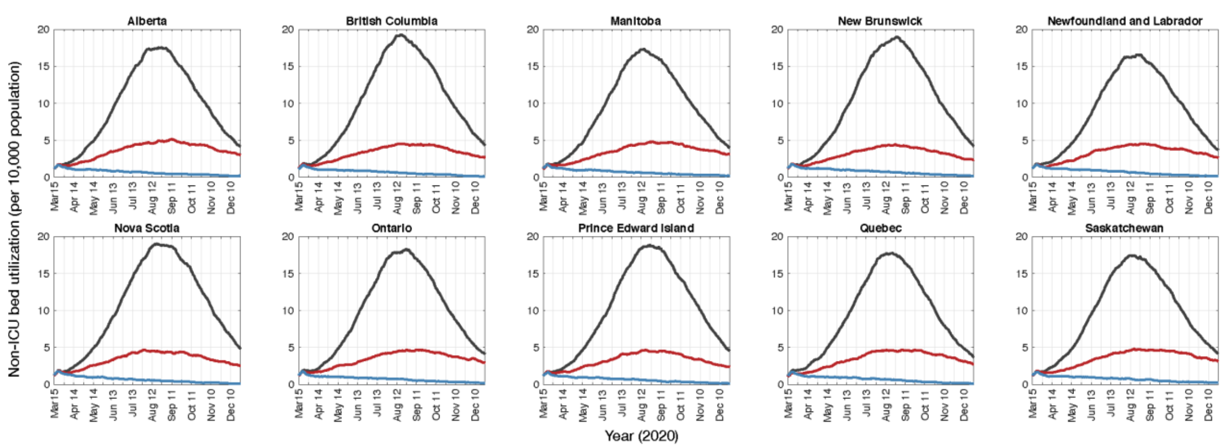

Figure A5. Projected number of non-ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

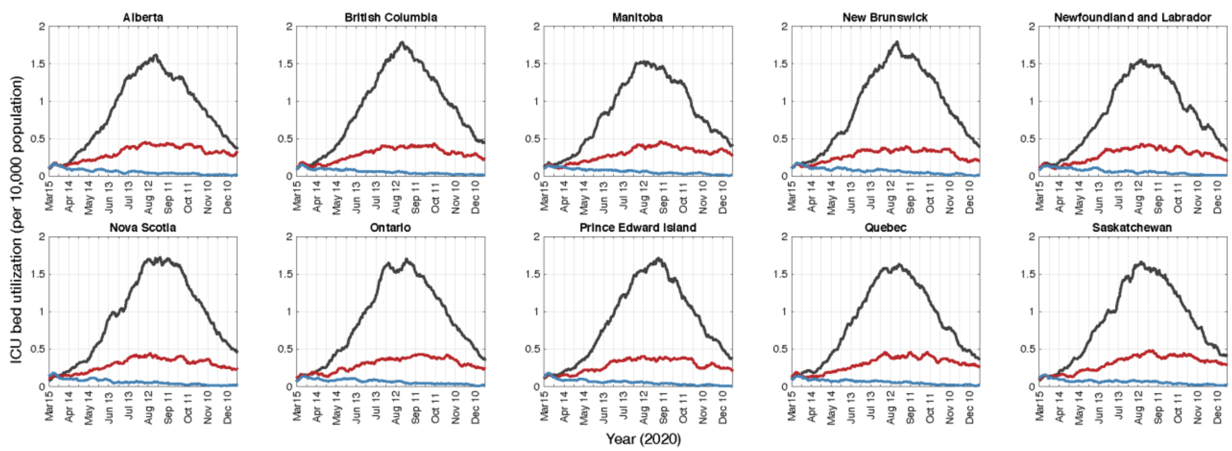

Figure A6. Projected number of ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

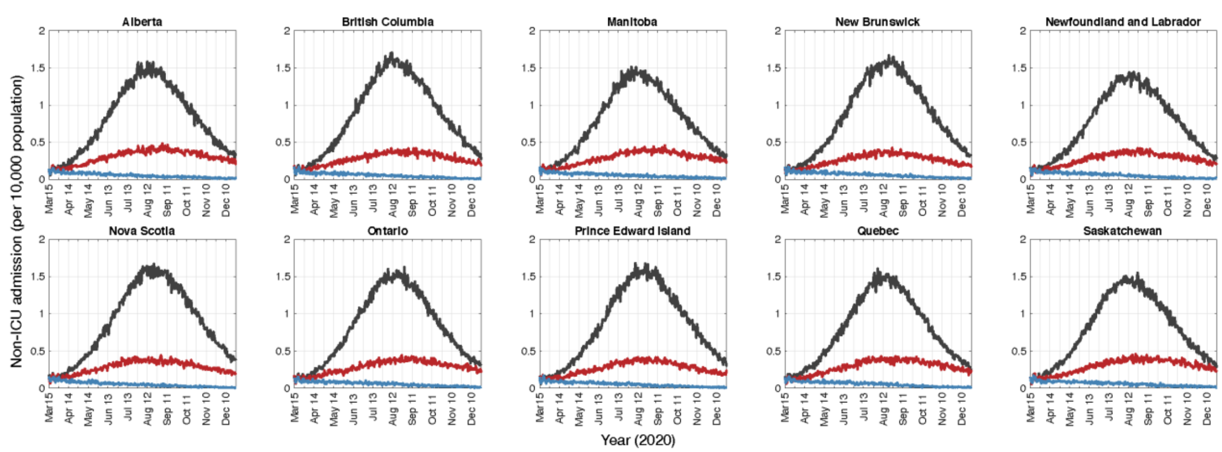

Figure A7. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

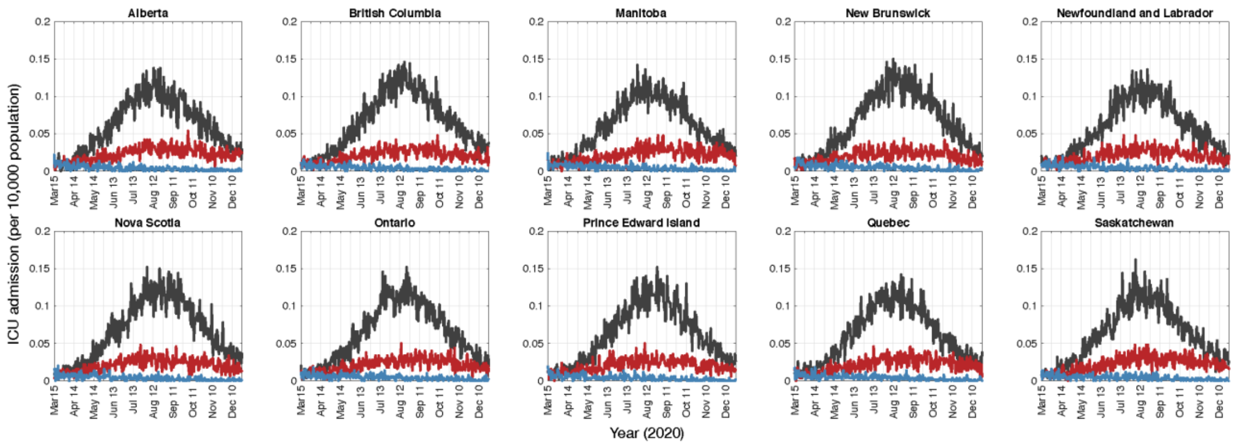

Figure A8. Projected daily incidence (per 10,000 population) of required ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to no self-isolation (black), 20% self-isolation (red), and 40% self-isolation (blue).

