Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

April 13, 2020

(data current to April 11, 2020)

Biocomplexity Institute Technical report: TR-2020-048

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Who We Are

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response and support for Influenza, Ebola, Zika, others
- COVID-19 researchers on today's panel

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Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections through the end of summer
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.

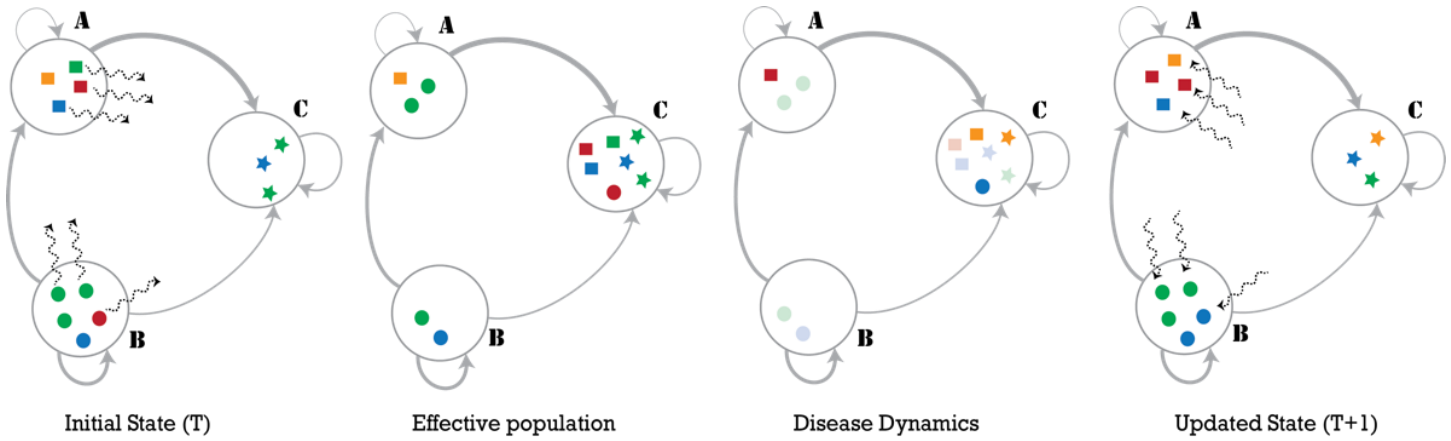
Even without perfect projections, we can confidently draw conclusions:

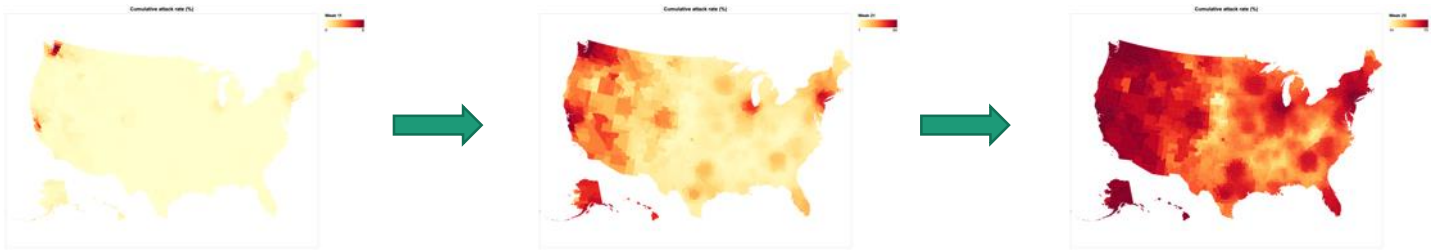
- **Current social distancing efforts are working.**
- Under current conditions, Virginia *as a whole* will have sufficient medical resources for at least the next couple months.
- Lifting social distancing restrictions too soon can lead quickly to a second wave.
- Further modeling could elucidate the effectiveness of test-trace-isolate policies.
- The situation is changing rapidly. Models will be updated regularly.

