SARS-CoV-2 (COVID-19) Modeling (Version 3.0)

May 13, 2020 (updated and extended May 18, 2020)

Stefan Gildemeister, State Health Economist

Eva Enns, Associate Professor, School of Public Health | Shalini Kulasingam, Associate Professor, School of Public Health

Overview

- Overview of changes in Version 3 and their impacts
- Three key scenarios/new model capabilities
  - Stay-at-home order
  - Testing
  - CDC criteria for return (and medical advancement)
- Supplemental information

Timeline of Minnesota COVID-19 Model

- Version 1: March 2020
  - Based on early data available at the time
- Version 2: April 2020
  - Included more specifics about Minnesota cases
- Version 3: May 2020
  - Integrates new details and capabilities
- Ongoing model updates planned within available capacity

Introduction

- The University of Minnesota and MDH created the Minnesota COVID-19 model as a tool to inform response strategies and resource planning
- Updated model documentation is available online at Minnesota COVID-19 Modeling (https://mn.gov/covid19/data/modeling) including:
  - References for parameter values
  - Underlying data
  - Model equations governing transitions of the population through COVID-19 health states
- Programming code posted at UMN/MDH Minnesota COVID-19 Modeling Collaboration (https://github.com/MN-COVID19-Model)

Why the Need for New Model Versions?

- COVID-19 remains **in early stages** and new evidence is emerging
- Ongoing model updates are needed to:
  - Reflect the **growing understanding** of COVID-19 transmission and outcomes
  - Incorporate newly emerging **data from the U.S. and Minnesota**
  - Refine projections by fitting model **Minnesota data on observed mortality and hospitalization data**
  - Add **new model capabilities** to illustrate potential mitigation strategies

Data Considerations

- Epidemic and evidence **still very new**
- Extent and impact of **key metrics** uncertain
- Evolving **clinical protocols** with halting dissemination of evidence
- **U.S. case data are limited and incomplete,** affecting availability of robust estimates

Data Considerations (cont.)

Limited U.S. data

- First studies with U.S. patients in late **March and April**
  - 4,226 cases in U.S. study: **outcomes (illness & death) were unknown** for 2,001
  - 5,700 patients hospitalized with COVID-19 in NYC area: **discharge or death status was known for only 46%**
  - Among hospitalized Minnesota COVID-19 patients: **nearly 32% remain in the hospital**

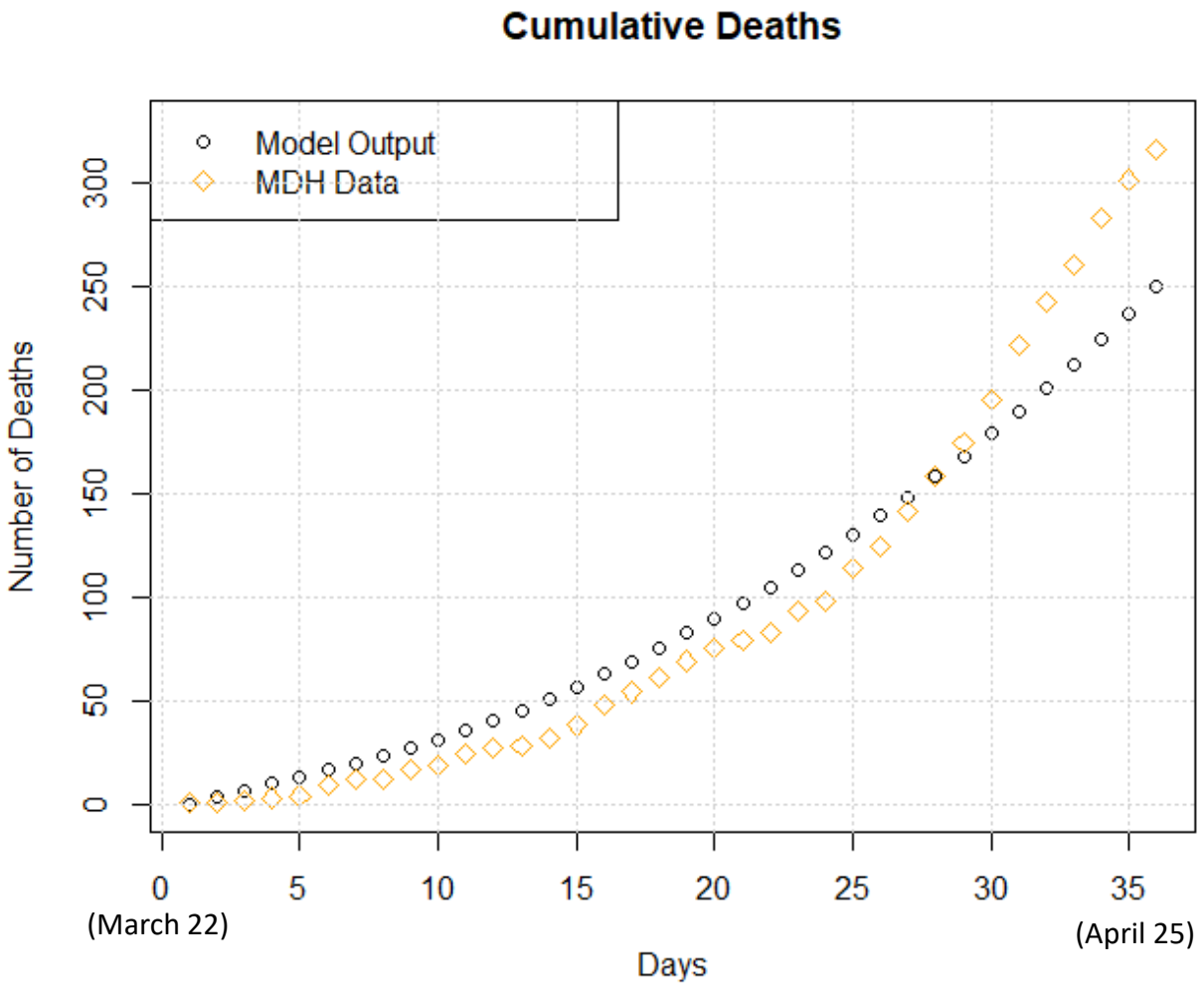
Five Key Changes to Model Version 3

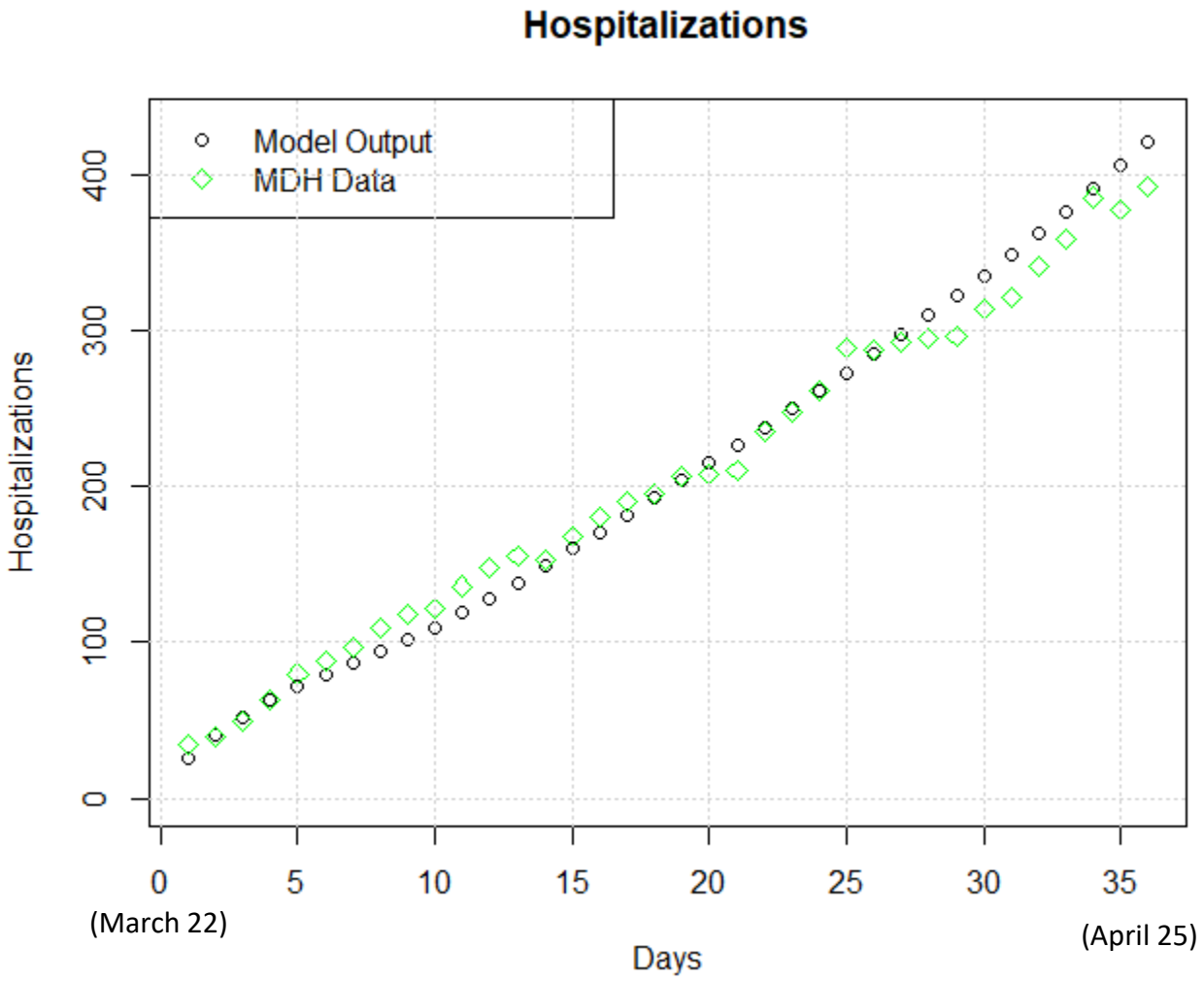
1. Structural changes to address
   - **Asymptomatic** infections
   - Deaths occurring **outside of hospital**
2. Restricted ICU metric to **ventilated cases**
3. Updated parameter estimates using **newly available US data**

