Estimation of COVID-19 Impact in Virginia

September 8th, 2021
(data current to September 4th - 7th)
Biocomplexity Institute Technical report: TR 2021-099
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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Overview

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

• **Approach:**
  • Calibrate explanatory mechanistic model to observed cases
  • Project based on scenarios for next 4 months
  • 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:

- **Case rates in Virginia continue to rise though the pace remains steady while US plateaus and some states start to decline; case rates remain very high**

- VA mean weekly incidence flat at 38/100K from 37/100K, US flat at 48/100K (from 48/100K)

- Projections continue to show significant uptick in activity, however, the reduced pace has decreased the overall impact

- Recent updates:
  - Adjustment to higher levels of assumed immunity waning (natural and vaccine)
  - Added a SeptSurge based on transmission rates from last year Labor Day to Thanksgiving with variant boosting
  - Added Fall surge scenario to capture potential rebounds and further test immunity from expanded vaccination

The situation continues to change. Models continue to be updated regularly.
Situation Assessment
Case Rates (per 100k) and Test Positivity

- Case rate increase across all health districts
- Some past 50% of winter peak and growing
- More than 50% of counties with TPR > 10%

County level RT-PCR test positivity

Green: <5.0% (or <20 tests in past 14 days)
Yellow: 5.0%-10.0% (or <500 tests and <2000 tests/100k and >10% positivity over 14 days)
Red: >10.0% (and not “Green” or “Yellow”)

**District Trajectories**

**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 (prev week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>Sustained decreases following a recent peak</td>
<td>below -0.9</td>
<td>3 (0)</td>
</tr>
<tr>
<td>Plateau</td>
<td>Steady level with minimal trend up or down</td>
<td>above -0.9 and below 0.5</td>
<td>2 (0)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>Sustained growth not rapid enough to be considered a Surge</td>
<td>above 0.5 and below 2.5</td>
<td>4 (3)</td>
</tr>
<tr>
<td>In Surge</td>
<td>Currently experiencing sustained rapid and significant growth</td>
<td>2.5 or greater</td>
<td>26 (32)</td>
</tr>
</tbody>
</table>
District Trajectories – last 10 weeks

<table>
<thead>
<tr>
<th>Status</th>
<th># Districts (prev week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declining</td>
<td>3 (0)</td>
</tr>
<tr>
<td>Plateau</td>
<td>2 (0)</td>
</tr>
<tr>
<td>Slow Growth</td>
<td>4 (3)</td>
</tr>
<tr>
<td>In Surge</td>
<td>26 (32)</td>
</tr>
</tbody>
</table>

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

Sept 6th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed $R_e$</th>
<th>Date Confirmed Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>1.003</td>
<td>-0.109</td>
</tr>
<tr>
<td>Central</td>
<td>0.908</td>
<td>-0.201</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.905</td>
<td>-0.167</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.936</td>
<td>-0.171</td>
</tr>
<tr>
<td>Near SW</td>
<td>1.019</td>
<td>-0.088</td>
</tr>
<tr>
<td>Northern</td>
<td>0.914</td>
<td>-0.198</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.982</td>
<td>-0.182</td>
</tr>
</tbody>
</table>

Methodology

- Wallinga-Teunis method (EpiEstim\textsuperscript{1}) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

Vaccination Administration Slows

Regional Vaccine courses initiated per day:

- Total counts of first dose of vaccines across regions
- Age-specific proportions of population vaccinated
Corrections to surveys:
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

<table>
<thead>
<tr>
<th>Region</th>
<th>COVIDcast accepting corrected</th>
<th>VDH proportion pop vaccinated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>78%</td>
<td>68%</td>
</tr>
<tr>
<td>Eastern</td>
<td>75%</td>
<td>64%</td>
</tr>
<tr>
<td>Far SW</td>
<td>64%</td>
<td>54%</td>
</tr>
<tr>
<td>Near SW</td>
<td>68%</td>
<td>60%</td>
</tr>
<tr>
<td>Northern</td>
<td>89%</td>
<td>78%</td>
</tr>
<tr>
<td>Northwest</td>
<td>75%</td>
<td>67%</td>
</tr>
<tr>
<td>Virginia</td>
<td>79%</td>
<td>69%</td>
</tr>
</tbody>
</table>

Grey Bar: Survey measured and corrected acceptance
Green Bar: Proportion of eligible population administered a vaccine
Dots: Proportion administered at least one dose for each county
Vaccine Acceptance Components over Time

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

Vaccine Acceptance adjusted to include scheduled appointments
• Steady rise in acceptance over the past couple months
• Unvaccinated Acceptance shows ~20% of those who are unvaccinated are definitely or probably willing to be vaccinated
• Scheduled appointments for vaccination has increased through August but seems to be leveling off.
Vaccine Acceptance by Region: COVIDcast

Levels of Acceptance and potential acceptance in flux:
- Most regions (except Central and Far SW) see vaccine uptake in the “Definitely Yes”.
- Among the unvaccinated, about 20-30% remain in the Definitely/Probably “Yes” categories.
- About 50% of the Unvaccinated seem to be in the “Definitely Not” category.