Model Configuration and Data Analysis

Simulation Engine – PatchSim

- Metapopulation model
  - Represents each population and its interactions as a single patch
  - 133 patches for Virginia counties and independent cities
- Extended SEIR disease representation
  - Includes asymptomatic infections and treatments
- Mitigations affect both disease dynamics and population interactions
- Runs fast on high-performance computers
  - Ideal for calibration and optimization





Venkatramanan, Srinivasan, et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

Model Configuration

- **Transmission:** parameters are calibrated to the observed case counts
  - **Reproductive number:** 2.1 - 2.3
  - **Infectious period** (time of infectiousness before full isolation): 3.3 to 5 days
- **Initial infections:** Start infections from confirmed cases by county
  - Timing and location based on onset of illness from VDH data
  - Assume 15% detection rate, so one confirmed case becomes ~7 initial infections
- **Mitigations:** Duration and intensity of mitigations into the future are unknowable, thus explored through 5 scenarios

Mitigation Scenarios

- **Consider 5 possible futures**
  - Two levels of intensity with two durations and one with no effect
- **Start of social distancing:** March 15th, as measured from VDH data
- **Duration:** Lift on April 30th or lift on June 10th
- **Intensity of mitigation:**
  Slowing growth vs. Pausing growth
  - **Slowing –** Social distancing slows the growth, but new cases do increase
  - **Pausing –** Social distancing pauses growth, keeping new cases steady
  - Pausing scenarios track the data better

Duration (lift date)	Intensity	Short Name	Description
Apr 30th	Slowing	Slow - Apr30	Slowing intensity, lift April 30th
June 10th	Slowing	Slow - Jun10	Slowing intensity, lift June 10th
Apr 30th	Pausing	Pause – Apr30	Pausing intensity, lift April 30th
June 10th	Pausing	Pause – Jun10	Pausing intensity, lift June 10th
None	Unmitigated	Unmitigated	No effect of social distancing