Overview of Model Changes in Version 3

4. Estimate uncertain parameters through model calibration, including
   - Proportion of 70+ year-olds **dying in non-hospital settings**
   - **Reduction in contacts** under social distancing and under stay-at-home order
5. Fitted model to Minnesota deaths and hospitalizations through April 25

Model Fit to Observed Cumulative Deaths (through 4/25)





MN COVID-19 Model Version 3: Outputs

What?

- **Less time** to epidemic peak
- Some **upward movement** in estimated total mortality

Why?

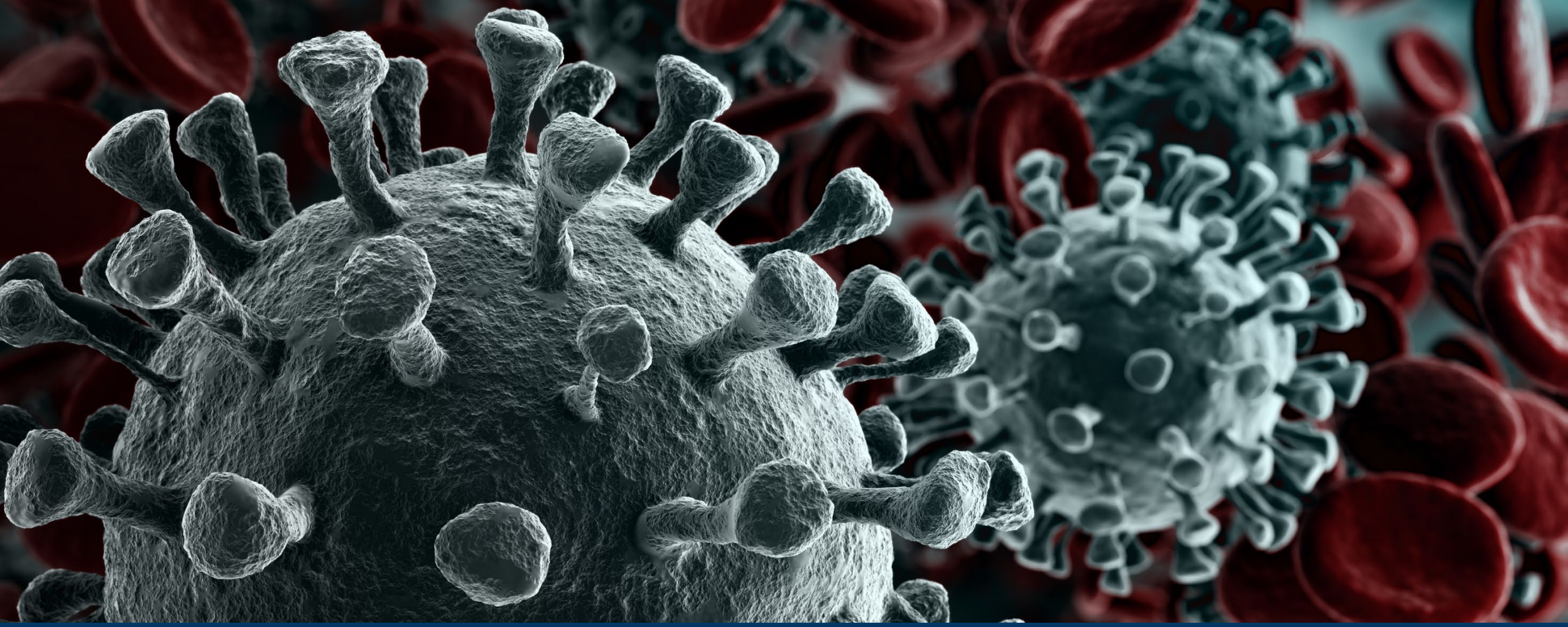
- Calibration to **rising MN deaths**
- **Mitigation less effective** than assumed for:
  - Initial physical distancing (37.6%, not 50%)
  - Stay-at-home order (55.1%, not 80%)
- Changes to **ICU mortality** assumptions & data

Estimates of mitigation effectiveness corrected from presentation on May 13.

Model Changes: "Stay-at-Home Order in Place for 6 Weeks"

Scenario 4*	V 2.0 (incl. uncertainty)	V 3.0 (incl. uncertainty)
Weeks until peak	16 (13 to 21)	13 (11 to 13)
Weeks until ICU capacity reached	16 (13 to 21)	13 (12 to 13)
Top ICU (ventilator) demand	3,700 (2,700 to 4,900)	3,600 (2,000 to 5,200)§
Mortality (cumulative for 12 months)	21,800 (9,900 to 36,000)	29,000 (16,000 to 44,000)
Mortality (through end of May)	N/A	1,700 (1,400 to 2,000)

*Stay-at-Home order in place for a total of 6 weeks (through: May 8, 2020), followed by physical distancing and longer-term stay-at-home recommendation for most vulnerable; § Assuming no ICU capacity constraints



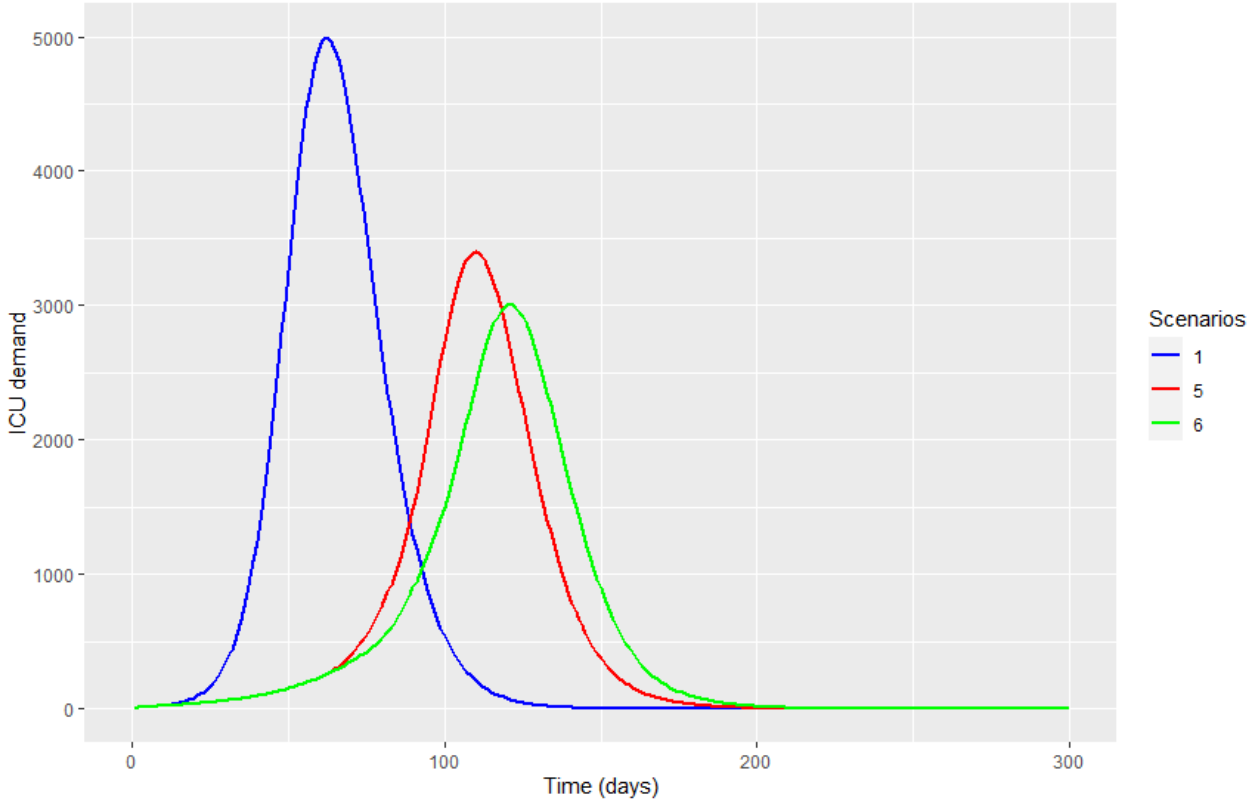
Scenarios & Model Capabilities: An Illustration of Trade-offs

Status Update (May 11, 2020)

- Model-derived estimates:
  - R_t (April 11 through April 25): 1.88
  - Cumulative detection rate: 5.15 percent
  - Percent ever infected: 4.84 percent
- Estimates from case counts:
  - Doubling rate: 19.9 days
  - Community transmission (no known contact): 30.8%

Doubling rate is three-day moving average. Full reporting has five- to seven-day data lag. Community transmission among cases with exposure determined through case interviews; it represents a seven-day average.