Data Source: https://covidcast.cmu.edu
Reasons for Hesitancy vary across tiers of likeliness to accept the vaccine

- **Probably Yes** and **Probably No** most concerned about side effects & are waiting to see
- **Definitely No** are concerned about side effects but also don’t think they need the vaccine and don’t trust the government, though don’t need is declining
- **Most other reasons** are below 30% within these tiers of likeliness

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
Reasons for Hesitancy of Probably No by Region

Reasons for Hesitancy vary across Regions

• Side effects and waiting to see safety are primary
• Most movement in last couple weeks seen in trust of govt and efficacy

Data Source: https://covidcast.cmu.edu
Mask Usage Increases

Self-reported mask usage has declined for months, but rebounded

- State-wide continues to rise, now outpaces US (64% vs. 62%)
- Progress in some counties has stalled or declined

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)
Mask Wearing by Vaccine Willingness

Among the different tiers of vaccine acceptance, mask wearing increasing

- Only those who would “definitely not” take the vaccine if offered have a low level of mask usage
- Slight decline for No, Probably Not
- Vaccinated continues to have higher mask wearing than unvaccinated across all tiers of willingness

Data Source: https://covidcast.cmu.edu
SARS-CoV-2 Variants of Concern

Emerging new variants will alter the future trajectories of pandemic and have implications for future control

- Emerging variants can:
  - Increase transmissibility
  - Increase severity (more hospitalizations and/or deaths)
  - Limit immunity provided by prior infection and vaccinations

- Genomic surveillance remains very limited
  - Challenges ability to estimate impact in US to date and estimation of arrival and potential impact in future

<table>
<thead>
<tr>
<th>New WHO Name</th>
<th>Transmissibility</th>
<th>Immune Evasiveness</th>
<th>Vaccine Effectiveness*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancestral</td>
<td>—</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>D614G</td>
<td>+</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.1.7 Alpha</td>
<td>+++</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.351 Beta</td>
<td>+</td>
<td>+++</td>
<td>✓</td>
</tr>
<tr>
<td>P1 Gamma</td>
<td>++</td>
<td>+</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.429 Epsilon</td>
<td>+</td>
<td>+</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.526 Iota</td>
<td>+</td>
<td>+</td>
<td>✓</td>
</tr>
<tr>
<td>B.1.6.17 Delta</td>
<td>+++</td>
<td>++</td>
<td>✓</td>
</tr>
</tbody>
</table>

*Relative transmissibility to B.1.1.7 yet to be fully defined
*Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.6.17 Delta for which 1-dose of mRNA or AZ is only ~30% effective *May carry more immune escape than P1, to be determined

WHO and Eric Topol

9-Sep-21

CDC Variant Tracking
SARS-CoV2 Variants of Concern

Previous Variants

**Alpha α - Lineage B.1.1.7**
Virginia - 0.0% (B.1.1.7)
Last Sample: 2021-08-17

**Beta β - Lineage B.1.351**
Virginia - 0.0% (B.1.351)
Last Sample: 2021-08-17

**Gamma γ - Lineage P.1**
Virginia - 0.0% (P.1)
Last Sample: 2021-08-17

Emerging Variants

**Lambda λ - Lineage C.37**
Virginia - 0.0% (C.37)
Last Sample: 2021-08-17

**Mu μ - Lineage B.1.621**
Virginia - 0.0% (B.1.621)
Last Sample: 2021-08-17

Delta seems to be outcompeting Lambda and Mu in South America
Trevor Bedford Tweet & Nextstrain Analysis
SARS-CoV2 Variants of Concern

**Delta δ - Lineage B.1.617.2** and related subvariants

- Delta plus δ+ lineage which contains the K417N mutation is emerging as a sub-variant that is even more transmissible; declared a VoC in India
- Delta variant now dominates most of Europe and US
- CDC recommends resumption of mask wearing indoors due to reports of breakthrough infections of the vaccinated possibly being transmissible
- **Recent study from Mayo clinic** shows Delta reducing the efficacy of mRNA vaccines (Pfizer more so than Moderna) along with other reports. Israeli study showed 64% efficacy against infection, however, a 3rd dose may **counteract this reduction**
- **Public Health Scotland study in Lancet** suggests Delta is 2x more likely to cause hospitalization than Alpha
- Subvariants AY.3 (15%) and AY.4 (1.5%) of Delta are more prevalent, these subvariants are mainly clustered in the US, others mainly outside of US
1. Pfizer Vaccine was estimated to have high vaccine effectiveness in pregnant women: 96% effectiveness against documented infection and 97% effectiveness against symptomatic infection 7–56 d after receipt of the second vaccine

2. CDC: Community vaccination, in coordination with testing strategies and other prevention measures, is critical to protecting pediatric populations from SARS-CoV-2 infection and severe COVID-19.