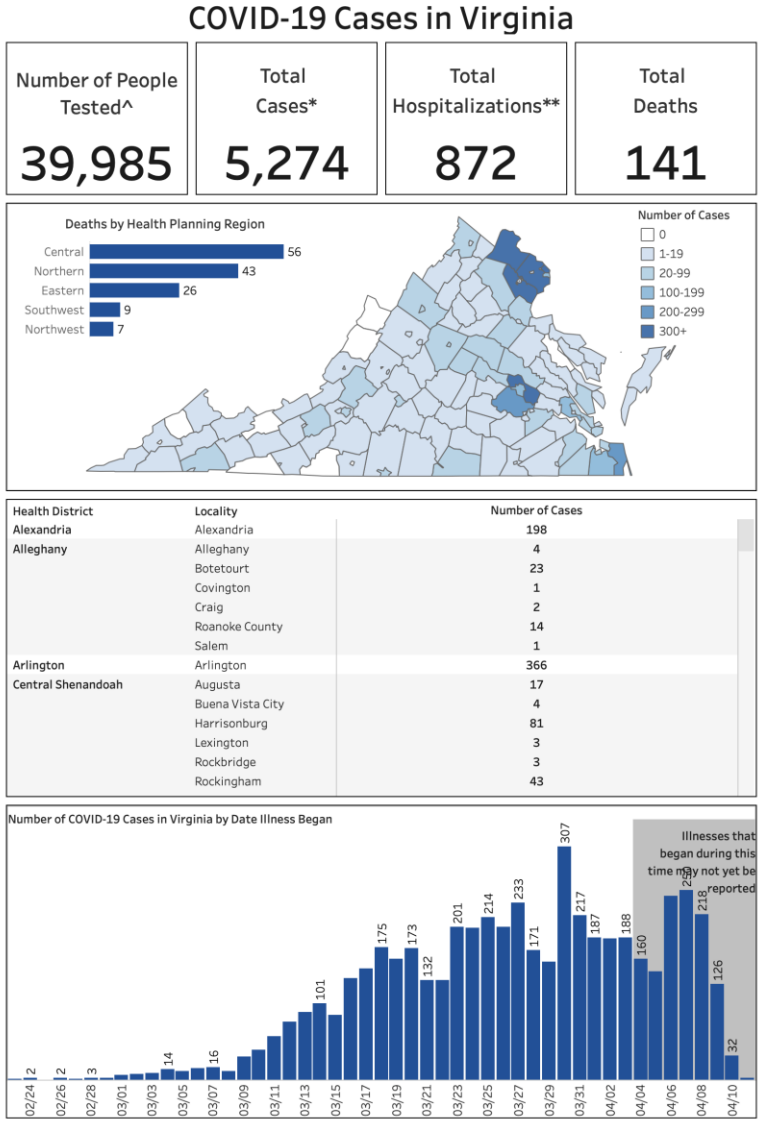
Full Parameters

Parameter	Estimated Values	Description [Source]
Transmissibility (R0)	2.2 [2.1 – 2.3]	Reproductive number *
Incubation period	5 days	Time from infection to Infectious *
Infectious period	3.3 - 5 days	Duration of infectiousness *
Proportion asymptomatic	50%	Proportion of infections that don't exhibit symptoms *
Proportion hospitalized	5.5% (~20% of confirmed)	Symptomatic Infections becoming Hospitalized *
Proportion in ICU	20%	Hospitalized patients that require ICU *
Proportion ventilated	70%	Proportion of ICU requiring ventilation *
Onset to hospitalization	5 days	Time from symptoms to hospitalization *
Hospitalization to ventilation	3 days	Time from hospitalization to ventilation *
Duration hospitalized	10 days	Time spent in the hospital
Duration ventilated	14 days	Time spent on a ventilator †
Infection detection rate	15%	One confirmed case becomes ~7 initial infections #

* CDC COVID-19 Modeling Team. "Best Guess" scenario. Planning Parameters for COVID-19 Outbreak Scenarios. Version: 2020-03-31.
† Up-to-date. COVID-19 Critical Care Issues. https://www.uptodate.com/contents/coronavirus-disease-2019-covid-19-critical-care-issues?source=related_link
# Li et al., *Science* 16 Mar 2020:eabb3221 https://science.sciencemag.org/content/early/2020/03/24/science.abb3221

Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Model:** PatchSim initialized with disease parameter ranges from literature
- **Calibration:** fit model to observed data
  - Search transmissibility and duration of infectiousness
  - Markov Chain Monte Carlo (MCMC) particle filtering finds best fits while capturing uncertainty in parameter estimates
- **Project:** future cases and outcomes using the trained particles



Accessed 1pm April 12, 2020

https://public.tableau.com/views/VirginiaCOVID-19Dashboard/VirginiaCOVID-19Dashboard

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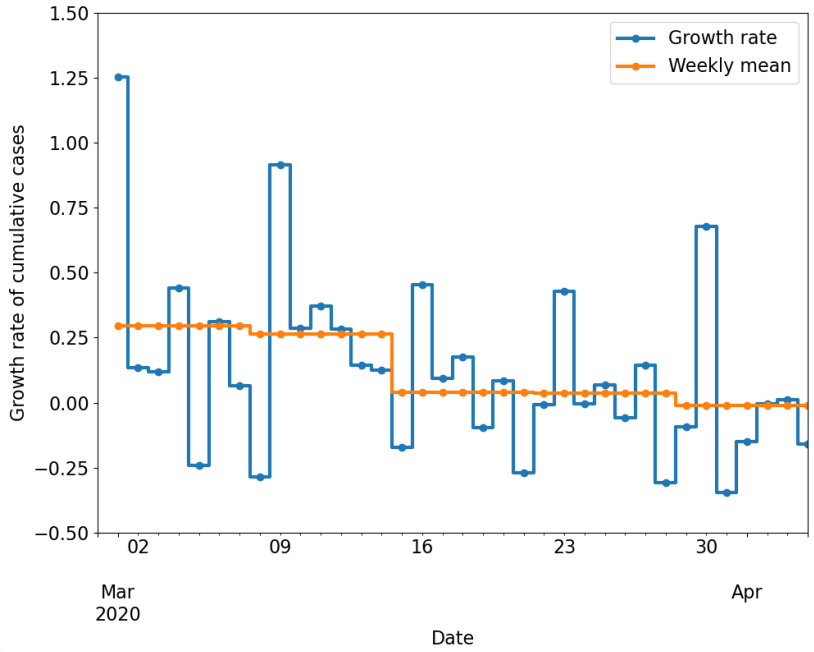
Impact of Interventions