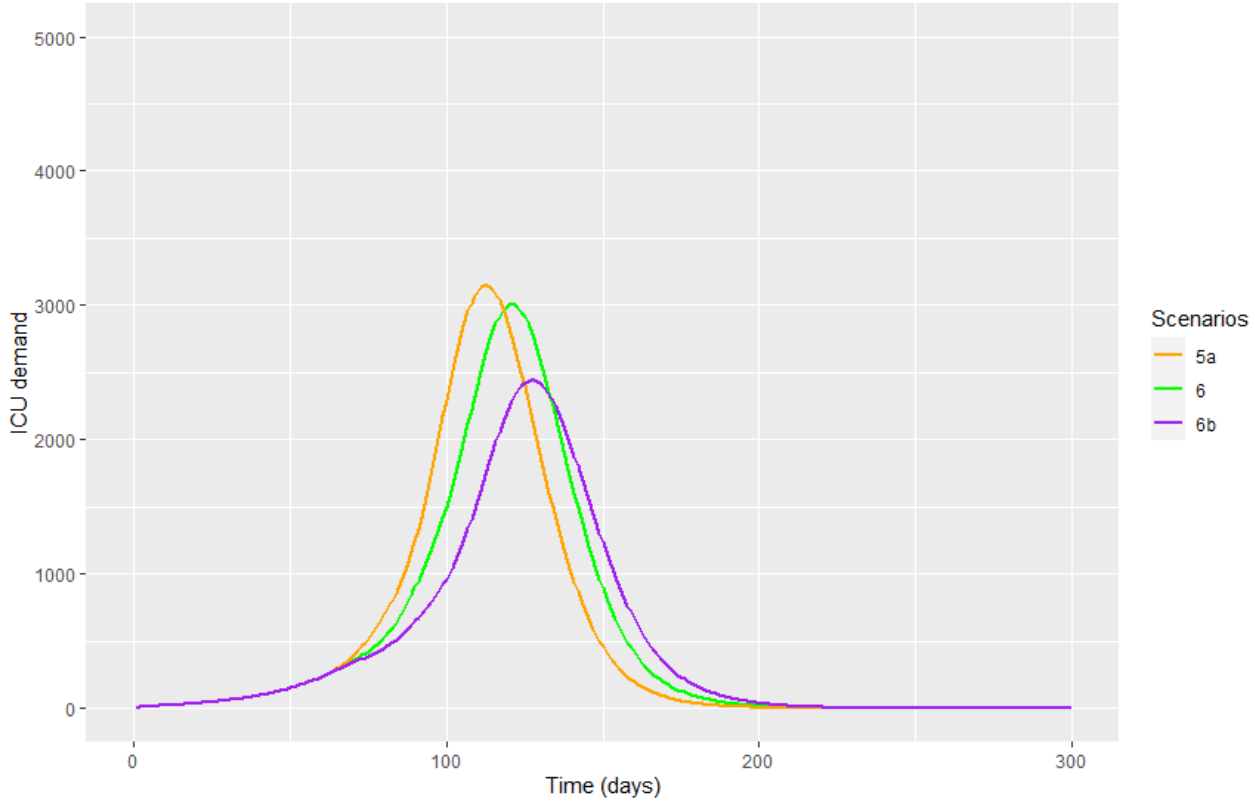
Unmitigated and Extended Stay-at-Home Orders



	Scenario 1 Unmitigated (blue)	Scenario 5 SHO till 5/18 (red)	Scenario 6 SHO till 5/31 (green)
Date of peak infection	May 11	June 29	July 6
Top ICU/vent demand	4,991	3,397	3,006
Mortality (full year)	57,035	29,030	28,231
Mortality (thru May)	42,032	1,441	1,388

Stay-at-home order followed by three weeks physical distancing (reduction of contacts by 37.6%) and ongoing stay-at-home recommendation for most vulnerable (50%).

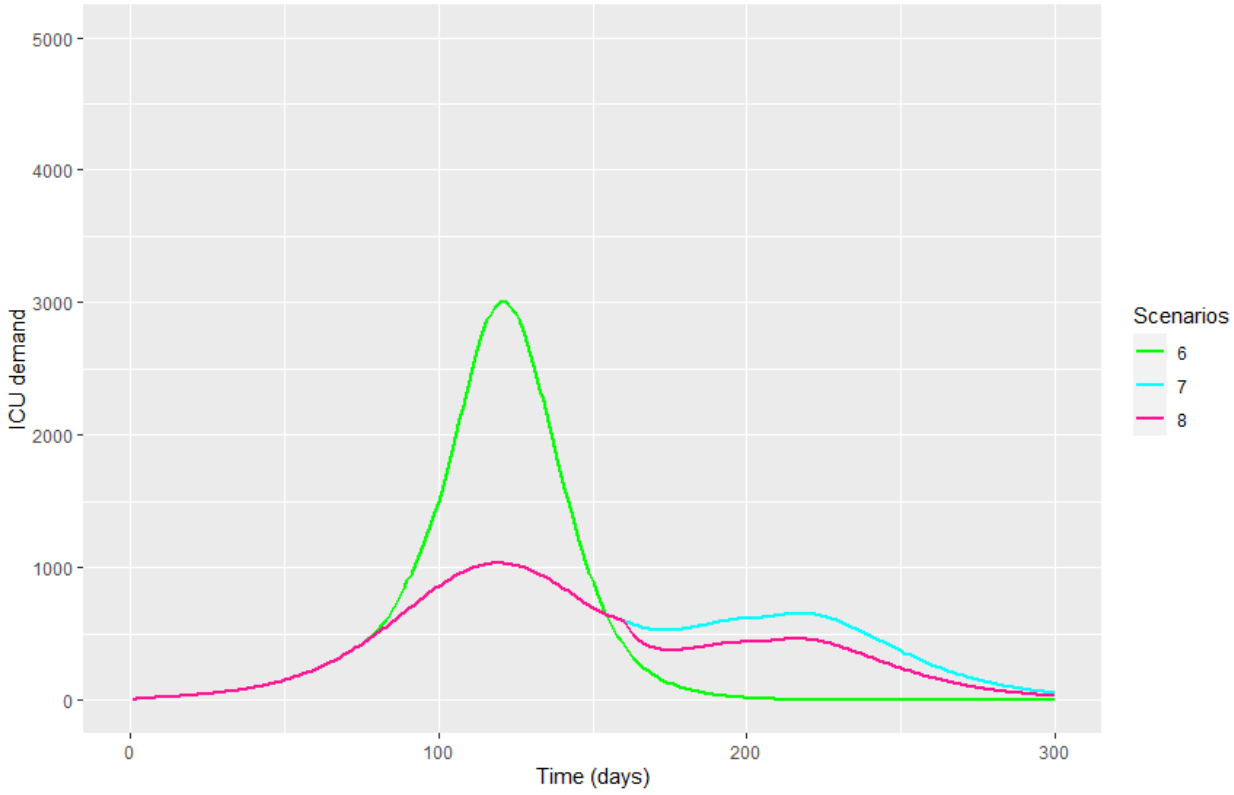
Extended Stay-at-Home Orders & Testing



	Scenario 6 SHO till 5/31 (green)	Scenario 5a worst testg: 70% sens 10k tests (orange)	Scenario 6b best testg: 95% sens 20k tests (purple)
Date of peak infection	July 6	June 29	July 13
Top ICU/vent demand	3,006	3,150	2,444
Mortality (full year)	28,231	26,914	22,589
Mortality (thru May)	1,388	1,430	1,375

At this point the impact of testing applies only to tested individual by reducing their rate of contact (assuming isolation for confirmed positive cases); tests are distributed to "I" states and non-"I" states, through probabilities of testing access.
Reduced contact through contact tracing is currently not built into the model.