3. CDC: Preventive measures to reduce transmission and severe outcomes in children and adolescents are critical, including vaccination, universal masking in schools, and masking by persons aged ≥2 years in other indoor public spaces and child care centers.

4. Australian study predicts vaccinating over 85% of the population including children would likely be needed to achieve population protection at the most plausible effective reproduction number

5. University of California – San Diego healthcare worker study shows high vaccine effectiveness across the months until July when Delta began to dominate

### Table 1. Symptomatic SARS-CoV-2 infection and mRNA Vaccine Effectiveness among UCDMH Health Workers, March through July 2021.

<table>
<thead>
<tr>
<th>Month</th>
<th>Fully vaccinated</th>
<th>mRNA-1273 (Moderna)</th>
<th>BNT162b2 (Pfizer-BioNTech)</th>
<th>Unvaccinated</th>
</tr>
</thead>
<tbody>
<tr>
<td>March</td>
<td>18,946</td>
<td>36,407</td>
<td>7,862</td>
<td>3,230</td>
</tr>
<tr>
<td>April</td>
<td>18,992</td>
<td>36,408</td>
<td>7,909</td>
<td>3,250</td>
</tr>
<tr>
<td>May</td>
<td>19,000</td>
<td>36,408</td>
<td>7,943</td>
<td>3,321</td>
</tr>
<tr>
<td>June</td>
<td>19,035</td>
<td>36,506</td>
<td>8,104</td>
<td>3,490</td>
</tr>
<tr>
<td>July</td>
<td>19,014</td>
<td>36,623</td>
<td>8,175</td>
<td>3,646</td>
</tr>
</tbody>
</table>

### Figure 1

An observational cohort study of pregnant women aged 16 years or older, with no history of SARS-CoV-2, who were vaccinated between 20 December 2020 and 3 June 2021. A total of 10,861 vaccinated pregnant women were matched to 10,861 unvaccinated pregnant women using demographic and clinical characteristics.

https://www.nature.com/articles/s41591-021-01490-8

### Figure 2

Pfizer Vaccine was estimated to have high vaccine effectiveness in pregnant women: 96% effectiveness against documented infection and 97% effectiveness against symptomatic infection 7–56 d after receipt of the second vaccine

### Figure 3

COVID-19 cases, emergency department visits, and hospital admissions increased from June to August 2021 among persons aged 0–17 years. Emergency department visits and hospital admissions in a 2-week period in August 2021 were higher in states with lower population vaccination coverage and lower in states with higher vaccination coverage.

https://www.cdc.gov/mmwr/volumes/70/wr/mm7036e1.htm?s_cid=mm7036e1_w

### Figure 4

Australian modeling study investigates vaccination levels necessary to protect population. Gives potentially valuable parameterization to different vaccine schedules


### Figure 5

Weekly COVID-19–associated hospitalization rates among children and adolescents rose nearly five-fold during late June–mid-August 2021, coinciding with increased circulation of the highly transmissible SARS-CoV-2 Delta variant.

https://www.cdc.gov/mmwr/volumes/70/wr/mm7036e2.htm?s_cid=mm7036e2_w
Vaccine Efficacies – Simpson’s Paradox

Simpson’s Paradox Explained

Example from Israeli Data

Illustrative Toy Example (Tweet by Srini)
Variant of Concern Trajectories

United States

Virginia

Prevalence

9-Sep-21
Other State Comparisons

Trajectories of States

- Most of the country remains in Surge, but many states have are now in decline (9) or are plateaued (3)
- Case rates remain very high, but nationally growth has plateaued

Virginia and her neighbors

- VA and many neighbors continue to surge but most show signs of slowing, several states have plateaued
- Most remain at very high case rates

9-Sep-21
Age-Specific Case Rates

**Case Rates (per 100K) by Age Groups**

- Rapid growth in many regions in the 0-19 age range, many exceeding 20% of current case rates (nearly 10% for 0-9)
- Case Rate in under 40 group far exceeds 40+ in all districts
Recent Cases Correlate with Vax Coverage

