Estimation of COVID-19 Impact in Virginia

September 23rd, 2020
(data current to September 22nd)
Biocomplexity Institute Technical report: TR 2020-115
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

Overview

• **Goal:** Understand impact of COVID-19 mitigations in Virginia

• **Approach:**
  • Calibrate explanatory mechanistic model to observed cases
  • Project infections through November
  • 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:

• **Mixed trends remain, surges continue in several districts.**

• VA weekly incidence (11.6/100K) below national average (14/100K) which is slightly down compared to last week.

• Projections are also mixed across a range of slow-growth, plateaus, and declines.

• Recent updates:
  • Adaptive Fitting projection remains, slight adjustments to projection filtering.
  • Planning Scenarios moved to Oct 1st.

• The situation is changing rapidly. Models will be updated regularly.
Situation Assessment
Case Rate (per 100k) by VDH District

Mixed trends in case rates
• Sharp rises in many districts with large universities
• Southwest continues to have strong surges
• Plateaus 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
Hockey stick fit used to describe recent growth patterns

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

**Plateau**: Steady level with minimal trend up or down

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

**In Surge**: Currently experiencing sustained rapid growth and exceeds recent inflection points

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**District Trajectories – New Surges starting**

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts (last week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>13 (13)</td>
</tr>
<tr>
<td>Plateau</td>
<td>6 (10)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>13 (10)</td>
</tr>
<tr>
<td>In Surge</td>
<td>3 (2)</td>
</tr>
</tbody>
</table>

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**Hockey stick fit**

**Portsmouth**

RSS: 3961.872

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**Report Date**

- April 2020
- May
- Jun
- Jul
- Aug
District Trajectories – Declines outpace Growth

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</table>
Estimating Daily Reproductive Number

September 12th 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>0.883</td>
<td>-0.011</td>
</tr>
<tr>
<td>Central</td>
<td>0.898</td>
<td>-0.067</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.921</td>
<td>0.130</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.769</td>
<td>-0.045</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.764</td>
<td>-0.224</td>
</tr>
<tr>
<td>Northern</td>
<td>0.929</td>
<td>0.096</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.948</td>
<td>-0.035</td>
</tr>
</tbody>
</table>

Methodology

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

Changes in Case Detection

Testing Encounters and test positivity have steadied and increased

<table>
<thead>
<tr>
<th>Timeframe (weeks)</th>
<th>Mean days</th>
<th>% difference from overall mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>April (13-16)</td>
<td>8.42</td>
<td>39%</td>
</tr>
<tr>
<td>May (17-21)</td>
<td>5.66</td>
<td>-7%</td>
</tr>
<tr>
<td>June (22-25)</td>
<td>5.85</td>
<td>-3%</td>
</tr>
<tr>
<td>July (26-30)</td>
<td>6.26</td>
<td>3%</td>
</tr>
<tr>
<td>Aug (31-34)</td>
<td>4.67</td>
<td>-23%</td>
</tr>
<tr>
<td>Sept [first week] (35)</td>
<td>3.94</td>
<td>-35%</td>
</tr>
<tr>
<td>Overall (13-33)</td>
<td>6.06</td>
<td>0%</td>
</tr>
</tbody>
</table>

Test positivity vs. Onset to Diagnosis

Steady plateau has given way to slight dip in positivity as testing volume picks up
Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

• Younger age groups outpace older in many districts
Shift back to higher income zip codes partially driven by surges in areas surrounding universities

Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes, then recently back to denser wealthier zip codes
Other State Comparisons

Trajectories of States

- Mixture of trajectories
- VA plateauing
- WV surging, but many others declining
- MD, DE, PA, SC showing slow growth

Tests per Day and Test Positivity

- Test positivity mixed, VA shows steady pattern with recent dip.
- Testing volumes steady and plateaued in most states.
Other State Comparisons

Reproductive Number ($R_e$) has downward trend across hotspots and Virginia’s neighbors

- New states in Midwest and Plains emerging as hot spots: MO, ND, OK, WI, WY, as well as WV
- Virginia and neighboring states are mostly at and below 1

Estimated $R_e$* for select States and Neighbors

* Based on confirmed cases per day

New hotspots in Midwest and Plains emerging
VA and neighbors continued steady
Evolution of Infections by District