Extended Stay-at-Home Order, CDC Guidelines for "Opening Up" and Medical Advancement



	Scenario 6 SHO till 5/31 (green)	Scenario 7 CDC Opening (aqua)	Scenario 8 CDC Opening + Tx (pink)
Date of peak infection	July 6	July 6	July 6
Top ICU/vent demand	3,006	1,034	1,034
Mortality (full year)	28,231	26,294	25,392
Mortality (thru May)	1,388	1,388	1,388

Source: Guidelines: Opening Up America Again, White House/CDC, slide deck; assumes downward trajectory of hospitalizations for 14 days following the peak (or through Sept. 7, 2020). [Guidelines: Opening Up America Again (https://www.whitehouse.gov/openingamerica/) 5/8/2020, 11:43:00PM]
Rx treatment (Tx) only for hospitalized patients, 30% reduction in LOS & mortality

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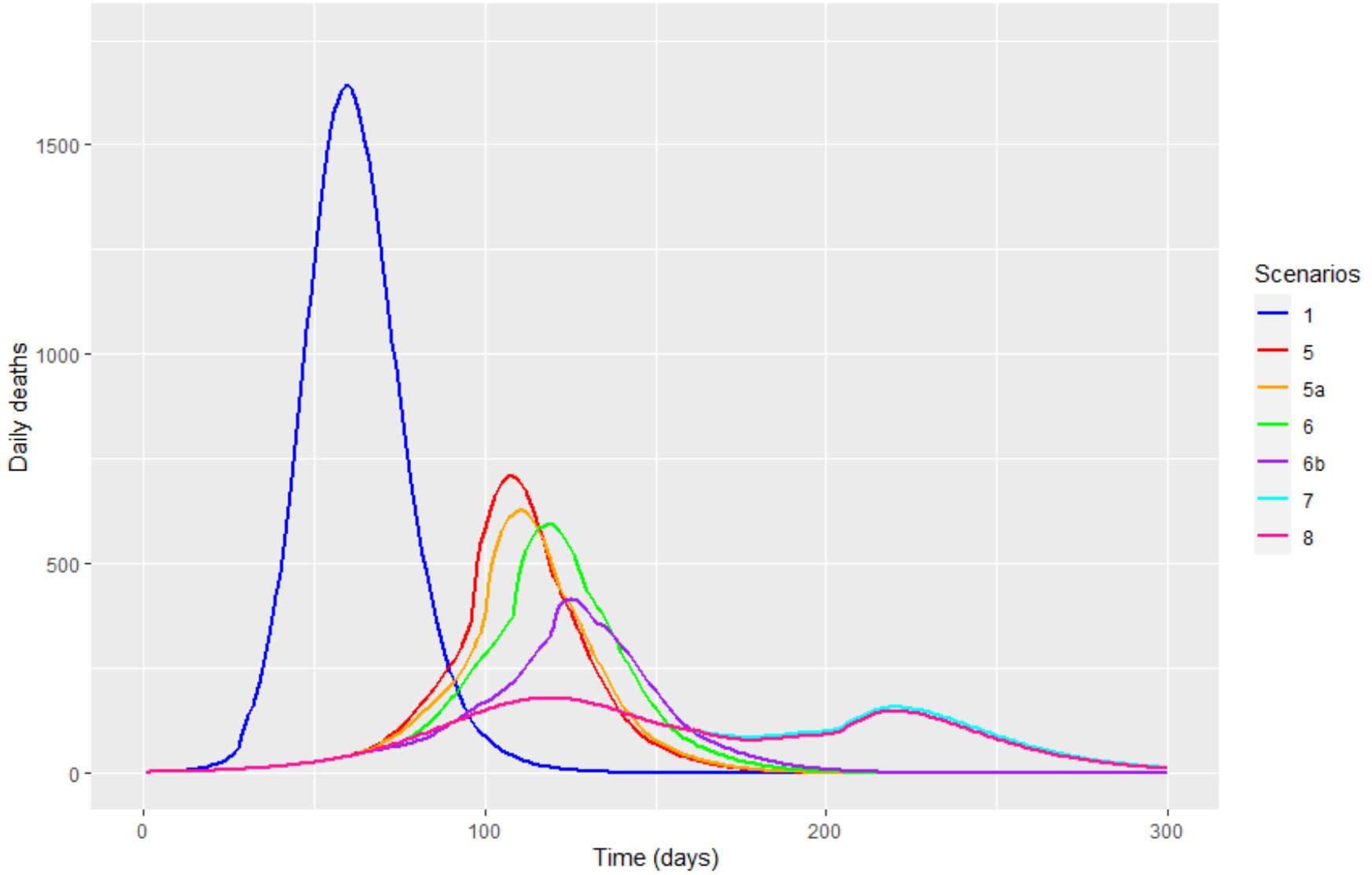
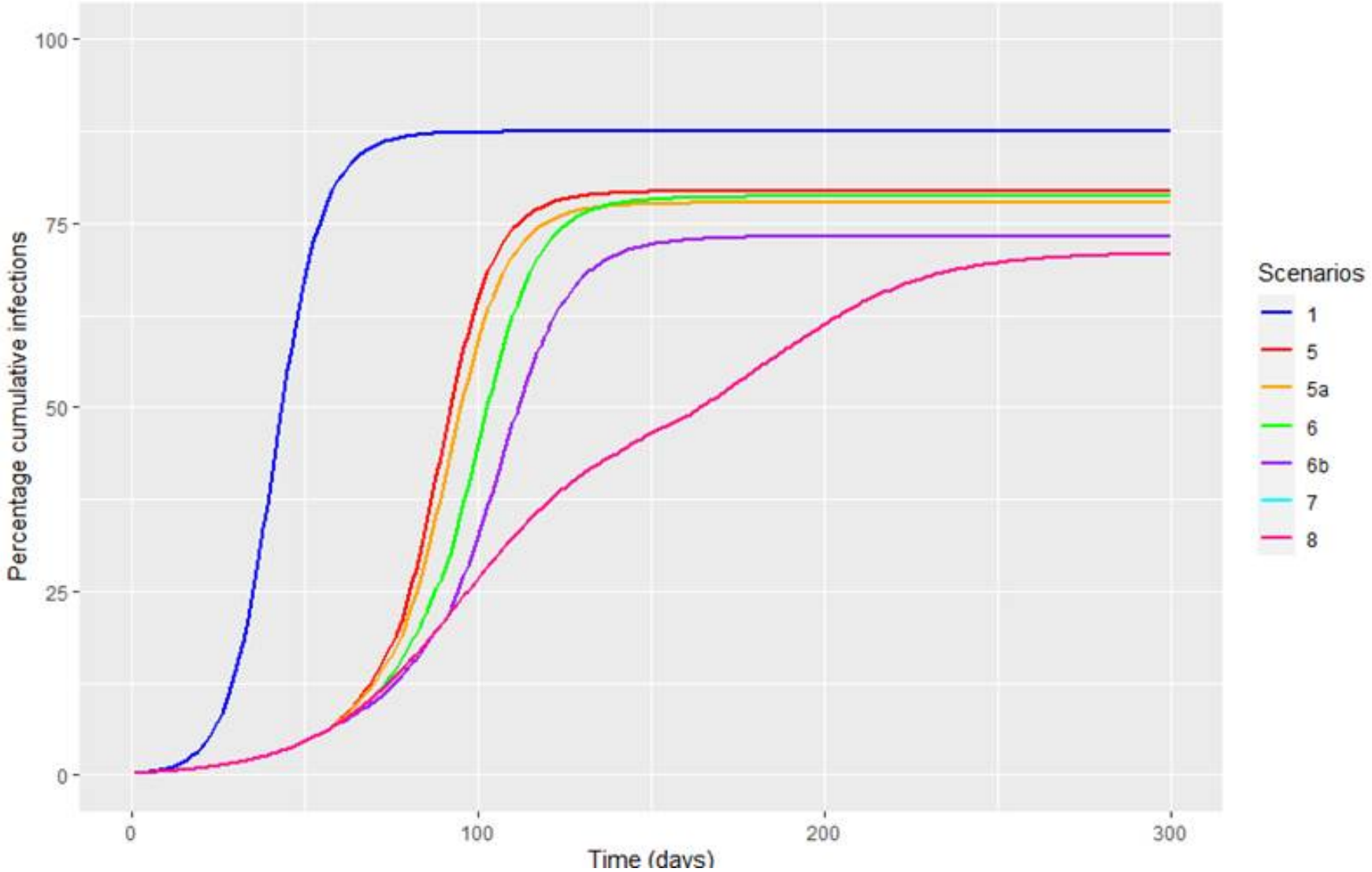
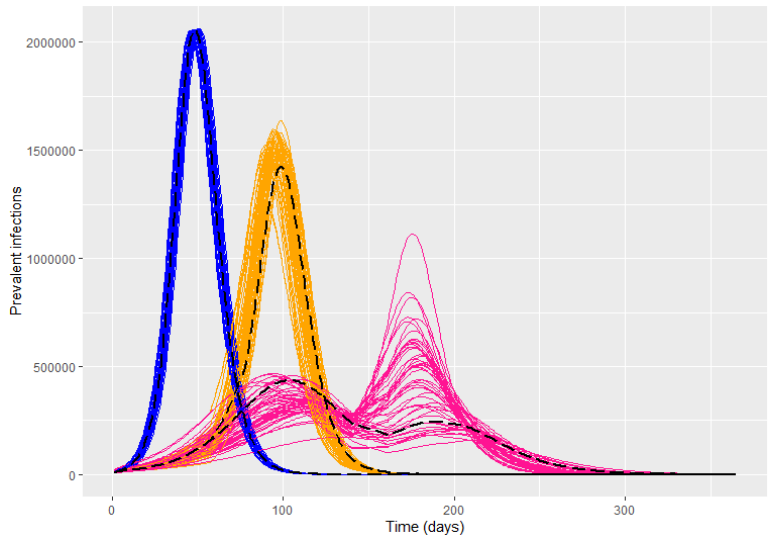
Daily Deaths – All Scenarios