Mean cases per 100K vs. vaccine coverage
- States with lower vax coverage have had the worst case spikes
- Virginia 14th out of 51 states in fully vaccinated coverage

Virginia Counties
- Counties with higher vax coverage are maintaining lower case rates
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Color scaled adjusted to accommodate the very high prevalence levels this week
- Clusters of high prevalence in Southwest and Eastern
- Some counts are low and suppressed to protect anonymity, those are shown in white

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code</th>
<th>Name</th>
<th>Prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22807</td>
<td>Harrisonburg</td>
<td>4,290</td>
</tr>
<tr>
<td>2</td>
<td>24314</td>
<td>Bastian</td>
<td>3,150</td>
</tr>
<tr>
<td>3</td>
<td>24226</td>
<td>Clinchco</td>
<td>2,920</td>
</tr>
<tr>
<td>4</td>
<td>24553</td>
<td>Gladstone</td>
<td>2,380</td>
</tr>
<tr>
<td>5</td>
<td>24350</td>
<td>Ivanhoe</td>
<td>2,180</td>
</tr>
<tr>
<td>6</td>
<td>22742</td>
<td>Sumerduck</td>
<td>2,090</td>
</tr>
<tr>
<td>7</td>
<td>24431</td>
<td>Crimora</td>
<td>2,030</td>
</tr>
<tr>
<td>8</td>
<td>23846</td>
<td>Elberon</td>
<td>1,950</td>
</tr>
<tr>
<td>9</td>
<td>24120</td>
<td>Meadows of Dan</td>
<td>1,900</td>
</tr>
<tr>
<td>10</td>
<td>24479</td>
<td>Swoope</td>
<td>1,840</td>
</tr>
</tbody>
</table>

Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.
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)

- **Group Size**: Assumes 2 undetected infections per confirmed case (ascertainment rate from recent seroprevalence survey), and shows minimum size of a group with a 50% chance an individual is infected by zip code (e.g., in a group of 16 in Harrisonburg, there is a 50% chance someone will be infected).

**From Last Week**

**Group Size Needed for 50% Likelihood of ≥1 Infected**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Zip Code Name</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22807 Hamsonburg</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>24314 Bastian</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>24226 Clinchco</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>24553 Gladstone</td>
<td>29</td>
</tr>
<tr>
<td>5</td>
<td>24350 Nannieh</td>
<td>31</td>
</tr>
<tr>
<td>6</td>
<td>22742 Sumerduck</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>24431 Crimora</td>
<td>34</td>
</tr>
<tr>
<td>8</td>
<td>22346 Elibon</td>
<td>35</td>
</tr>
<tr>
<td>9</td>
<td>24120 Meadows of Dan</td>
<td>36</td>
</tr>
<tr>
<td>10</td>
<td>24470 Swoope</td>
<td>37</td>
</tr>
</tbody>
</table>

**Group Size Needed for 50% Likelihood of ≥1 Infected**

- Only includes zip codes with ≥0.003 and no-zero data
- Denotes zip codes with zero infections
HCW Prevalence

• **HCW prevalence**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator
  - Clusters of high HCW point prevalence in far southwest (Wise & Dickinson Counties) and south of Richmond (Lunenburg and Prince Edward to Surry Counties)

• **HCW Ratio**: HCW Prevalence / Total Case Prevalence
  - (blue = higher case rate among public, red = higher case rate among HCW)

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<table>
<thead>
<tr>
<th>Rank</th>
<th>Name</th>
<th>Prev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Craig County</td>
<td>1590</td>
</tr>
<tr>
<td>2</td>
<td>Russell County</td>
<td>1080</td>
</tr>
<tr>
<td>3</td>
<td>Bland County</td>
<td>990</td>
</tr>
<tr>
<td>4</td>
<td>Alleghany County</td>
<td>930</td>
</tr>
<tr>
<td>5</td>
<td>Buchanan County</td>
<td>830</td>
</tr>
<tr>
<td>6</td>
<td>Emporia City</td>
<td>820</td>
</tr>
<tr>
<td>7</td>
<td>Warren County</td>
<td>810</td>
</tr>
<tr>
<td>8</td>
<td>Hopewell City</td>
<td>750</td>
</tr>
<tr>
<td>9</td>
<td>Franklin City</td>
<td>720</td>
</tr>
<tr>
<td>10</td>
<td>Nottoway County</td>
<td>710</td>
</tr>
</tbody>
</table>

**HCW Prevalence**

HCW Point Prevalence by Zip Code
(2021-09-04)

