Estimation of COVID-19 Impact in Virginia

October 28th, 2020
(data current to October 27th)
Biocomplexity Institute Technical report: TR 2020-133
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

Points of Contact

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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 December
  • 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:

• **Virginia remains steady while many states surge, mixed districts.**

• VA weekly incidence (12.1/100K) is steady and below the growing national average (27/100K).

• Projections are mostly up, but many districts continue to decline.

• Recent updates:
  • Planning Scenarios adjusted, as Adaptive Fitting tracks recent surge, to represent population’s ability to exert further control on transmission following Thanksgiving holidays, Nov 26th.
  • Case ascertainment parameters now bounded by updated seroprevalence data.

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

Mixed trends in case rates

- Some increased activity in the Northern and Eastern districts
- Many districts remain steady but at high levels of incidence
- Southwest continues to have strong surges
Test Positivity by VDH District

**Weekly changes in test positivity by district**

- Most districts maintaining lower overall positivity
- Increasing levels in Southwest
**Goal:** Define epochs of a Health District’s COVID-19 incidence to characterize the current trajectory

**Method:** Find recent peak and use hockey stick fit to find inflection point afterwards, then use this period’s slope to define the trajectory

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>Description</th>
<th>Weekly Case Rate (per 100K) bounds</th>
<th># Districts (last week)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Declining</strong></td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>10 (4)</td>
</tr>
<tr>
<td><strong>Plateau</strong></td>
<td>Steady level with minimal trend up or down</td>
<td>above -0.9 and below 0.5</td>
<td>10 (7)</td>
</tr>
<tr>
<td><strong>Slow Growth</strong></td>
<td>Sustained growth not rapid enough to be considered a Surge</td>
<td>above 0.5 and below 2.5</td>
<td>11 (17)</td>
</tr>
<tr>
<td><strong>In Surge</strong></td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>4 (7)</td>
</tr>
</tbody>
</table>

*Hockey stick fit*
District Trajectories

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts (last week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>10 (4)</td>
</tr>
<tr>
<td>Plateau</td>
<td>10 (7)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>11 (17)</td>
</tr>
<tr>
<td>In Surge</td>
<td>4 (7)</td>
</tr>
</tbody>
</table>

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive
Estimating Daily Reproductive Number

October 17ᵗʰ 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>0.968</td>
<td>-0.069</td>
</tr>
<tr>
<td>Central</td>
<td>0.912</td>
<td>-0.131</td>
</tr>
<tr>
<td>Eastern</td>
<td>1.042</td>
<td>0.114</td>
</tr>
<tr>
<td>Far SW</td>
<td>1.230</td>
<td>0.063</td>
</tr>
<tr>
<td>Near SW</td>
<td>0.976</td>
<td>-0.264</td>
</tr>
<tr>
<td>Northern</td>
<td>0.970</td>
<td>-0.061</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.917</td>
<td>0.085</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim¹) 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

<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>8.6</td>
<td>48%</td>
</tr>
<tr>
<td>May (17-21)</td>
<td>5.6</td>
<td>-3%</td>
</tr>
<tr>
<td>June (22-25)</td>
<td>5.9</td>
<td>2%</td>
</tr>
<tr>
<td>July (26-30)</td>
<td>6.3</td>
<td>8%</td>
</tr>
<tr>
<td>Aug (31-34)</td>
<td>4.8</td>
<td>-17%</td>
</tr>
<tr>
<td>Sept (35-38)</td>
<td>4.4</td>
<td>-25%</td>
</tr>
<tr>
<td>Oct (39-40)</td>
<td>4.0</td>
<td>-30%</td>
</tr>
<tr>
<td>Overall (13-37)</td>
<td>5.8</td>
<td>0%</td>
</tr>
</tbody>
</table>

Test positivity vs. Onset to Diagnosis

- Positivity remains steady at ~5%

Days from Onset to Diagnosis and Test Positivity - Weekly

- July 6.3 days
- Aug 4.8 days
- Oct 4.0 days
- Sept 4.4 days
Mask usage in Virginia

State level mask usage as reported via Facebook surveys over the past month shows ranges from 83% to 89%

- Relatively stable over time
- Limited variance across the commonwealth
- ~3000 daily responses from VA.