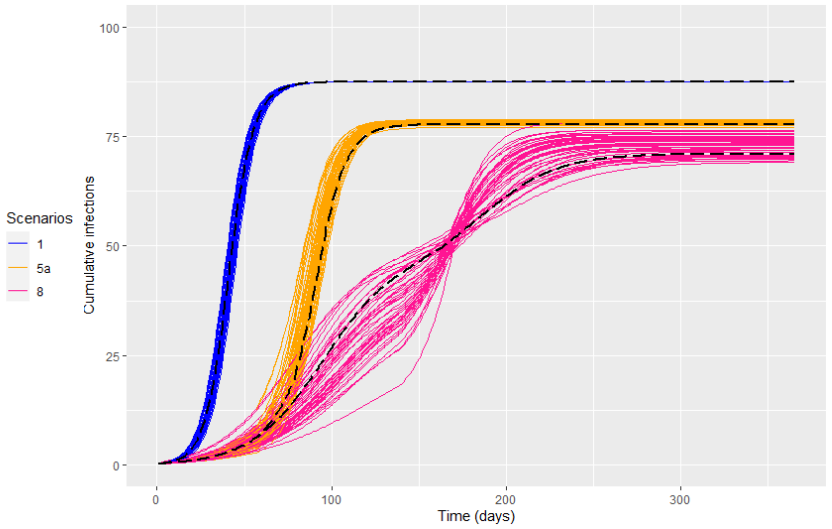


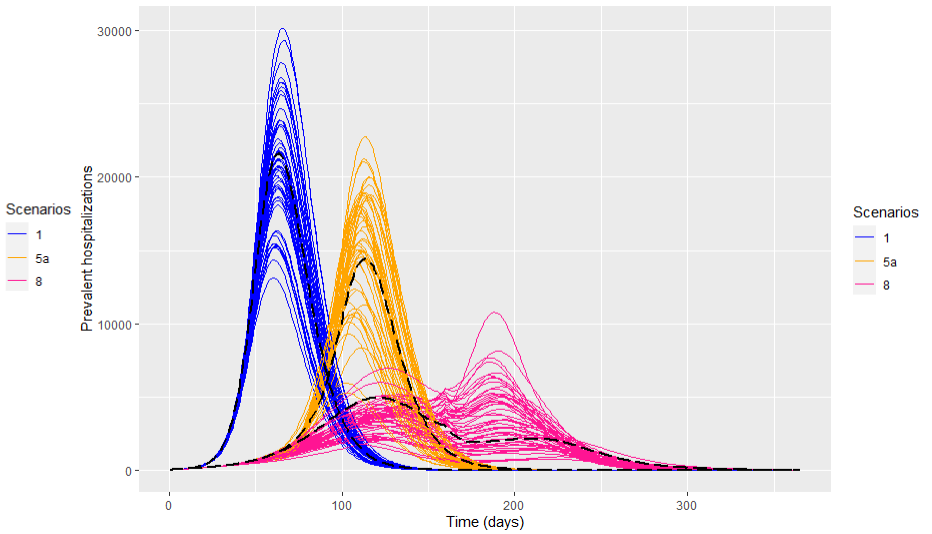
Cumulative Infections – All Scenarios

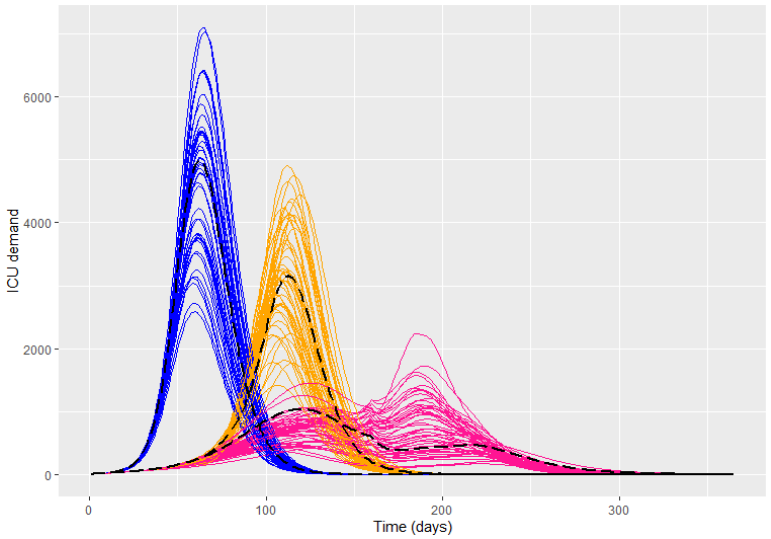


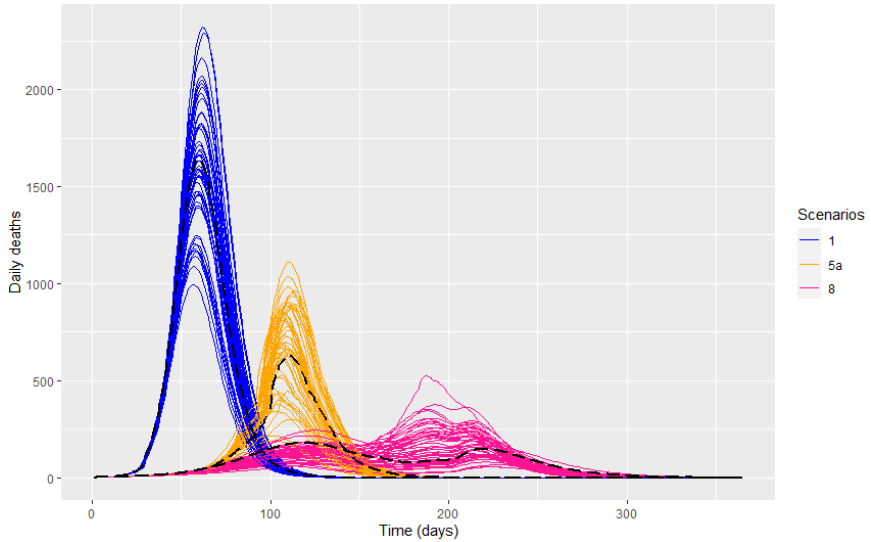
Uncertainty Estimates for Key Model Outcomes











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Consideration for Next Steps

- More and better data from U.S. epidemic
- Refined scenarios
  - Treatment: evidence on home treatment
  - Testing: incorporate impact of contact tracing
- Enhancements: cycling mitigation

Thank You!

