Estimation of COVID-19 Impact in Virginia

August 26th, 2020
(data current to August 25th)
Biocomplexity Institute Technical report: TR 2020-104

Network Systems Science & Advanced Computing
Biocomplexity Institute & Initiative
University of Virginia

biocomplexity.virginia.edu
About Us

• Biocomplexity Institute at the University of Virginia
  • Using big data and simulations to understand massively interactive systems and solve societal problems
• Over 20 years of crafting and analyzing infectious disease models
  • Pandemic response for Influenza, Ebola, Zika, and others

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Biocomplexity COVID-19 Response Team

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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 October
  • 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:

• **Surges are fading and incidence is declining.**
• Majority of districts are plateauing or declining
• Projections are mixed across a range of slow-growth, plateaus, and declines
• Recent model updates:
  • Adaptive Fitting projection remains, slight adjustments to projection filtering
  • Seasonal effects scenarios for planning for end of summer changes
• The situation is changing rapidly. Models will be updated regularly.
Situation Assessment
Case Rate (per 100k) by VDH District

Mixed bag of case growth across districts

- Many Eastern districts continue their decline after several weeks of surge
- Some Southwest districts continue to surge
- Slow and steady growth in Northern districts
Test Positivity by VDH District

Weekly changes in test positivity by district
- Most districts moving towards lower overall percents
- Areas with most growth also showing high and increasing test positivity, especially in Southwest
Other State Comparisons

Case Rate per 100K population

- Most states experiencing declines or plateaus in last couple weeks
- DE and NC showing some rebounds
- TN declining but still quite high

Tests per Day and Test Positivity

- Good signs as test positivity shows recent decline in most states
- Testing volumes plateau, potentially due to long turnaround times and individuals deciding to not seek a test
Estimating Daily Reproductive Number

August 15th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Current $R_e$</th>
<th>Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>0.926</td>
<td>-0.006</td>
</tr>
<tr>
<td>Central</td>
<td>0.917</td>
<td>-0.024</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.848</td>
<td>0.057</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.838</td>
<td>-0.013</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.979</td>
<td>-0.063</td>
</tr>
<tr>
<td>Northern</td>
<td>1.018</td>
<td>-0.001</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.885</td>
<td>-0.094</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim\(^1\)) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

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Other State Comparisons

Reproductive Number ($R_e$) has downward trend across hotspots and Virginia’s neighbors
- Most of the national hotspots such as AZ, CA, TX, FL are now below 1
- Virginia and neighboring states are mostly at and below 1

Estimated $R_e^*$ for select States and Neighbors

* Based on confirmed cases per day

VA and neighbors continued decline
Changes in Case Detection

Days to Diagnosis dropped but rebounding
- Mid March to Late April = 8.4 days
- Late April to Late May = 5.8 days
- Late May to Late June = 5.6 days
- Early July to mid Aug = 5.8 days

Returning to lower levels

Testing Encounters and test positivity have steadied and increased

Test positivity vs. Onset to Diagnosis

Steady plateau has been maintained for past several weeks

Changes in Case Detection – By District/Age

Slight variations by age group (0-9, 70-79 and 80-89 have lower medians)
No significant variation by severity (hosp./ICU)

Only ~35% records have entries
Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts

Legend: Age Categories
- 0-29
- 30-49
- 50-69
- 70-79
- 80+

Age-adjusted Cumulative Prevalence Rate Per 100k District Population

- Land Fairfax
- Rappahannock
- Fredericksburg
- Prince William
- Alexandria
- Allegheny
- Thomas Jefferson
- Chickahominy
- Henrico
- Three Rivers
- Peninsula
- Hampton
- Eastern Shore
- Virginia Beach
Estimating Effects of Social Distancing

Google Mobility data shows continued slow rebound (as of July 26\textsuperscript{th})
https://www.google.com/covid19/mobility/

- Continued slow reduction of those staying at home. Workplace levels remain low.
  - Urban/Rural variations in levels (e.g., Northern vs Far SW)
- Essential shopping back to baseline. Other shopping/transit trending towards baseline.
- Parks and recreation significantly higher than baseline (seasonal effects).
- Mask usage not evenly distributed, higher in Northern central, lower Southwest and Richmond area
Surges Fading

Fading Resurgence: Recent surges now decreasing

- Most districts have slowed and started to decline, however, some continue to have sustained rapid growth

Surge Detection:

- Using “hockey stick” fit to assess timing of surge
- **Surging:** Best fits with slope greater than 2.5 cases / 100K / week
- **Slowing:** Surge with a peak in last 10 days
- **Ended:** Surge has peaked more than 10 days ago without rebound

Mount Rogers - Surging

Only 1 district being tracked (compared to 8 last week)

**In:** --No new surges--

**Out:** Central Virginia, Chickahominy, Crater, Lenowisco, Pittsylvania-Danville, Southside, West Piedmont
District Trajectories

Hockey stick fit used to describe recent growth patterns

**Declining**: Sustained decreases following a recent peak

**Plateau**: Steady level or mixed increases and decreases

**Slow Growth**: Sustained growth not rapid enough to be considered a Surge

**In Surge**: Currently experiencing sustained rapid growth

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>17</td>
</tr>
<tr>
<td>Plateau</td>
<td>15</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>2</td>
</tr>
<tr>
<td>In Surge</td>
<td>1</td>
</tr>
</tbody>
</table>
Impact across Density and Income

Lower 20% income zip codes now reporting highest case rates

Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes
Zip-code level weekly Case Rate (per 100K)

Cases in the last week by zip-code

- Concentrations of prevalence along southern border, Central VA
- Rural populations showing high case rates
- Many counts are low and suppressed to protect anonymity, those are assumed to be 1 case (per zip per day) and shown with the speckled pattern
Model Update – Adaptive Fitting
Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