**HCW to Public Prevalence Ratio**

HCW Prevalence / Case Prevalence
(2021-09-04)

Note: Scale differs from general public prevalence maps.
Current Hot-Spots

Case rates that are significantly different from neighboring areas or model projections

- **Spatial**: Getis-Ord Gi* based hot spots compare clusters of zip codes with weekly case prevalence higher than nearby zip codes to identify larger areas with statistically significant deviations

- **Temporal**: The weekly case rate (per 100K) projected last week compared to observed by county, which highlights temporal fluctuations that differ from the model’s projections

### Spatial Hotspots

**Point Prevalence Hot Spots by Zip Code**

<table>
<thead>
<tr>
<th>Spot</th>
<th>Zip Code Name</th>
<th>Conf.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22907 Harrisonburg</td>
<td>99%</td>
</tr>
<tr>
<td>2</td>
<td>24314 Bastian</td>
<td>99%</td>
</tr>
<tr>
<td>3</td>
<td>24226 Clinchco</td>
<td>99%</td>
</tr>
<tr>
<td>4</td>
<td>24553 Gladstone</td>
<td>90%</td>
</tr>
</tbody>
</table>

*Only includes zip codes with p < 0.05 and no missing data. * Denotes zip codes with state precalc.

**Getis-Ord Gi* HotSpots**

- Cold Spot - 99% Confidence
- Cold Spot - 99% Confidence
- Cold Spot - 90% Confidence
- Not Significant
- Hot Spot - 90% Confidence
- Hot Spot - 95% Confidence
- Hot Spot - 99% Confidence

### Clustered Temporal Hotspots

**Weekly Point Prevalence Model Residuals**

Model 25AUG Predicting Week ending 2021-09-05

Moran's I = 0.074571, Z-Score = 1.648037, P-value = 0.000284

Residual Autocorrelation DETECTED
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
Using Ensemble Model to Guide Projections

Ensemble methodology that combines the Adaptive with machine learning and statistical models such as:

- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

Weekly forecasts done at county level.

Models chosen because of their track record in disease forecasting and to increase diversity and robustness.

Ensemble forecast provides additional ‘surveillance’ for making scenario-based projections.

Also submitted to CDC Forecast Hub.
Seroprevalence updates to model design

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

- CDC Nationwide Commercial Laboratory Seroprevalence Survey

These findings are equivalent to an ascertainment ratio of ~2x in the future, with bounds of (1.3x to 3x)

- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainmentas 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 and ensemble’s forecast
  - 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 generated using the collection of fit models run into the future
  - Mean trend from last 7 days of observed cases and first week of ensemble’s forecast used
  - Outliers removed based on variances in the previous 3 weeks
  - 2 week interpolation to smooth transitions in rapidly changing trajectories

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COVID-19 in Virginia:

**Cases, Hospitalizations and Deaths**

<table>
<thead>
<tr>
<th>Cases</th>
<th>Hospitalizations</th>
<th>Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>769,842</td>
<td>33,808</td>
<td>11,861</td>
</tr>
</tbody>
</table>

Accessed 10:45am September 8, 2021
https://www.vdh.virginia.gov/coronavirus/
Scenarios – Transmission Conditions

• Variety of factors continue to drive transmission rates
  • Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices

• Waning Immunity: Mean of one year protection (rate of 0.0027) similar to Pfizer study

• Projection Scenarios:
  • Adaptive: Control remains as is currently experienced into the future with assumption that Delta remains as the majority strain
  • Adaptive-SeptSurge: Following Labor Day 2021, transmission rates return to the median level from Sept-Nov of 2020 with a 60% boost over ancestral strain that dominated then.
  • Adaptive-Surge Control: Starting in one week behaviors and mitigation efforts ramp up over a 2-week period culminating in a 25% reduction in transmission
  • Adaptive-Fall: Control remains as is currently experienced into the future, with an increase in transmission that is 60% stronger than the median experienced October 2020 through February 2021 starting on Nov 1st
Scenarios – Vaccination Conditions

Vaccine Characteristics

• **Pfizer/Moderna**: 50% after first dose, 95% after second dose (3.5 week gap) J & J : 67% efficacy after first dose
• Delay to efficacy from doses is 14 days, immunity lasts at least 7m (**NEJM study**)

Vaccine Administration Scenarios

• **Status quo (no label)**: COVIDcast corrected acceptance estimates (statewide mean is ~80% adults, 65% of population) reached by end of October.
• **Optimistic (VaxOpt)**: Expand VA mean acceptance to include ”probably not” (~85% adults) with addition of childhood (5-11 yo) rollout starting in Nov 1st. This follows the same rates as observed of adolescents and results in a net increase of ~10% of population by end of February. Additionally, all counties guaranteed to reach a minimum of 65%, max of 95% by end of October
• Acceptance at county level = regional acceptance +/- relative current vax
• Front-loaded rollout (two-thirds of the remaining in half the time)
## Projection Scenarios – Combined Conditions