University of Minnesota School of Public Health
Eva Enns (eenns@umn.edu) | Shalini Kulasingam (kulas016@umn.edu)
Media: unews@umn.edu

Minnesota Department of Health
Stefan Gildemeister (Stefan.Gildemeister@state.mn.us)
Media: health.media@state.mn.us

More on COVID-19 in MN
Coronavirus Disease in Minnesota (mn.gov/covid19/) | Minnesota COVID-19 Modeling (https://mn.gov/covid19/data/modeling.jsp)

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Scenarios with Uncertainty Estimates

Scenarios	Unmitigated (1)	Stay-at-home until 5/18 (5)	Stay-at-home until 6/1 (6)	Stay-at-home until 5/31 – 20k tests per day, 95% sens (6b)	Stay-at-home until 5/18, 10k tests per day/75% sens (5a)	CDC reopening strategy (7)	CDC reopening strategy + medical advancement (8)
Weeks until Peak (range)	7 (6 to 7) May 11, 2020	14 (13 to 14) June 29, 2020	15 (14 to 16) July 6, 2020	16 (15 to 17) July 13, 2020	14 (13 to 15) June 29, 2020	15 (13 to 26) July 6, 2020	15 (13 to 26) July 6, 2020
Weeks until ICU capacity reached (range)	4 (4 to 4) April 20, 2020	14 (13 to 15) June 29, 2020	15 (14 to 16) July 6, 2020	17 (16 to 18) July 20, 2020	14 (13 to 15) June 29, 2020	Does not reach capacity (24 to 27)	Does not reach capacity (25 to 26)
Top ICU Demand (range)	4,991 (2,761 to 6,928)	3,397 (1,875 to 5,039)	3,006 (1,577 to 4,739)	2,444 (1,223 to 3,667)	3,150 (1,719 to 4,644)	1,034 (547 to 2,520)	1,034 (480 to 1,822)
Mortality – 1 year (range)	57,035 (31,036 to 79,580)	29,030 (15,726 to 43,868)	28,231 (15,834 to 43,152)	22,589 (12,903 to 32,012)	26,914 (14,804 to 40,608)	26,294 (14,617 to 37,269)	25,392 (14,044 to 35,179)
Mortality – end of May (range)	42,032 (24,736 to 53,908)	1,441 (1,082 to 1,554)	1,388 (988 to 1,494)	1,375 (980 to 1,481)	1,430 (1,069 to 1,543)	1,388 (988 to 1,494)	1,388 (988 to 1,494)
Percentage of population infected – 1 year (range)	87.5% (87.4% to 87.5%)	79.4% (79.0% to 80.4%)	78.7% (77.9% to 80.3%)	73.3% (70.8% to 75.7%)	77.8% (77.1% to 78.9%)	71.0% (69.3% to 76.5%)	71.0% (69.3% to 76.5%)

Input Parameters

Parameter	V1	V2	V3
Unmitigated basic reproduction number (R0)	2.38	3.87	3.87
Transmission probability (per contact between infected/susceptible persons)	0.009¶	0.035◆ (0.025-0.045)	0.0295◆
Latent period	5 days	5 days	5.2 days
Infectious period	8 days	8 days	7.8 days
ICU duration	22.6 days	10.3 days	8 days
Hospitalization duration	8 days	13.3 days	11 days
Increased mortality factor with ≥ 1 comorbidity	7.6	7.6	1.0 (not used)
Increased mortality factor if ICU capacity exceeded	1.5 to 16.5	1.5 to 16.5	Assume death
Hospitalized cases requiring ICU (age ranges)	5.0% to 70.9%	5.0% to 70.9%	11.9% to 29.6%*
ICU mortality rate (age ranges)	0.000 to 0.111	0.000 to 0.111	0.0005 to 0.779§

¶ Corresponds to an R0 of 2.38; ◆Corresponds to an R0 of 3.87; * Restricted to ventilated cases
§ Probability of dying

Model Parameters Estimated Through Calibration

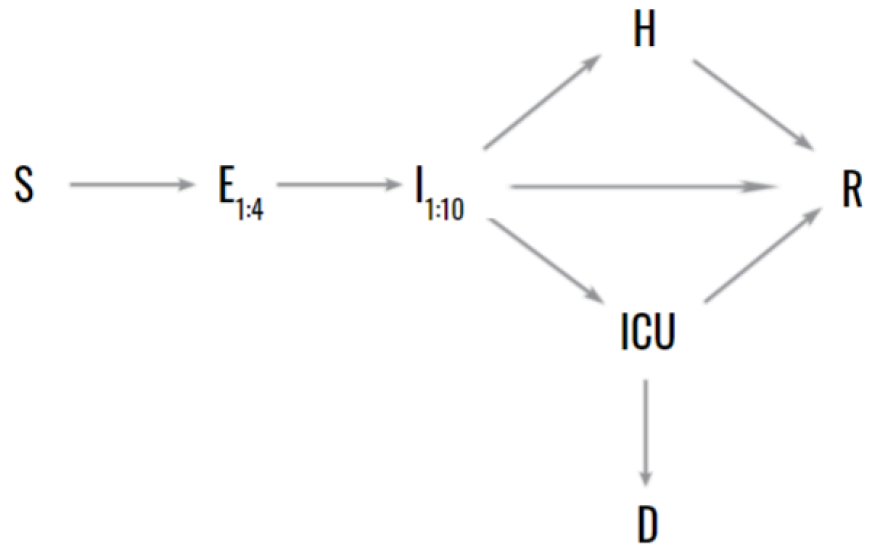
Parameter	V1	V2	V3
Proportion of cases detected prior to start of model simulation*	0.119 (input)	0.01	0.021
Hospitalized infections (age ranges)	0.1% to 27.3%	0.1% to 27.3%	10.3%**
Proportion of people aged 70 or older with a symptomatic infection die at home	N/A	N/A	0.139
Proportion of infections which are mild or asymptomatic	0.0 (input)	0.25 (input)	0.41
Estimated contact reduction caused by the social distancing	0.5 (input)	0.5 (input)	37.6%
Estimated contact reduction caused by the stay-at-home order	0.8 (input)	0.8 (input)	55.1%

*Case detection rate only used for model initialization

**Calculate age-specific hospitalization probabilities, prop hosp, the relative proportion of symptomatic cases by age is multiplied by the calibrated values for the probability of 80+ year-olds who are hospitalized.