In the absence of self-isolation, we projected a total of 271 ICU bed days per 10,000 population would be required on average in each province. When 20% and 40% of symptomatic cases practiced self-isolation, the overall utilization of ICU bed days was reduced by 61% and 93%, respectively, compared to no-isolation (Figure A9).

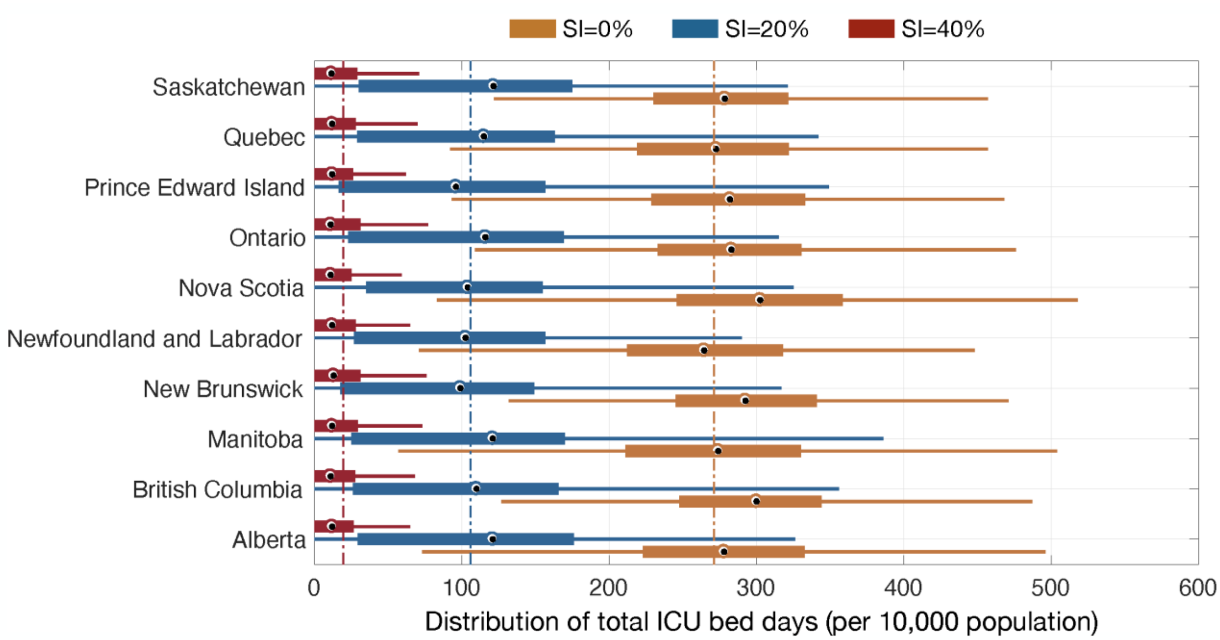

Figure A9. Distribution of the cumulative ICU bed days per 10,000 population during the COVID-19 outbreaks in different provinces with R_0=2. Boxplots correspond to the level of self-isolation (SI) among mild symptomatic cases: SI=0% (orange), SI=20% (blue) and SI=40% (red). Vertical dashed lines correspond to the average ICU bed days in all provinces without self-isolation (orange line=271), 20% self-isolation (blue line=106), and 40% self-isolation (Red line=19).

Results for R_0=2.5 with 60% and 80% self-isolation

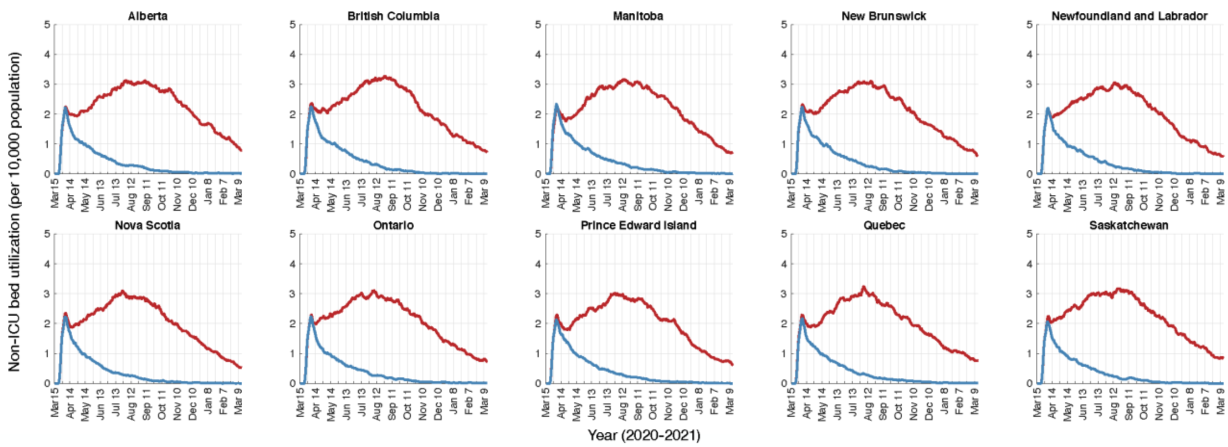

Figure A10. Projected number of non-ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