Data Source: https://covidcast.cmu.edu

Correlations seen at national level with mask use and case rate not emerging across VA counties, reflecting high use across commonwealth

Some county level fluctuations since beginning of Sept., though data quality may be affected by sample sizes.
Race and Ethnicity Attack Rates (per 100K)

Cumulative Race and Ethnicity Attack Rates (per 100k)

• Black and Latinx populations have much higher case, hospitalization, and death rates
• Disparity is more pronounced in some districts than others
• Based on 2019 census race-ethnicity data by county
Race and Ethnicity cases per 100K

Rates per 100K of each Racial-Ethnic population by Health District
- Each Health District’s Racial-Ethnic population is plotted by their Hospitalization and Case Rate
- Points are sized based on their overall population size
- Overlapping labels removed for clarity
Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

- Younger age groups outpace older in many districts
- Some districts with previous surge in young cases now show a spillover from 0-29 to 30-49 (eg. Alleghany)

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

Age-adjusted Cumulative Prevalence Rate Per 100k District Population
Shift back to higher income zip codes partially driven by surges in areas surrounding universities, which has since receded with the lower 40% bearing higher rates of disease.

Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes, then back to denser wealthier zip codes, with an additional shift back again to poorer and less dense areas.
Other State Comparisons

Trajectories of States

- VA and other mid-Atlantic states in plateaus with signs of growth
- TN and IN remain in surge (along 15 others across nation)
- Most of the Mid-Atlantic at or above 10/100K

Tests per Day and Test Positivity

- Test positivity mixed, VA’s declining rate has slowed.
- Testing volumes remain steady and relatively high
Growth Associated with Temperature and Humidity

Curve shows smoothed case rate (per 100K)
Trajectories of states in label & chart box
Case Rate curve colored by Reproductive

- As weather cools and humidity drops, COVID-19 survival and chance of transmission may rise.
- This may be contributing, with other factors, to the rise in cases in plains and Midwest as well as Northeast.

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
- Trend back towards very high rates in a few zips and lower in surrounding areas
- Southwest has considerable concentration of high prevalence zips
- Some counts are low and suppressed to protect anonymity, those are shown in white

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code Name</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22729 Mitchells</td>
<td>8,280</td>
</tr>
<tr>
<td>2</td>
<td>24016 Roanoke</td>
<td>2,470</td>
</tr>
<tr>
<td>3</td>
<td>24277 Pennington Gap</td>
<td>2,140</td>
</tr>
<tr>
<td>4</td>
<td>24250 Fort Blackmore</td>
<td>1,470</td>
</tr>
<tr>
<td>5</td>
<td>22576 Weems</td>
<td>1,370</td>
</tr>
<tr>
<td>6</td>
<td>24639 Raven</td>
<td>1,350</td>
</tr>
<tr>
<td>7</td>
<td>24141 Radford</td>
<td>1,330</td>
</tr>
<tr>
<td>8</td>
<td>24526 Big Island</td>
<td>1,320</td>
</tr>
<tr>
<td>9</td>
<td>24271 Nickelsville</td>
<td>1,220</td>
</tr>
<tr>
<td>10</td>
<td>23829 Capron</td>
<td>1,190</td>
</tr>
</tbody>
</table>
Zip code level weekly Case Rate (per 100K)
Risk of Exposure by Group Size

Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25 or 50)

- Assumes 3 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey)
- Moderate risk for groups of 50 across the commonwealth, especially in the southern half of the state
- Some zip codes have high likelihood of exposure even in groups of 25
Zip Code Hot Spots

Previous weeks

• Similar number of hotspots this week compared to last week
• Fewer university associated hotspots

<table>
<thead>
<tr>
<th>Hot Spot Significance</th>
<th># of Zips (last week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>99%</td>
<td>11 (5)</td>
</tr>
<tr>
<td>95%</td>
<td>3 (3)</td>
</tr>
<tr>
<td>90%</td>
<td>3 (2)</td>
</tr>
</tbody>
</table>

Hotspots across commonwealth

Point Prevalence Hot Spots by Zip Code

(2020-10-24)
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
Seroprevalence updates to model design

Several seroprevalence studies provide better picture of how many actual infections have occurred

- Virginia Serology Study estimated 2.4% of Virginians estimated infected (as of Aug 15th)
- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 3.9% [1.7% – 7.1%] seroprevalence as of Aug 15th

These findings are equivalent to an ascertainment ratio of ~3x, with bounds of (1x to 7x)

- Thus for 3x there are 3 total infections in the population for every confirmed case
- Uncertainty design has been shifted to these bounds (previously higher ascernments as was consistent earlier in the pandemic were being used)

https://covid.cdc.gov/covid-data-tracker/#national-lab

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 (1x to 7x) guided by seroprevalence studies
    • 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

COVID-19 in Virginia: Cases

Accessed 9:00am October 28, 2020
https://www.vdh.virginia.gov/coronavirus/
Scenarios – Seasonal Effects

• Societal changes in the past month have led to an increase in transmission rates, these could continue to drive transmission
  • Seasonal impact of weather patterns
  • More interactions at places of learning
  • Travel related to holidays and traditional large family gatherings
  • Fatigue with infection control practices

• Population’s behaviors determine the level of control of transmission we can achieve