<table>
<thead>
<tr>
<th>Name</th>
<th>Txm Controls</th>
<th>Vax</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptive</td>
<td>C</td>
<td>SQ</td>
<td>Likely trajectory based on conditions remaining similar to the current experience</td>
</tr>
<tr>
<td>Adaptive-VaxOpt</td>
<td>C</td>
<td>VO</td>
<td>Vaccination through October reaches an optimistically high level of expanded coverage (85%)</td>
</tr>
<tr>
<td>Adaptive-Fall</td>
<td>Fall</td>
<td>SQ</td>
<td>Same as Adaptive, with increased transmissibility driven by seasonality and/or another variant starting Nov 1st</td>
</tr>
<tr>
<td>Adaptive-Fall-VaxOpt</td>
<td>Fall</td>
<td>VO</td>
<td>Optimistically expand vaccination with increased transmissibility driven by seasonality and/or another variant starting Nov 1st</td>
</tr>
<tr>
<td>Adaptive-SurgeControl</td>
<td>25%</td>
<td>SQ</td>
<td>Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta</td>
</tr>
<tr>
<td>Adaptive-SeptSurgeSurge</td>
<td>Sept</td>
<td>SQ</td>
<td>Transmission rates return to rates experienced in May 2021 with status quo vaccination and increasing prevalence of Delta</td>
</tr>
</tbody>
</table>

**Transmission Controls:**
- C = Current levels persist into the future
- 25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks
- Fall = Current levels until Nov 1st, then the median level from Oct-Feb of last year with 60% variant boost
- Sept = Transmission rates return to median of Sept-Nov 2020 with 60% boost following Labor Day

**Vaccinations:**
- SQ = Status quo acceptance leads to low rates of vaccination through the summer
- VO = Vaccination acceptance optimistically expands with increased rates through the summer
Model Results
Outcome Projections

**Confirmed cases**

Virginia Daily Confirmed - Comparison

- Adaptive
- Adaptive-VaxOpt
- Adaptive-Fall
- Adaptive-Fall-VaxOpt
- Adaptive-SeptSurge
- Adaptive-SeptSurge-VaxOpt
- Adaptive-SurgeControl

**Daily Deaths**

Death ground truth from VDH “Event Date” data, most recent dates are not complete

**Daily Hospitalized**

**Estimated Hospital Occupancy**

- Central
- Eastern
- Far SW
- Near SW
- Northern
- Northwest

9-Sep-21
Outcome Projections – Closer Look

Confirmed cases
Virginia Daily Confirmed - Comparison

- Adaptive
- Adaptive-VaxOpt
- Adaptive-Fall
- Adaptive-Fall-VaxOpt
- Adaptive-SeptSurge
- Adaptive-SeptSurge-VaxOpt
- Adaptive-SurgeControl

Daily Hospitalized
Virginia Daily Hospitalized - Comparison

Daily Deaths
Virginia Daily Death - Comparison

Death ground truth from VDH “Event Date” data, most recent dates are not complete
District Level Projections: Adaptive

Projections by Region

Near SW

Northwest

Northern

Far SW

Central

Eastern

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-VaxOpt

**Projections by Region**

- Near SW
- Northwest
- Northern
- Far SW
- Central
- Eastern

**Projections by District**

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario.

---

*University of Virginia*  
*BIOCOMPlexITY INSTITUTE*
District Level Projections: SurgeControl

Projections by Region

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: SeptSurge

Projections by Region

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-Fall

Projections by Region

Near SW  Northwest  Northern
Far SW  Central  Eastern

Projections by District

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario
District Level Projections: Adaptive-Fall-VaxOpt

Projections by Region

- Near SW
- Northwest
- Northern
- Far SW
- Central
- Eastern

Projections by District

- Central Shenandoah
- Rappahannock
- Prince William
- Alexandria
- Alleghany
- Blue Ridge
- Chickahominy
- Henrico
- Three Rivers
- Cumberland
- New River
- Roanoke City
- Central Virginia
- Piedmont
- Chesterfield
- Richmond
- Peninsula
- Hampton
- Lunenburg
- Mount Rogers
- West Piedmont
- Pittsylvania-Danville
- Southside
- Crater
- Western Tidewater
- Chesapeake
- Norfolk
- Virginia Beach

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario.
Impact of expanded vaccine acceptance