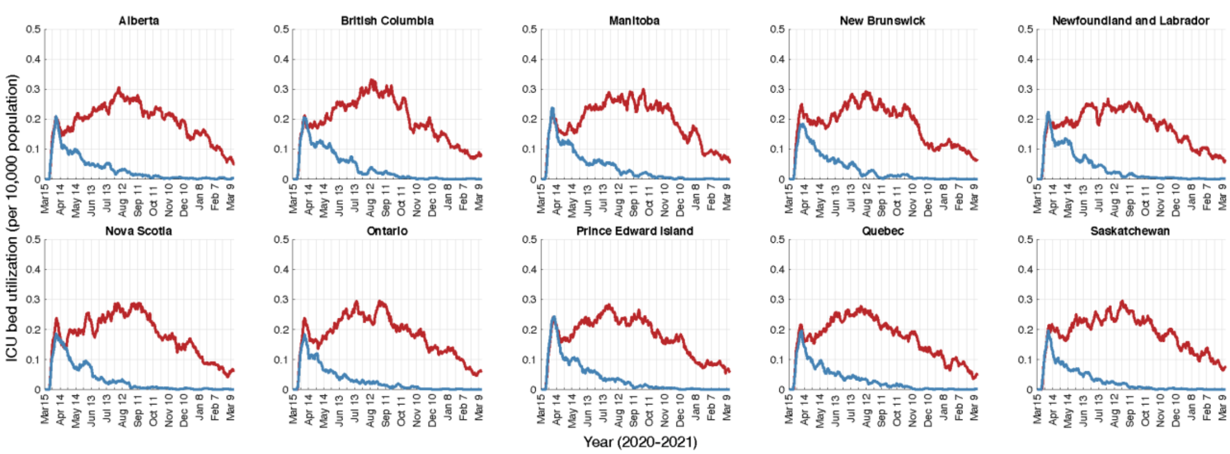

Figure A11. Projected number of ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

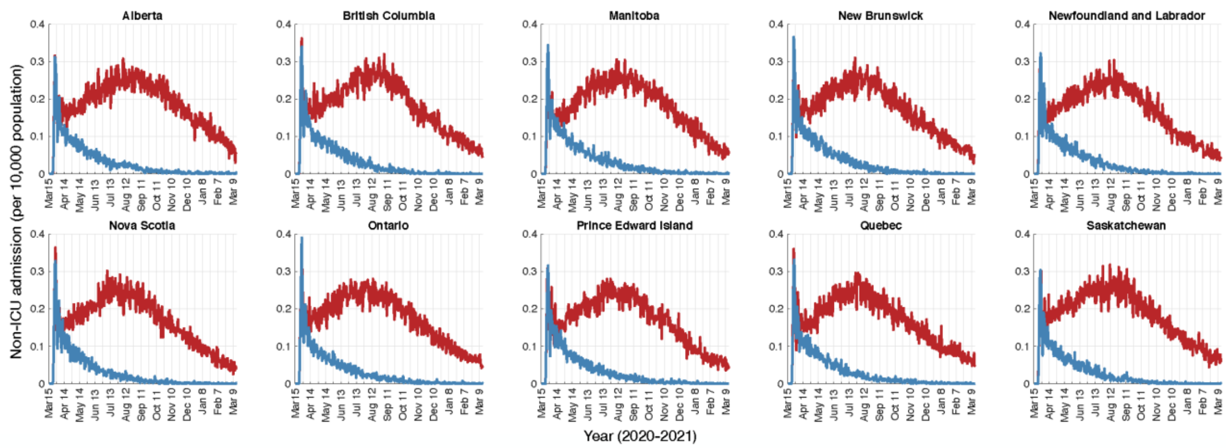

Figure A12. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

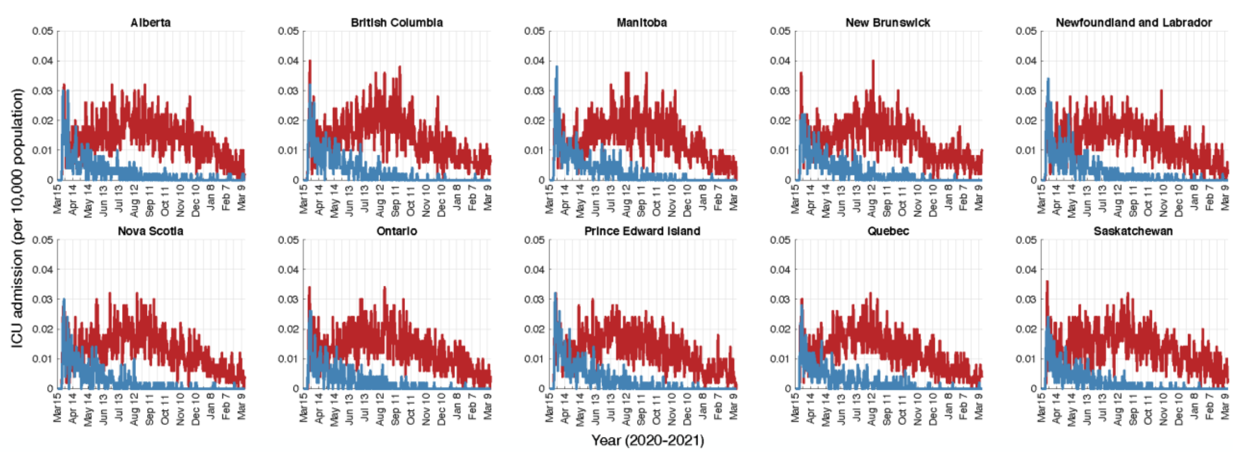

Figure A13. Projected daily incidence (per 10,000 population) of required ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