- From January to Present
- Cumulative cases vs. Daily Incidence
- Placed on log scale to minimize the differences between districts
- Colors represent cumulative deaths per million population
- Size changes based on daily estimated reproductive number
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Concentrations of very high prevalence in some zip codes
- Southern border continues to be higher than northern and western
- Many counts are low and suppressed to protect anonymity, those are assumed to be 1 case (per zip per day) and shown with the red outline pattern
Zip code level weekly Case Rate (per 100K)

Roanoke / B’burg

Albemarle

Northern Virginia

Far Southwest

Richmond

Tidewater
Zip Code Hot Spots

Previous weeks

Point Prevalence Hot Spots by Zip Code
(2020-09-05)

Getis-Ord Gi* HotSpots
- Cold Spot - 99% Confidence
- Cold Spot - 95% Confidence
- Cold Spot - 90% Confidence
- Not Significant
- Hot Spot - 90% Confidence
- Hot Spot - 95% Confidence
- Hot Spot - 99% Confidence

Point Prevalence Hot Spots by Zip Code
(2020-09-19)

University of Virginia
BIOCOMPLEXITY INSTITUTE
School Age Prevalence

If all schools were open this past week, how many infected students might we expect to be in attendance?

- Based on prevalence during week of Sept 13th – Sept 20th
- 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
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 September 23, 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 at beginning of flu season, Oct 1\textsuperscript{st}, 2020
  • Adaptive: No change from base projection
  • Adaptive-Low: 10% increase in transmission starting Oct 1\textsuperscript{st}, 2020
  • Adaptive-High: 20% increase in transmission starting Oct 1\textsuperscript{st}, 2020
Model Results
Outcome Projections

**Confirmed cases**

*Virginia - Daily Confirmed - Comparison*

- Adaptive-High
- Adaptive-Low
- Adaptive

**Estimated Hospital Occupancy**

*Virginia: Daily Total Confirmed Hospitalized Versus Sim - 8 Day Rolling*

- Central - Daily Hospitalized
- Eastern - Daily Hospitalized
- Far Southwest - Daily Hospitalized
- Near Southwest - Daily Hospitalized
- Northern - Daily Hospitalized
- Northwest - Daily Hospitalized

**Daily Deaths**

*Virginia - Daily Death - Comparison*

- Adaptive-High
- Adaptive-Low
- Adaptive

**Cumulative Confirmed cases**

*Virginia - Cumulative Confirmed - Comparison*

- Adaptive-High
- Adaptive-Low
- Adaptive
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

* Assumes average length of stay of 8 days

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Adaptive</th>
<th>Adaptive-High</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/20/20</td>
<td>6,852</td>
<td>6,852</td>
</tr>
<tr>
<td>9/27/20</td>
<td>6,983</td>
<td>6,983</td>
</tr>
<tr>
<td>10/4/20</td>
<td>7,372</td>
<td>7,392</td>
</tr>
<tr>
<td>10/11/20</td>
<td>7,803</td>
<td>8,630</td>
</tr>
<tr>
<td>10/18/20</td>
<td>8,256</td>
<td>10,578</td>
</tr>
<tr>
<td>10/25/20</td>
<td>8,518</td>
<td>11,898</td>
</tr>
<tr>
<td>11/1/20</td>
<td>8,558</td>
<td>12,756</td>
</tr>
<tr>
<td>11/8/20</td>
<td>8,306</td>
<td>12,984</td>
</tr>
<tr>
<td>11/15/20</td>
<td>7,812</td>
<td>12,710</td>
</tr>
<tr>
<td>11/22/20</td>
<td>7,248</td>
<td>12,190</td>
</tr>
<tr>
<td>11/29/20</td>
<td>6,608</td>
<td>11,512</td>
</tr>
<tr>
<td>12/06/20</td>
<td>5,948</td>
<td>10,804</td>
</tr>
</tbody>
</table>

Based on Adaptive-High scenario
- No regions forecast to exceed capacity
Key Takeaways

Projecting future cases precisely is impossible and unnecessary. Even without perfect projections, we can confidently draw conclusions:

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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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Supplemental Slides
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/