Estimating Effects of Social Distancing

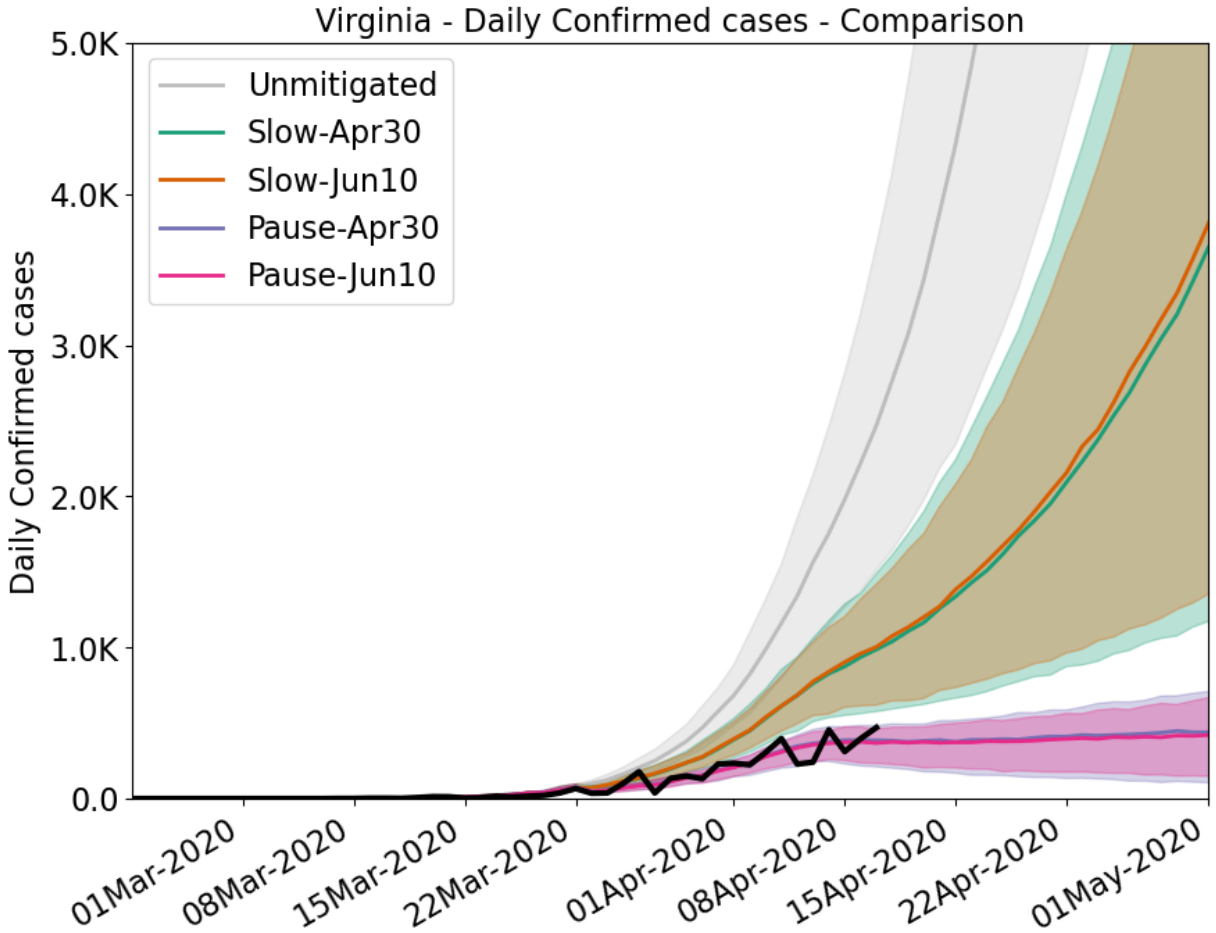
- **Anonymized open mobility data shows Virginia greatly reduced activities**
  - Google: -44% retail & recreation, -18% grocery stores, -39% workplaces
  - Cuebiq: >50% reduction of average individual mobility compared to Year Avg.
- **VDH data shows reductions in growth rate starting in mid-March**
  - Weekly average growth rate by date of onset
    - Week before March 15 = 0.3
    - Week after March 15 = 0.03
  - Equivalent reproductive number change
    - 2.2 before March 15th
    - 1.1 after March 15th