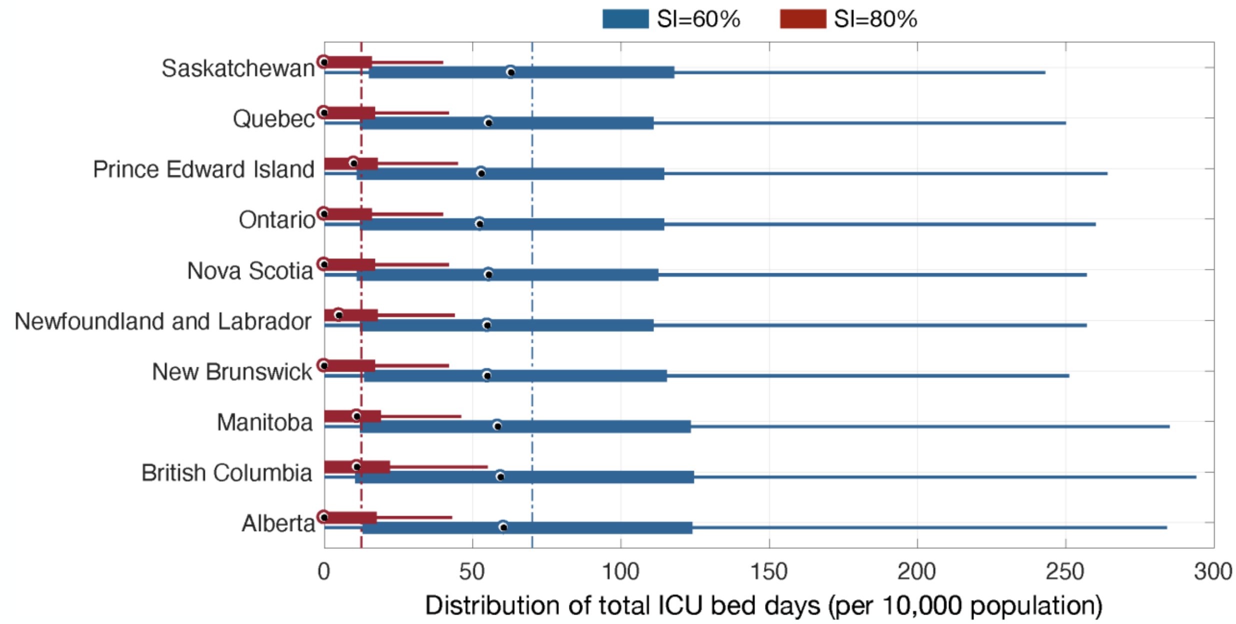

Figure A14. Distribution of the cumulative ICU bed days per 10,000 population during the COVID-19 outbreaks in different provinces with R_0=2.5. Boxplots correspond to the level of self-isolation (SI) among mild symptomatic cases: SI=60% (blue) and SI=80% (red). Vertical dashed lines correspond to the average ICU bed days in all provinces with 60% self-isolation (blue line=70), and 80% self-isolation (Red line=12).

Results for R_0=2 with 60% and 80% self-isolation

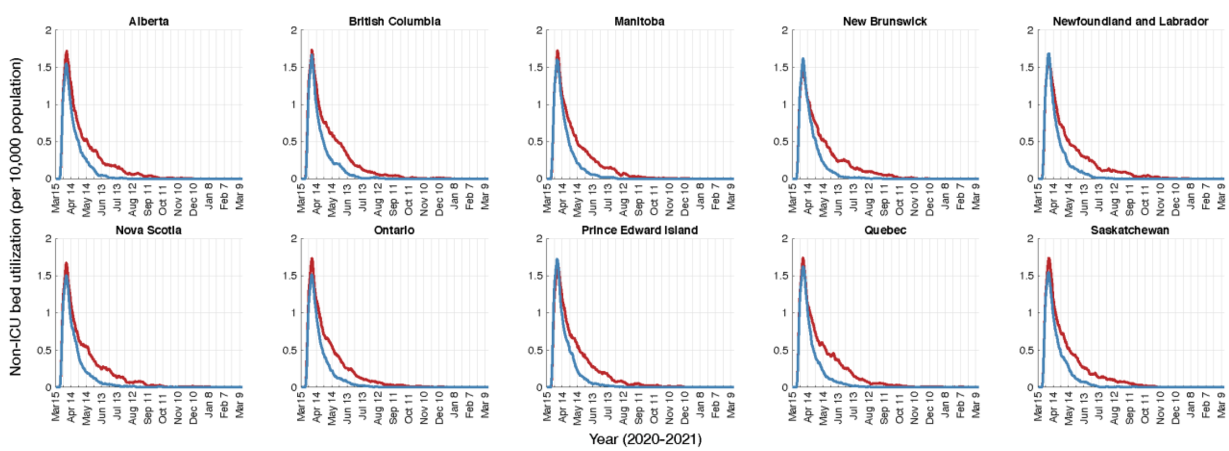

Figure A15. Projected number of non-ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

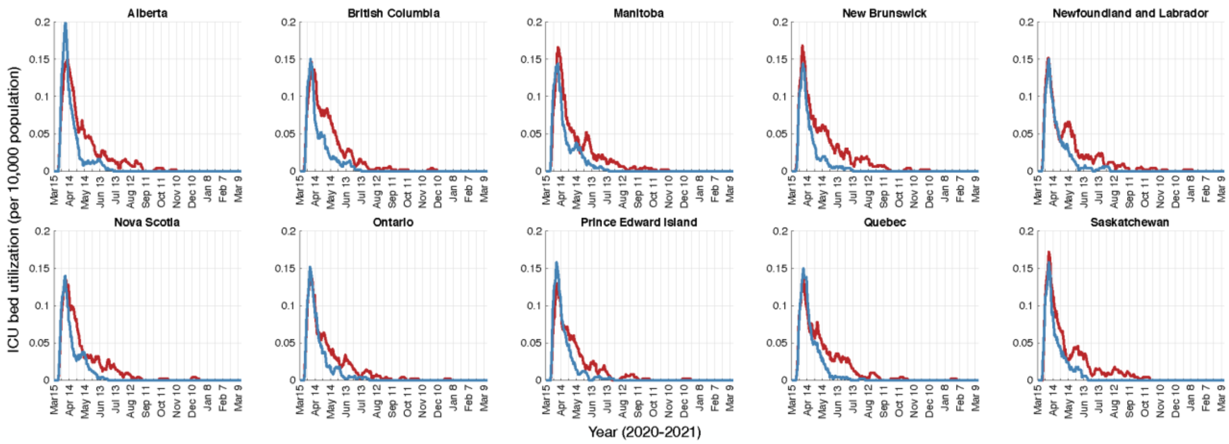

Figure A16. Projected number of ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