• Three scenarios capture possible trajectories starting Nov 26th, 2020
  • Adaptive: No change from base projection
  • Adaptive-MoreControl: 15% decrease in transmission starting Nov 26th, 2020
  • Adaptive-LessControl: 15% increase in transmission starting Nov 26th, 2020
Model Results
District Level Projections: Adaptive

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario
District Level Projections: Adaptive-MoreControl

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario
District Level Projections: Adaptive-LessControl

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases rate (per 100K) by Region (blue solid) with simulation colored by scenario
Hospital Demand and Bed Capacity by Region

Capacities by Region – Adaptive-LessControl
COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds

If Adaptive-LessControl scenario persists:
- Far Southwest may begin to exceed capacity in early December
- Near Southwest trends toward capacity as well by January

* Assumes average length of stay of 8 days

<table>
<thead>
<tr>
<th>Week Ending</th>
<th>Adaptive</th>
<th>Adaptive-LessControl</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/18/20</td>
<td>7,470</td>
<td>7,470</td>
</tr>
<tr>
<td>10/25/20</td>
<td>7,204</td>
<td>7,204</td>
</tr>
<tr>
<td>11/1/20</td>
<td>7,528</td>
<td>7,524</td>
</tr>
<tr>
<td>11/8/20</td>
<td>8,000</td>
<td>7,988</td>
</tr>
<tr>
<td>11/15/20</td>
<td>8,530</td>
<td>8,490</td>
</tr>
<tr>
<td>11/22/20</td>
<td>9,330</td>
<td>9,276</td>
</tr>
<tr>
<td>11/29/20</td>
<td>10,347</td>
<td>10,272</td>
</tr>
<tr>
<td>12/06/20</td>
<td>11,438</td>
<td>12,292</td>
</tr>
<tr>
<td>12/13/20</td>
<td>12,224</td>
<td>14,582</td>
</tr>
<tr>
<td>12/20/20</td>
<td>12,903</td>
<td>16,610</td>
</tr>
<tr>
<td>12/27/20</td>
<td>13,310</td>
<td>18,280</td>
</tr>
<tr>
<td>1/3/20</td>
<td>13,672</td>
<td>20,174</td>
</tr>
</tbody>
</table>
Additional Projection Methods under development

An ensemble methodology that combines the Adaptive Fitting and other machine learning and statistical models has been developed to facilitate use of other data (weather, mobility, etc.)

• **Models**: Adaptive Fitting, ARIMA, LSTM, AR, spatially driven AR, Kalman Filters (ENKF)

• Ensemble will be folded into these projections after further training and evaluation

![Graph of Daily Confirmed cases in Virginia](image)
Key Takeaways

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

• **Virginia remains steady while many states surge, mixed districts.**

• VA weekly incidence (12.1/100K) is steady and below the growing national average (27/100K).

• Projections are mostly up, but many districts continue to decline.

• Recent updates:
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  • Case ascertainment parameters now bounded by updated seroprevalence data.

• The situation is changing rapidly. Models will be updated regularly.
References


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

Biocomplexity COVID-19 Response Team

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Supplemental Slides
Mask usage sample sizes
Test positivity across VA counties

- CMS weekly summary (used for guiding nursing homes testing protocol)
- Data: COVID-19 Electronic Lab Reporting (CELR); HHS Unified Testing Dataset;
- County level testing counts and test positivity rates for RT-PCR tests.
  - **Green**: Test positivity <5.0% or with <20 tests in past 14 days
  - **Yellow**: Test positivity 5.0%-10.0% or with <500 tests and <2000 tests/100k and >10% positivity over 14 days
  - **Red**: >10.0% and not meeting the criteria for “Green” or “Yellow”

<table>
<thead>
<tr>
<th>County</th>
<th>Sep-30</th>
<th>Oct-07</th>
<th>Oct-14</th>
<th>Oct-21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amherst County</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Bedford County</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Bristol City</td>
<td>Yellow</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Campbell County</td>
<td>Yellow</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Charlotte County</td>
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<td>Red</td>
<td>Red</td>
<td>Red</td>
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<tr>
<td>Craig County</td>
<td>Yellow</td>
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<td>Galax City</td>
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<td>Red</td>
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<td>Martinsville City</td>
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<td>Somerset County</td>
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<tr>
<td>Tazewell County</td>
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<td>Washington County</td>
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<td>Wise County</td>
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<td>Wythe County</td>
<td>Yellow</td>
<td>Yellow</td>
<td>Red</td>
<td>Red</td>
</tr>
</tbody>
</table>

Red on Oct 21 (latest)  
Red on Sep 30 (4-week back)

https://data.cms.gov/stories/s/q5r5-gjyu
**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

28-Oct-20
Medical Resource Demand Dashboard

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

[Image of a map and chart from the Medical Resource Demand Dashboard]

28-Oct-20

[University of Virginia logo]