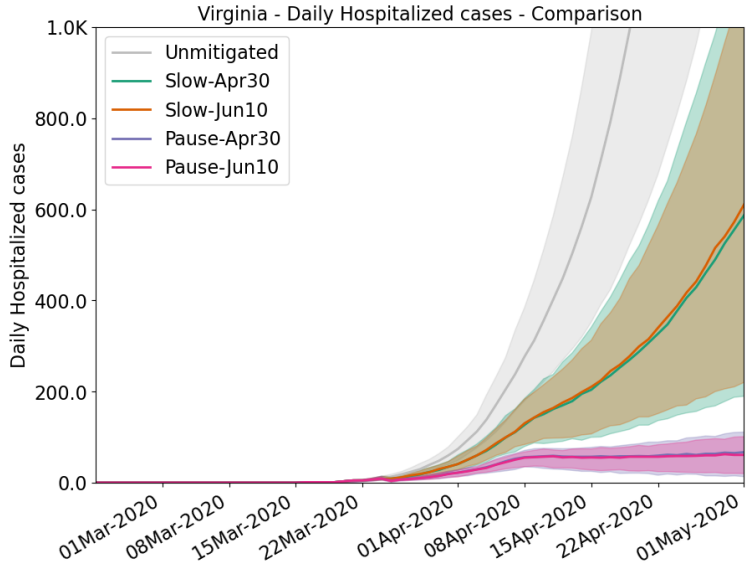
Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/
Cuebiq: COVID-19 Mobility insights. https://www.cuebiq.com/visitation-insights-covid19/