Model Structure

V1 and V2



S-Susceptible

E-Exposed

I-Infected

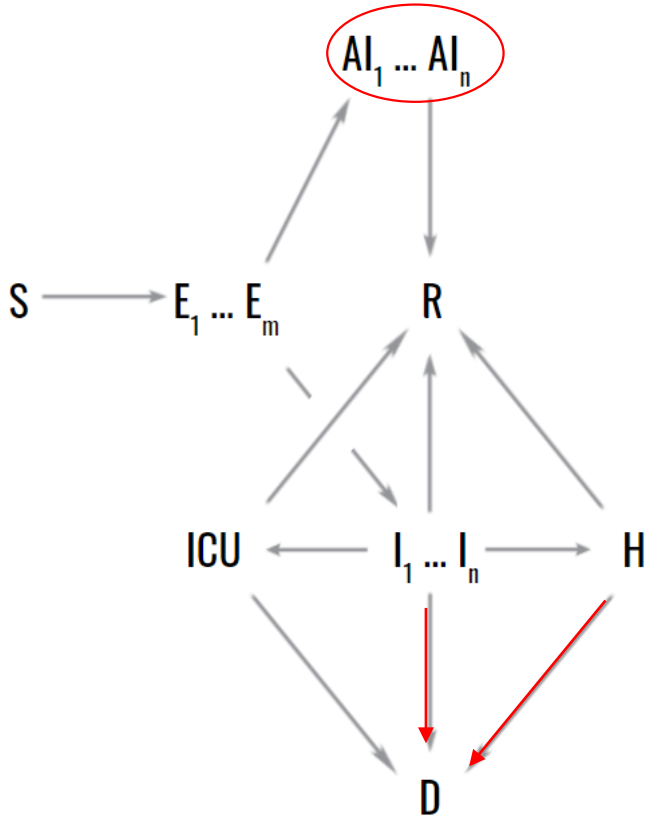
H-Hospitalized

ICU-In ICU

R-Recovered

D-Dead

V3



S-Susceptible

E-Exposed

AI-Asymptomatic Infection

I-Infected

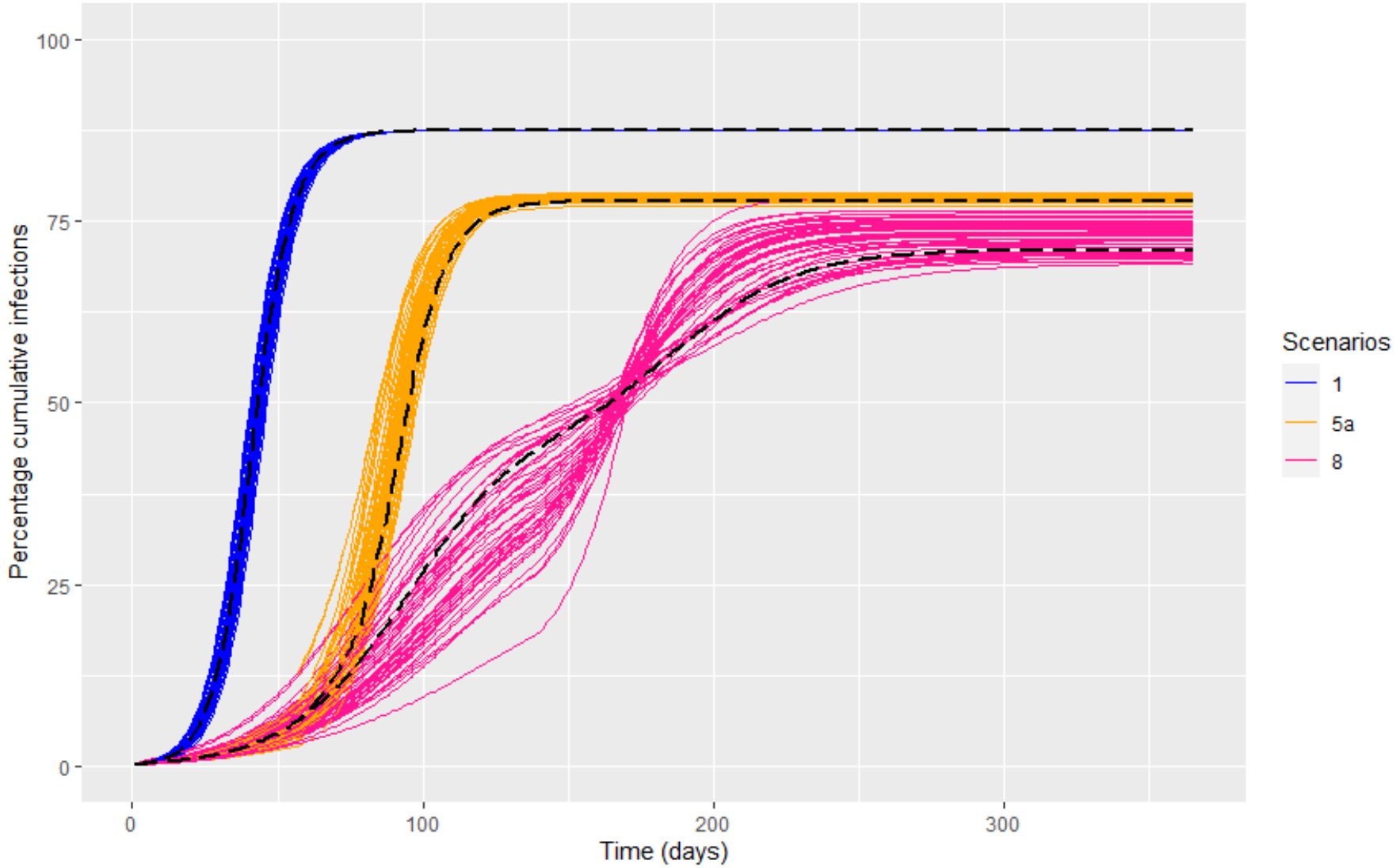
H-Hospitalized

ICU-ICU Eligible

R-Recovered

D-Dead

Uncertainty - Percentage Cumulative Infections



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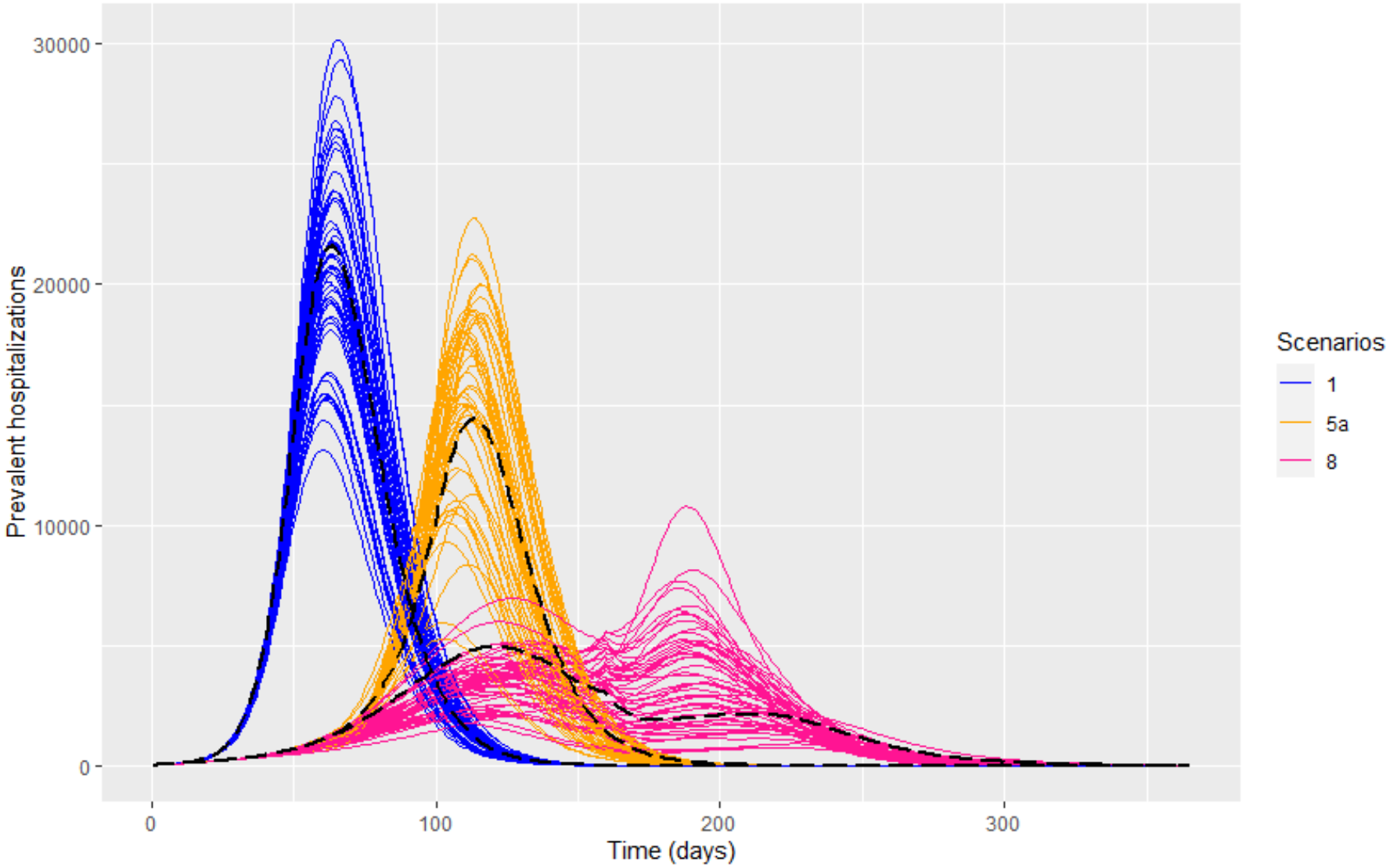
Uncertainty – Prevalent Hospitalizations



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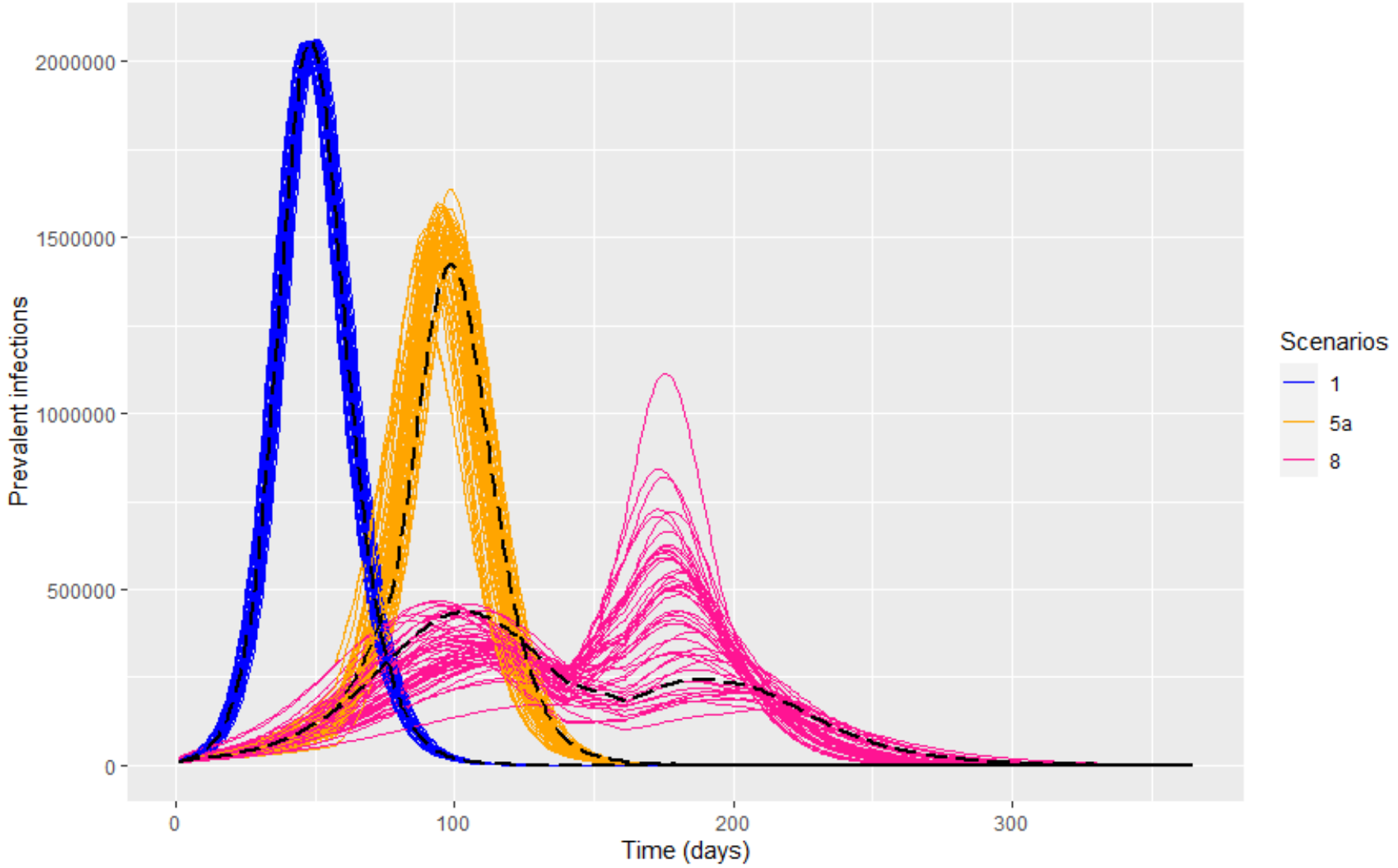
Uncertainty – Prevalent Infections