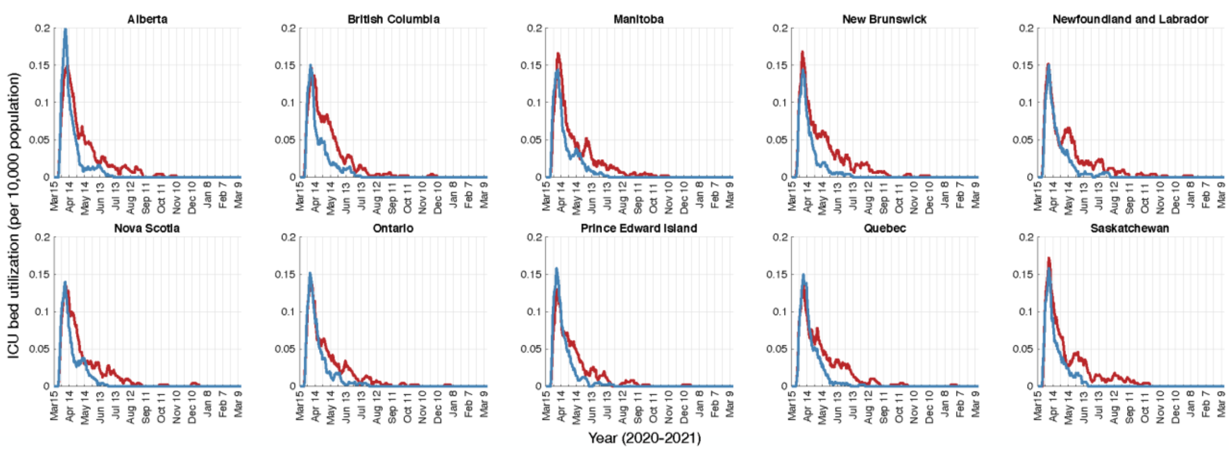

Figure A17. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

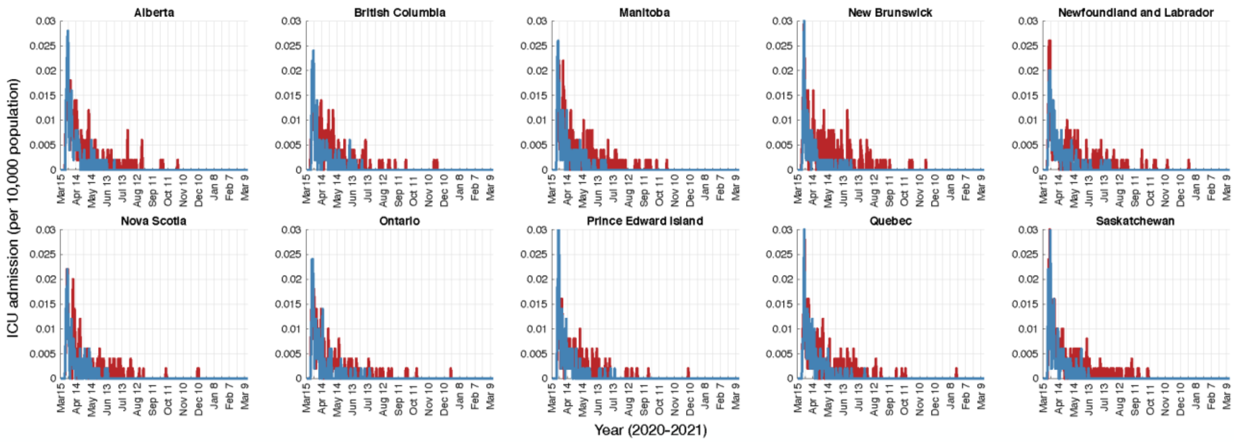

Figure A18. Projected daily incidence (per 10,000 population) of required ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 60% self-isolation (red), and 80% self-isolation (blue).

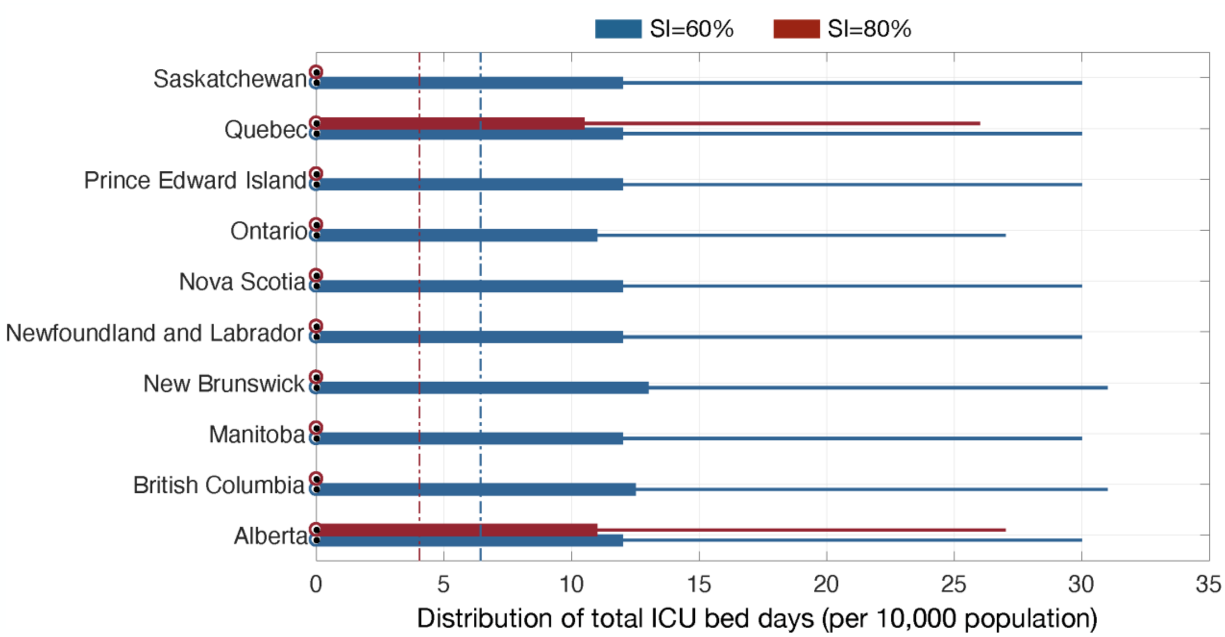

Figure A19. Distribution of the cumulative ICU bed days per 10,000 population during the COVID-19 outbreaks in different provinces with R_0=2.5. Boxplots correspond to the level of self-isolation (SI) among mild symptomatic cases: SI=60% (blue) and SI=80% (red). Vertical dashed lines correspond to the average ICU bed days in all provinces with 60% self-isolation (blue line=6), and 80% self-isolation (Red line=4).

Simulation results with 48 hours delay in self-isolation

This section provides simulation results for scenarios of R_0=2.5 and R_0=2, when self-isolation starts 48 hours after the onset of symptoms.

Results for R_0=2.5

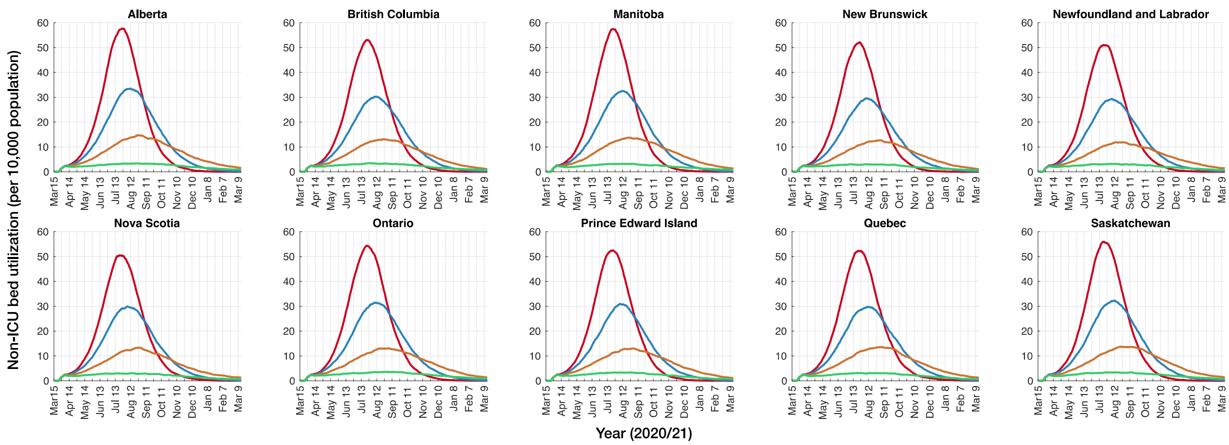

Figure A20. Projected number of non-ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