Short-term Projections

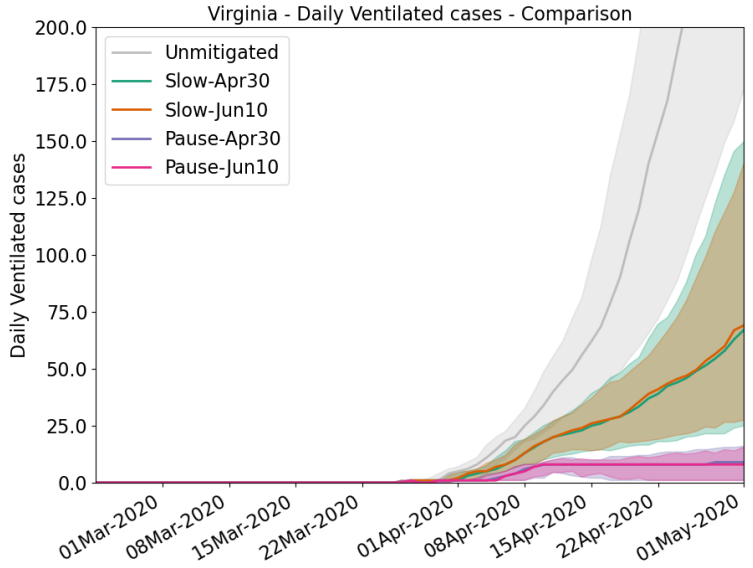
Confirmed cases



Hospitalizations



Ventilations



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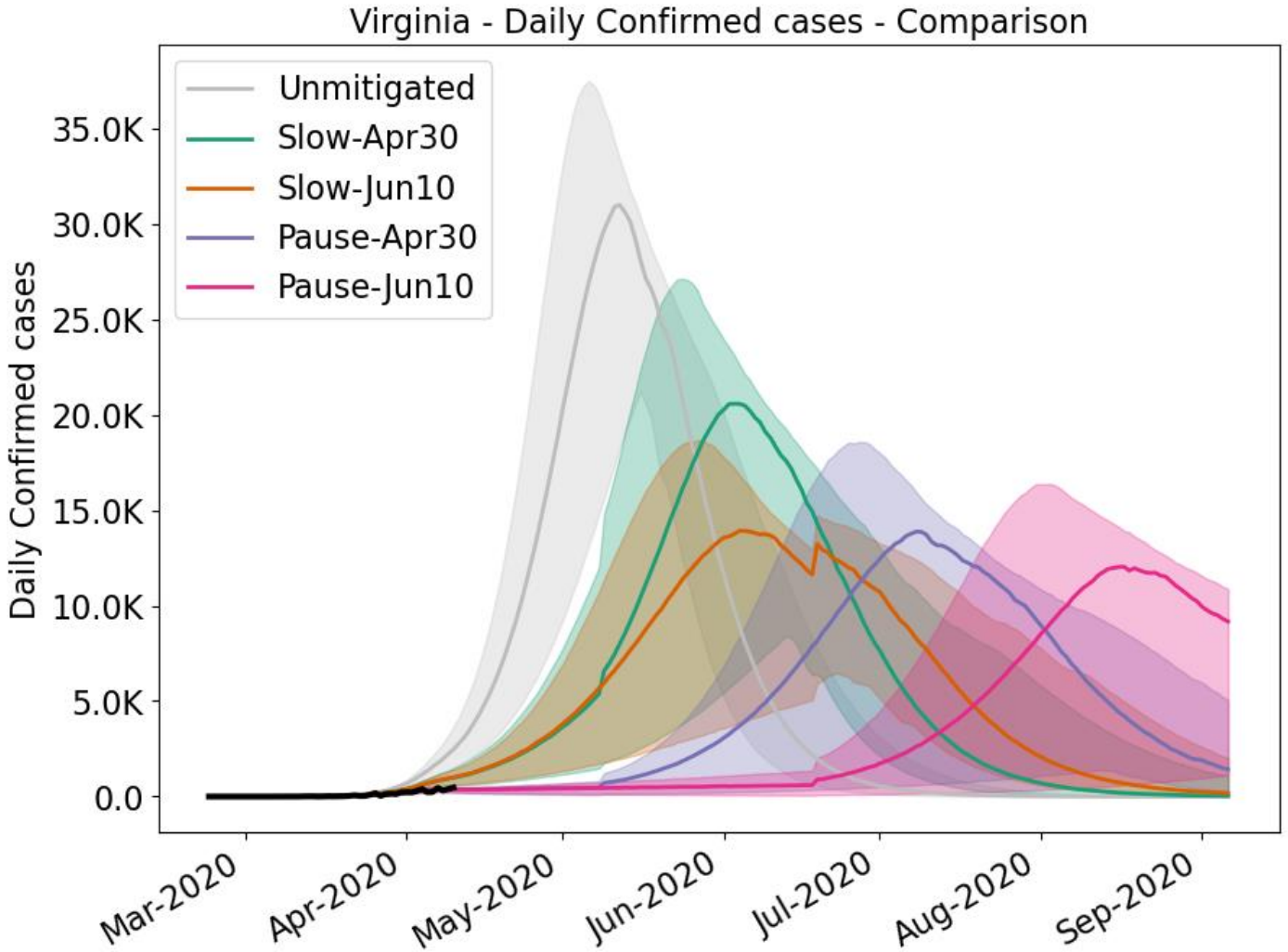
Stay the Course: Future Depends on Policy



Weekly New Confirmed Cases

Week ending	Unmitigated	Slow Jun10	Pause Jun10
4/12/20	11,846	5,518	2,469
4/19/20	25,712	8,502	2,599
4/26/20	53,562	13,076	2,742
5/3/20	101,876	19,881	2,944
5/10/20	164,527	29,567	3,151
5/17/20	200,184	42,312	3,345
5/24/20	182,818	57,679	3,558
5/31/20	136,652	73,380	3,770
6/7/20	84,016	85,874	3,962
6/14/20	46,350	89,390	4,144
6/21/20	23,363	85,226	4,470
6/28/20	11,366	91,648	7,850