- Allows history to be precisely captured, and used to guide bounds on projections

Model: An alternative use of the same meta-population model, PatchSim

- Allows for future “what-if” Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding
Calibration Approach

**Data:**
- County level case counts by date of onset (from VDH)
- Confirmed cases for model fitting

**Calibration:** fit model to observed data
- Tune transmissibility across ranges of:
  - Duration of incubation (5-9 days), infectiousness (3-7 days)
  - Undocumented case rate (2x to 15x)
  - Detection delay: exposure to confirmation (4-12 days)
- Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak

**Project:** future cases and outcomes using the most recent parameters with constraints learned from the history of the fit parameters
- Mean trend from last 7 days used, adjusted by variances in the previous 3 weeks
- 1 week interpolation to smooth transitions in rapidly changing trajectories
- Particles with high error or variance filtered out

Accessed 9am August 26, 2020
https://www.vdh.virginia.gov/coronavirus/
Scenarios – Seasonal Effects

• Societal changes in the coming weeks may lead to an increase in transmission rates
  • Start of in-person school
  • Changes to workplace attendance
  • Seasonal impact of weather patterns

• Three scenarios provided to capture possible trajectories related to these changes starting following Labor Day, Sept 7th, 2020
  • Adaptive: No change from base projection
  • Adaptive-Low: 10% increase in transmission starting Sept 8th, 2020
  • Adaptive-High: 20% increase in transmission starting Sept 8th, 2020
Model Results
Outcome Projections

Confirmed cases
Virginia - Daily Confirmed - Comparison

Confirmed cases
Virginia - Daily Confirmed - Comparison

Estimated Hospital Occupancy
Virginia: Daily Total Confirmed Hospitalized Versus Sim - 8 Day Rolling

Daily Deaths
Virginia - Daily Death - Comparison

Cumulative Confirmed cases
Virginia - Cumulative Confirmed - Comparison
District Level Projections: Adaptive

Adaptive projections by District

• Projections that best fit recent trends
• Daily confirmed cases by Region (blue solid) with simulation colored by scenario
District Level Projections: Adaptive-Low

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario
District Level Projections: Adaptive-High

Adaptive projections by District

• Projections that best fit recent trends
• Daily confirmed cases by Region (blue solid) with simulation colored by scenario
Hospital Demand and Capacity by Region

**Capacities by Region – Adaptive-High**

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

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Adaptive</th>
<th>Adaptive-High</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/23/20</td>
<td>6,342</td>
<td>6,342</td>
</tr>
<tr>
<td>8/30/20</td>
<td>6,254</td>
<td>6,254</td>
</tr>
<tr>
<td>9/6/20</td>
<td>6,158</td>
<td>6,158</td>
</tr>
<tr>
<td>9/13/20</td>
<td>6,168</td>
<td>6,237</td>
</tr>
<tr>
<td>9/20/20</td>
<td>6,225</td>
<td>7,482</td>
</tr>
<tr>
<td>9/27/20</td>
<td>6,348</td>
<td>8,498</td>
</tr>
<tr>
<td>10/4/20</td>
<td>6,482</td>
<td>9,600</td>
</tr>
<tr>
<td>10/11/20</td>
<td>6,606</td>
<td>10,674</td>
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<tr>
<td>10/18/20</td>
<td>6,680</td>
<td>11,663</td>
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<tr>
<td>10/25/20</td>
<td>6,661</td>
<td>12,318</td>
</tr>
<tr>
<td>11/1/20</td>
<td>6,552</td>
<td>12,648</td>
</tr>
<tr>
<td>11/8/20</td>
<td>6,358</td>
<td>12,684</td>
</tr>
</tbody>
</table>

* Assumes average length of stay of 8 days

Based on Adaptive-High scenario
- No regions forecast to exceed capacity
- Northern approaching capacity at the beginning of November
Counter-factual Analysis

“What If” the whole Summer was like late Spring?

• Scenario where the trends present up to Memorial Day week had persisted throughout the summer

• Over 62K cases averted
**Key Takeaways**

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Google. COVID-19 community mobility reports. [https://www.google.com/covid19/mobility/](https://www.google.com/covid19/mobility/)


Questions?

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School Age Prevalence

- Using school-age incidence in the last week, we estimate the likelihood any collection of school age kids in a school size of 500 will have at least one infection.

- Assume that for each confirmed case there are 6 other undetected infections.
Recent Parameter Validation

New York State announced sero-prevalence survey results on May 2\textsuperscript{nd}

- 15,000 antibody tests conducted randomly through the state at grocery stores
- **Total Attack Rate**: 12.3%

Estimation of undetected infections

- Total infections in NY = 2.46M, total of 300K confirmed cases
- Confirmed case detection = 12% of infections (close to 15% used in model)

Estimation of hospitalizations from infections

- Total infections in NY = 2.46M, total of 66K hospitalizations
- Hospitalizations = 2.7% of infections (close to 2.25% used in model)
Agent-based Model (ABM)

EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing

Synthetic Population
- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations

Detailed Disease Course of COVID-19
- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments
ABM Social Distancing Rebound Study Design

Study of "Stay Home" policy adherence
• Calibration to current state in epidemic
• Implement “release” of different proportions of people from "staying at home"

Calibration to Current State
• Adjust transmission and adherence to current policies to current observations
• For Virginia, with same seeding approach as PatchSim

Impacts on Reproductive number with release
• After release, spike in transmission driven by additional interactions at work, retail, and other
• At 25% release (70-80% remain compliant)
• Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels
Medical Resource Demand Dashboard

https://nssac.bii.virginia.edu/covid-19/vmrddash/