Expanded Vax coverage with higher adult coverage & 5-11 year olds in Nov

• Even if transmission rates decline after a Delta wave, expanded vax coverage can reduce case counts by ~140K, in addition to providing further resilience to future waves

• A Fall Surge can slow the declining rates following the Delta wave

• Expanded vaccination coverage including children can further curtail the impact of a Fall Surge by up to ~200K cases or dampen the effects of a boosted SeptSurge by ~180K cases
Virginia’s Progress on Population Immunity

Natural Immunity and Vaccines combine to produce a population level of immunity

- Duration of immunity from infection with SARS-CoV2 still not well understood
  - We assume a conservative 6 month period of protection for these calculations
  - Do not factor in variant immune escape
  - Natural immunity is well calibrated to recent seroprevalence surveys

- Vaccine induced immunity is likely to last longer, we assume indefinite protection
  - This also assumes that all administered vaccines remain protective against current and future variants

- Population immunity depends on a very high proportion of the population getting vaccinated
  - Current models track measured seroprevalence

<table>
<thead>
<tr>
<th>Region</th>
<th>% pop immune (est.)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>59%</td>
</tr>
<tr>
<td>Eastern</td>
<td>56%</td>
</tr>
<tr>
<td>Far SW</td>
<td>50%</td>
</tr>
<tr>
<td>Near SW</td>
<td>53%</td>
</tr>
<tr>
<td>Northern</td>
<td>67%</td>
</tr>
<tr>
<td>Northwest</td>
<td>58%</td>
</tr>
<tr>
<td>Virginia</td>
<td>59%</td>
</tr>
</tbody>
</table>

* As of Sept 5, 2021 (updated to account for entire population)
Hospital Demand and Bed Capacity by Region

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

Adaptive SeptSurge scenario shows that even with Delta enhanced severity:
- No regions should exceed their surge capacities
- Some regions may exceed initial capacities

* Assumes average length of stay of 8 days

[https://nssac.bii.virginia.edu/covid-19/vmrddash/](https://nssac.bii.virginia.edu/covid-19/vmrddash/)
Key Takeaways

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

• **Case rates in Virginia continue to rise though the pace remains steady while US plateaus and some states start to decline; case rates remain very high**

• VA mean weekly incidence flat at 38/100K from 37/100K, US flat to 48/100K (from 48/100K)

• Projections continue to show significant uptick in activity, however, the reduced pace has decreased the overall impact

• Recent updates:
  • Added a SeptSurge based on transmission rates from last year Labor Day to Thanksgiving with variant boosting
  • Added Fall surge scenario to capture potential rebounds and further test immunity from expanded vaccination
  • Updated Optimistic Vaccination to include potential inclusion of 5-11 year olds this Fall

The situation continues to change. Models continue to be updated regularly.
Additional Analyses
Estimating Daily Reproductive Number – Redistributed weekend gap

Sept 6th Estimates

<table>
<thead>
<tr>
<th>Region</th>
<th>Date Confirmed</th>
<th>Date Confirmed Diff Last Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-wide</td>
<td>0.933</td>
<td>-0.030</td>
</tr>
<tr>
<td>Central</td>
<td>0.908</td>
<td>-0.016</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.905</td>
<td>-0.009</td>
</tr>
<tr>
<td>Far SW</td>
<td>0.936</td>
<td>-0.048</td>
</tr>
<tr>
<td>Near SW</td>
<td>1.019</td>
<td>-0.080</td>
</tr>
<tr>
<td>Northern</td>
<td>0.914</td>
<td>-0.020</td>
</tr>
<tr>
<td>Northwest</td>
<td>0.982</td>
<td>-0.083</td>
</tr>
</tbody>
</table>

Skipping Weekend Reports biases estimates
Redistributed Monday to fill in weekend, and then estimate R from "smoothed" time series

Methodology

- Wallinga-Teunis method (EpiEstim1) for cases by confirmation date
- Serial interval: updated to discrete distribution from observations (mean=4.3, Flaxman et al, Nature 2020)
- Using Confirmation date since due to increasingly unstable estimates from onset date due to backfill

Overview of relevant on-going studies

Other projects coordinated with CDC and VDH:

• **Scenario Modeling Hub**: Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios

• **Genomic Surveillance**: Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.