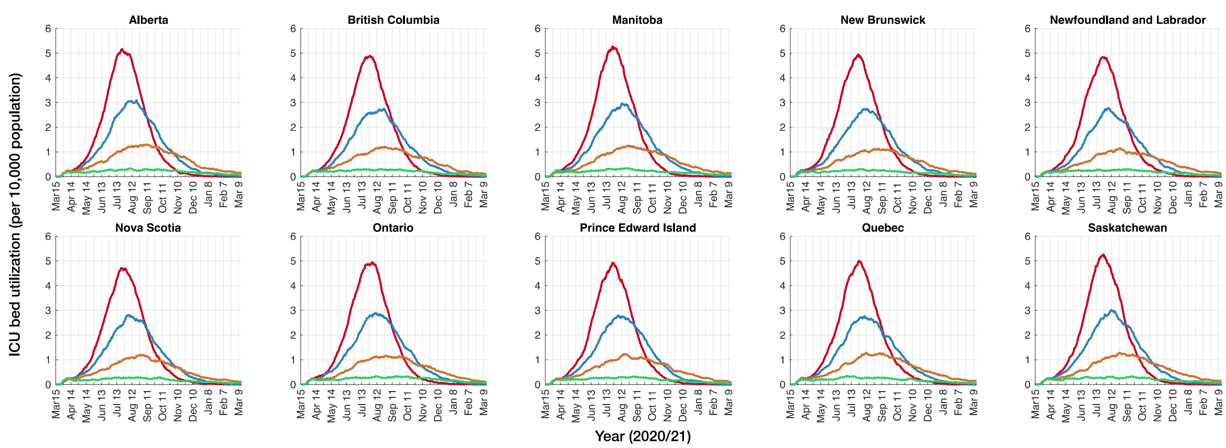

Figure A21. Projected number of ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