Numbers are medians of projections

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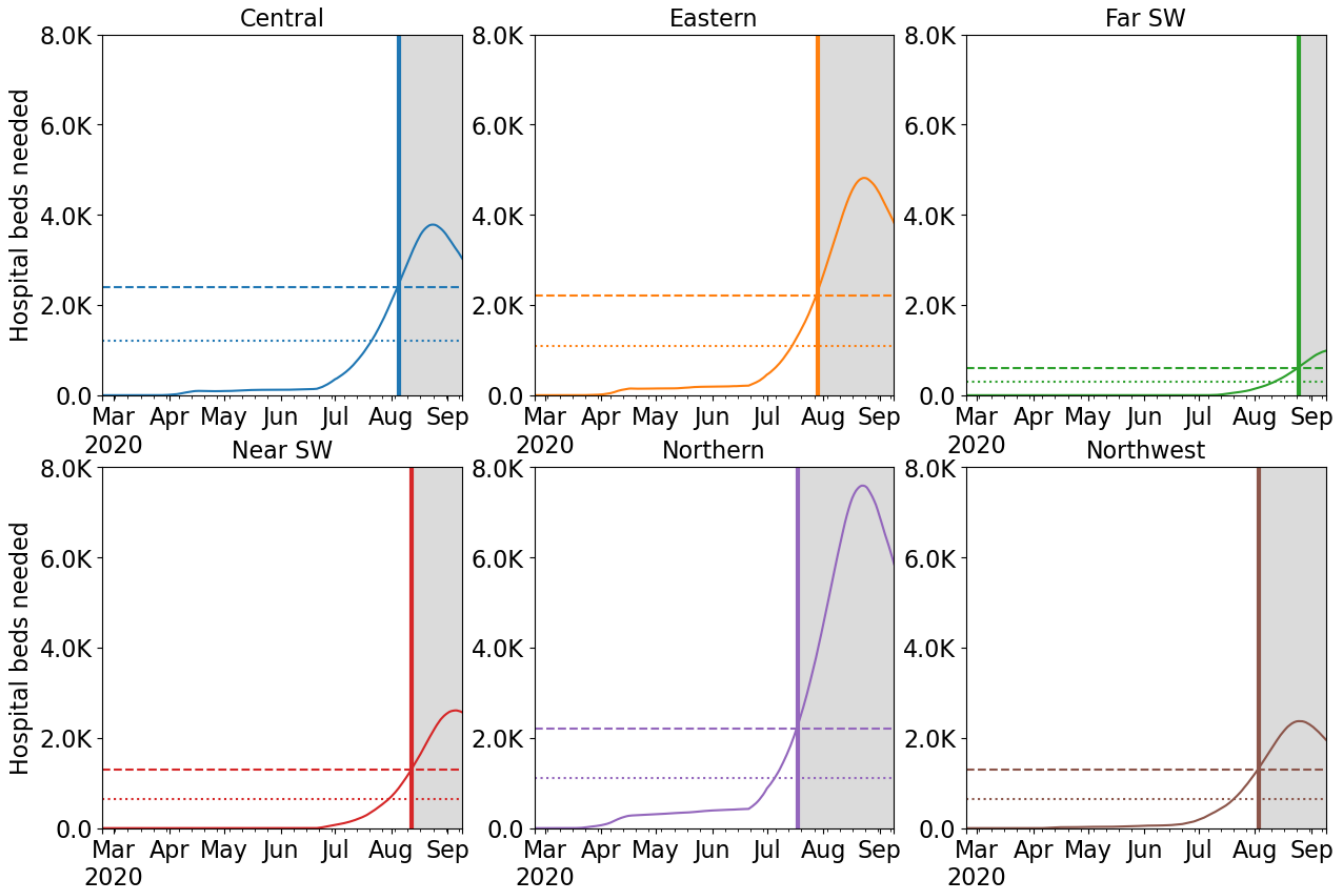
Hospital Demand and Capacity by Region

Capacities by Region – Pause June 10



Assumes average length of stay of 10 days

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

Date ranges when regions are estimated to exceed surge capacity

Scenario	Date Ranges
Slow – Apr30	Early May – Early June
Slow – Jun10	Early May – Mid June
Pause – Apr30	Mid June – Late July
Pause – Jun10	Mid July – Late August
Unmitigated	Late April – Mid May

Social Distancing postpones the time when capacity is exceeded 1 to 2.5 months

Timing estimates can be used for planning to augment existing capacities if needed

Ongoing Efforts and Improvements

- Incorporate age structure into transmission dynamics and stratify outcomes by age in these projections
- Incorporate Virginia-specific outcomes and durations which will better tailor these analyses to our Commonwealth
- Assess evidence for the role of seasonality, and incorporate if warranted
- Analyze Test-Trace-Isolate mitigations
- Connect forecast demand to VDH dashboard

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References

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Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. SIAM/ASA Journal on Uncertainty Quantification, 6(4):1685–1706, 2018.

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Biocomplexity Institute. COVID-19 Surveillance Dashboard. https://nssac.bii.virginia.edu/covid-19/dashboard/

Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Cuebiq: COVID-19 Mobility insights. https://www.cuebiq.com/visitation-insights-covid19/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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