• **Mobility Data driven Mobile Vaccine Clinic Site Selection**: Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify
COVID-19 Scenario Modeling Hub

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios that vary vaccine rates (high – low) and impact of the Delta variant (high and low)

• Round 8 in planning
• Round 7 now available

Round 4 Results were published May 5th, 2021 in MMWR

https://covid19scenariomodelinghub.org/viz.html
COVID-19 Scenario Modeling Hub – Round 7

Round 7 scenarios explore the effects of a variant similar to Delta (B.1.617.2) against different backgrounds of vaccination. Includes some vax escape

Vaccinations by Nov 30

- LowVacc – 70% overall coverage
- HighVacc – 80% overall coverage

Emerging Variant Impact (5% prevalence on May 29th)

- LowVar – 40% more transmissible
- HighVar – 60% more transmissible

See more detailed notes for each scenario below

<table>
<thead>
<tr>
<th>Vaccination (Low hesitancy)</th>
<th>Low vacc</th>
<th>High vacc</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Vaccination (Low hesitancy)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaccination:</td>
<td>Low Var</td>
<td>High Var</td>
</tr>
<tr>
<td>- Coverage saturates at 80% nationally among the vaccine-eligible population* by December 31, 2021**</td>
<td>Low Var</td>
<td>High Var</td>
</tr>
<tr>
<td>- VE is 50%/90% for Pfizer/Moderna against the Delta variant, against symptoms (1st/2nd dose)</td>
<td>Low Var</td>
<td>High Var</td>
</tr>
<tr>
<td>- JS or no longer used</td>
<td>Low Var</td>
<td>High Var</td>
</tr>
<tr>
<td>Variant:</td>
<td>Low Var</td>
<td>High Var</td>
</tr>
<tr>
<td>- 40% increased transmissibility as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams</td>
<td>Low Var</td>
<td>High Var</td>
</tr>
</tbody>
</table>

vaccinations by Nov 30

- LowVacc – 70% overall coverage
- HighVacc – 80% overall coverage

Emerging Variant Impact (5% prevalence on May 29th)

- LowVar – 40% more transmissible
- HighVar – 60% more transmissible

https://covid19scenariomodelinghub.org/viz.html

9-Sep-21
Modeling Hub – Round 7 Prelim Results

[Graph showing Virginia Daily Confirmed cases]

https://covid19scenariomodelinghub.org/viz.html
COVID-19 Scenario Modeling Hub – Round 8 (ongoing)

Round 8 scenarios targeted at exploring the effect of waning immunity (natural and vaccine-induced) and varying levels of protection after waning

Waning Rates

• Slow – exp. waning with mean=3yrs
• Fast – exp. waning with mean=1yr
• No waning (Sc A) as baseline

Protection after Waning

• Age stratified protection from infection
• 80% or 90% protection from hosp/death

---

<table>
<thead>
<tr>
<th>Slow Waning</th>
<th>Fast Waning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario A</strong></td>
<td><strong>Scenario B</strong></td>
</tr>
<tr>
<td>High protection against infection and severe disease after waning</td>
<td>No Waning: - Vaccine-induced and natural immunity retain their initial protection throughout the simulation period</td>
</tr>
<tr>
<td><strong>Scenario C</strong></td>
<td><strong>Scenario D</strong></td>
</tr>
<tr>
<td>Low protection against infection and severe disease after waning</td>
<td>Waning: - Exponentially distributed immune waning with mean of 3 years (time to transition to partially immune state)</td>
</tr>
<tr>
<td></td>
<td>In partially immune state: - Protection from infection is: - 70% ≤ 65yrs - 35% &gt; 65yrs - Protection from hospitalization and death is 80%</td>
</tr>
<tr>
<td></td>
<td>In partially immune state: - Protection from infection is: - 50% ≤ 65yrs - 25% &gt; 65yrs - Protection from hospitalization and death is 80%</td>
</tr>
</tbody>
</table>

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https://covid19scenariomodelinghub.org/
Data Recommended Mobile Vax Clinic Sites

Detailed and Timely Locations

Data Delivered and Disseminated to Locals
Provides a list of areas most visited by a given demographic group based on SafeGraph mobility data that links visits to specific sites and the home Census Block Group of the anonymized visitors.

Demographic Groups: Black, Lantinx, Young Adults (20-40), Unvaccinated, and Whole Population

Data Included: Rank, Weight, most visited Day of Week, Highly Visited Address, and Lat-Long of area

Goal: Provide frequently visited locations based on populations and vaccination levels one desires to reach

Example: List of location in the Southside frequented by 20-40 year olds
Data Recommended Mobile Vax Clinic Sites

Overlap of locations between groups

Different groups visit different areas
- Least overlap between Black and Latinx
- Overlap in ages highest, but drops with large gap
- Districts have different overlap patterns
References


NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. [https://github.com/NSSAC/PatchSim](https://github.com/NSSAC/PatchSim)


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

Questions?

Biocomplexity COVID-19 Response Team

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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