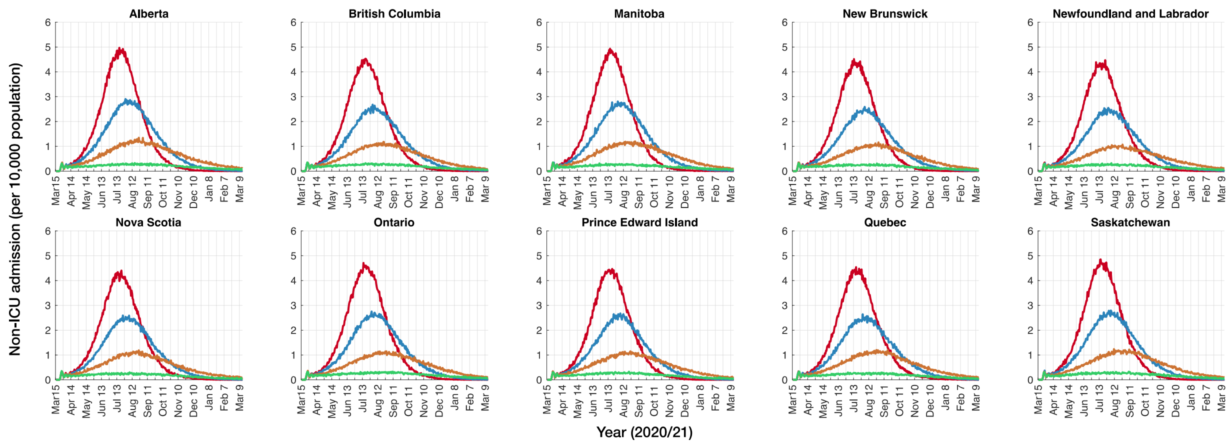

Figure A22. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

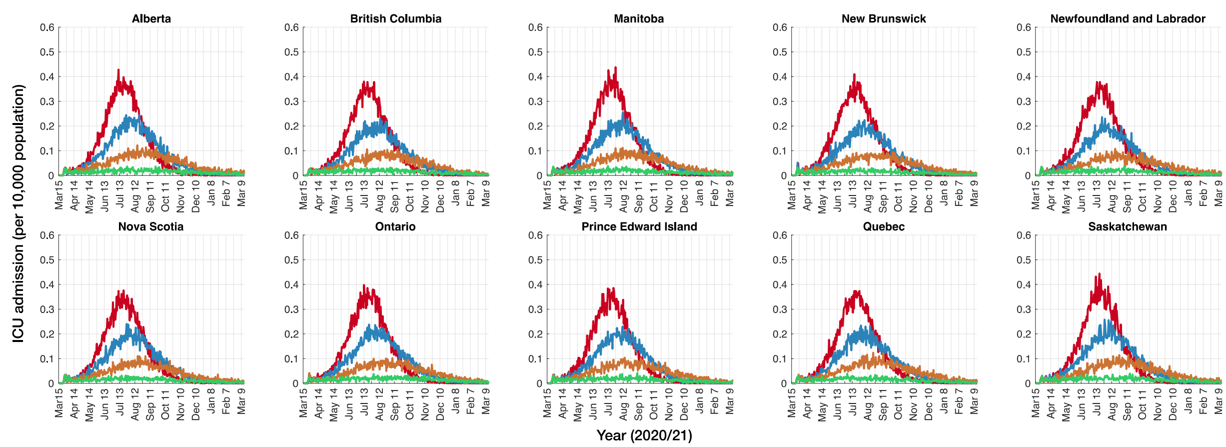

Figure A23. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

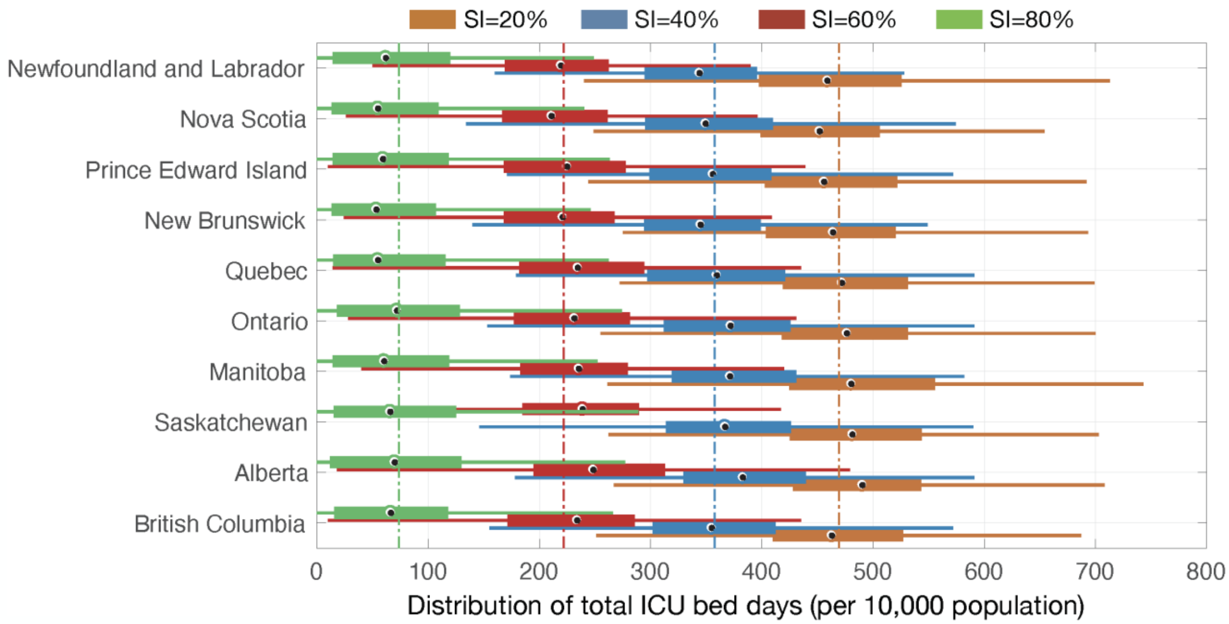

Figure A24. Distribution of the cumulative ICU bed days per 10,000 population during the COVID-19 outbreaks in different provinces with R_0=2.5. Boxplots correspond to the level of self-isolation (SI) among mild symptomatic cases: SI=20% (orange), SI=40% (blue), SI=60% (red), and SI=80% (green). Vertical dashed lines correspond to the average ICU bed days in all provinces with 20% self-isolation (orange line=469), 40% self-isolation (blue line=358), 60% self-isolation (red line=221), and 80% self-isolation (green line=74).

Results for R_0=2

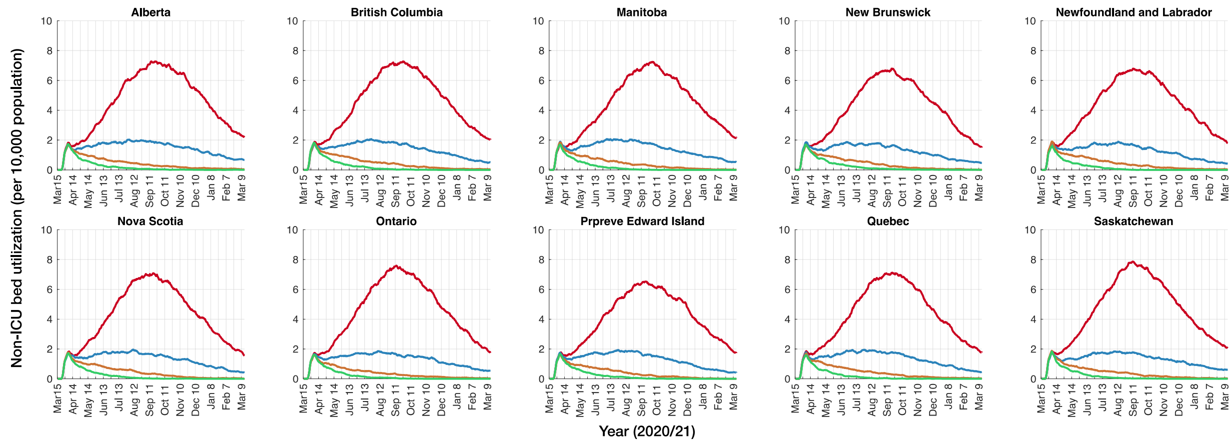

Figure A25. Projected number of non-ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

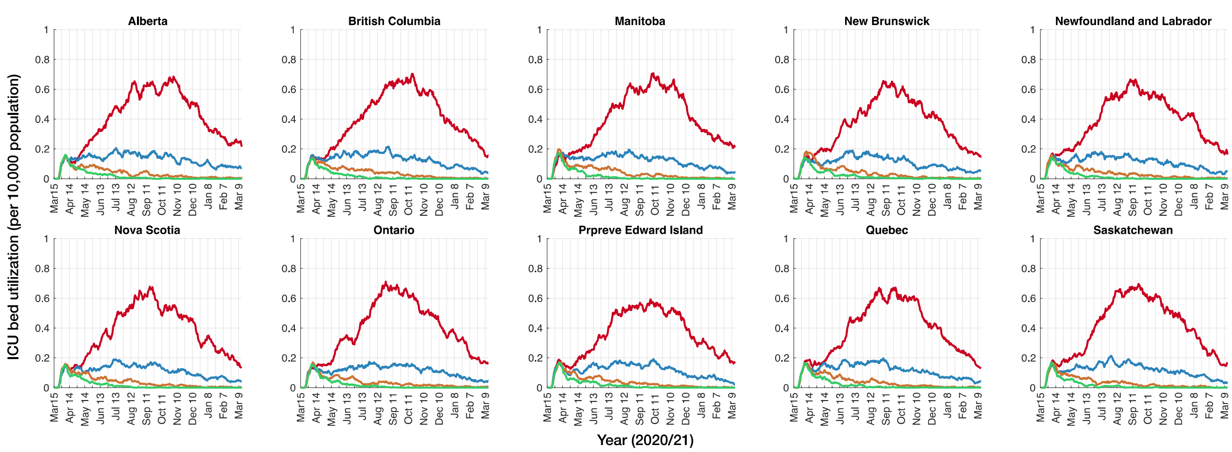

Figure A26. Projected number of ICU bed utilization (per 10,000 population) during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