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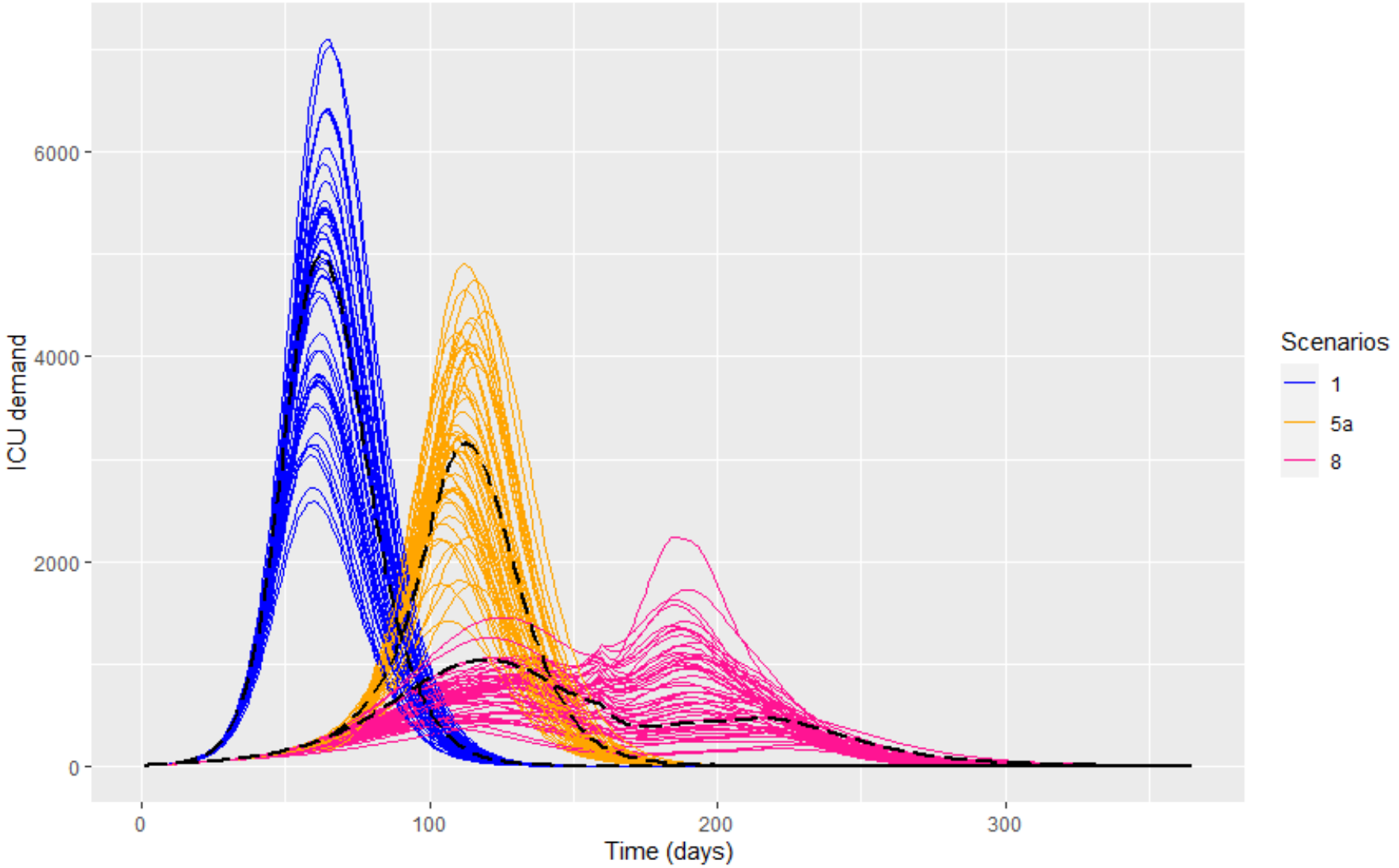
Uncertainty – ICU Demand



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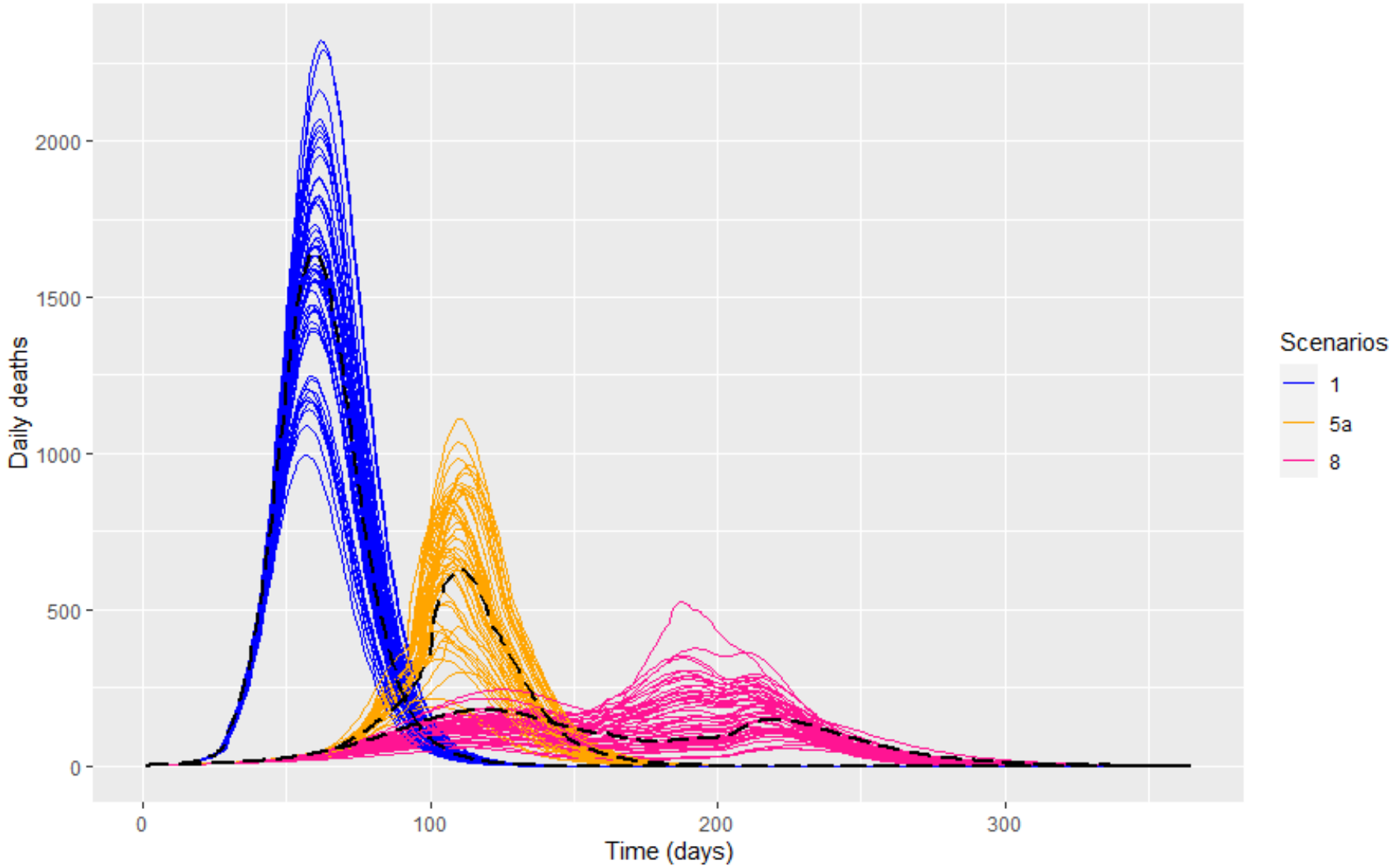
Uncertainty – Daily Deaths



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