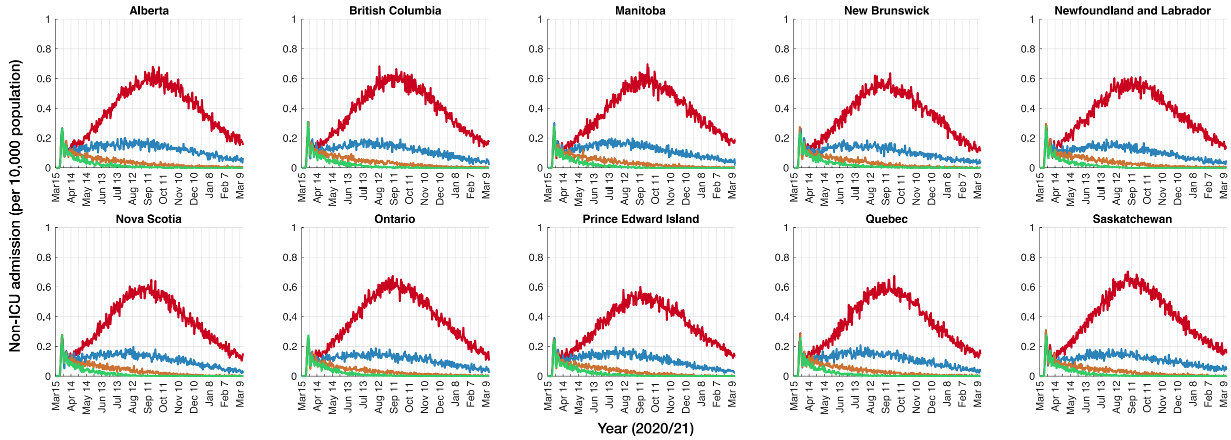

Figure A27. Projected daily incidence (per 10,000 population) of required non-ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

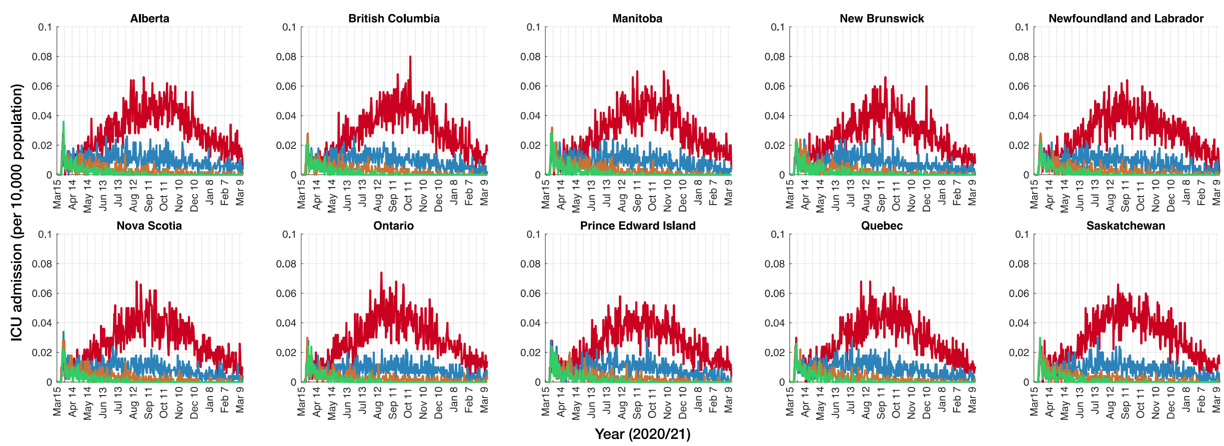

Figure A28. Projected daily incidence (per 10,000 population) of required ICU beds for new patients during COVID-19 outbreaks in each Canadian province. Colour curves correspond to 20% self-isolation (red), 40% self-isolation (blue), 60% self-isolation (orange), and 80% self-isolation (green).

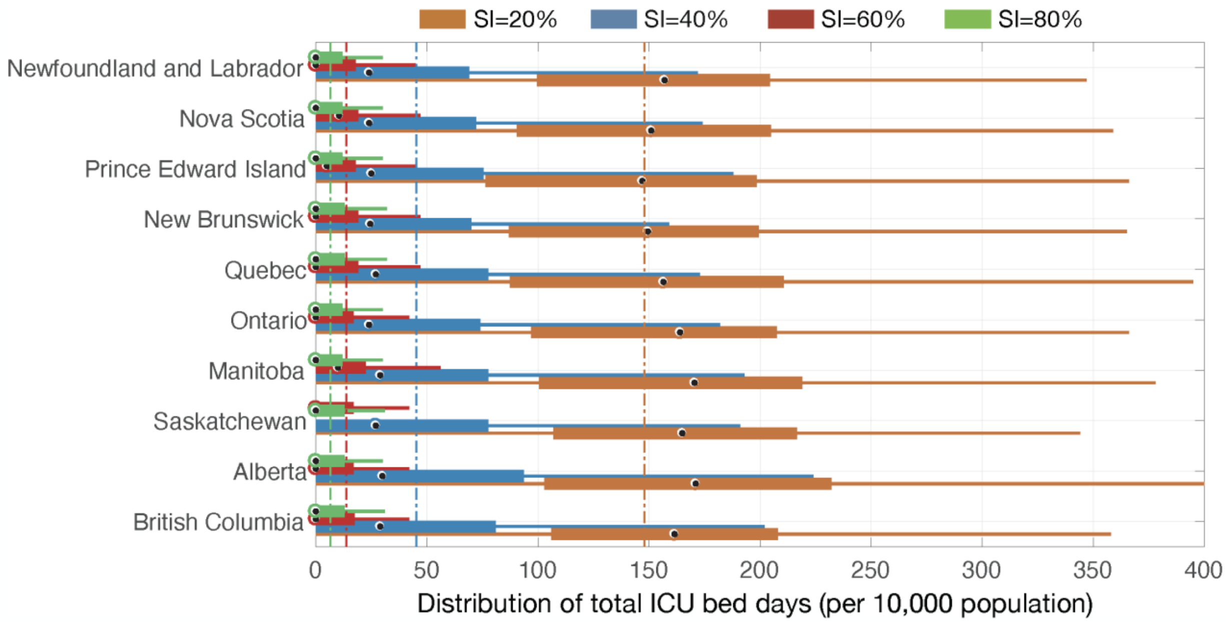

Figure A29. Distribution of the cumulative ICU bed days per 10,000 population during the COVID-19 outbreaks in different provinces with R_0=2.5. Boxplots correspond to the level of self-isolation (SI) among mild symptomatic cases: SI=20% (orange), SI=40% (blue), SI=60% (red), and SI=80% (green). Vertical dashed lines correspond to the average ICU bed days in all provinces with 20% self-isolation (orange line=148), 40% self-isolation (blue line=45), 60% self-isolation (red line=14), and 80% self-isolation (green line=7).

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1. Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) [Internet]. World Health Organization; 16-24 February 2020 [cited 2020 Mar 9]. Available from: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf

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