Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

# Estimation of COVID-19 Impact in Virginia

August 25th, 2021

(data current to August 22nd – 25th)

Biocomplexity Institute Technical report: TR 2021-095

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# 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:

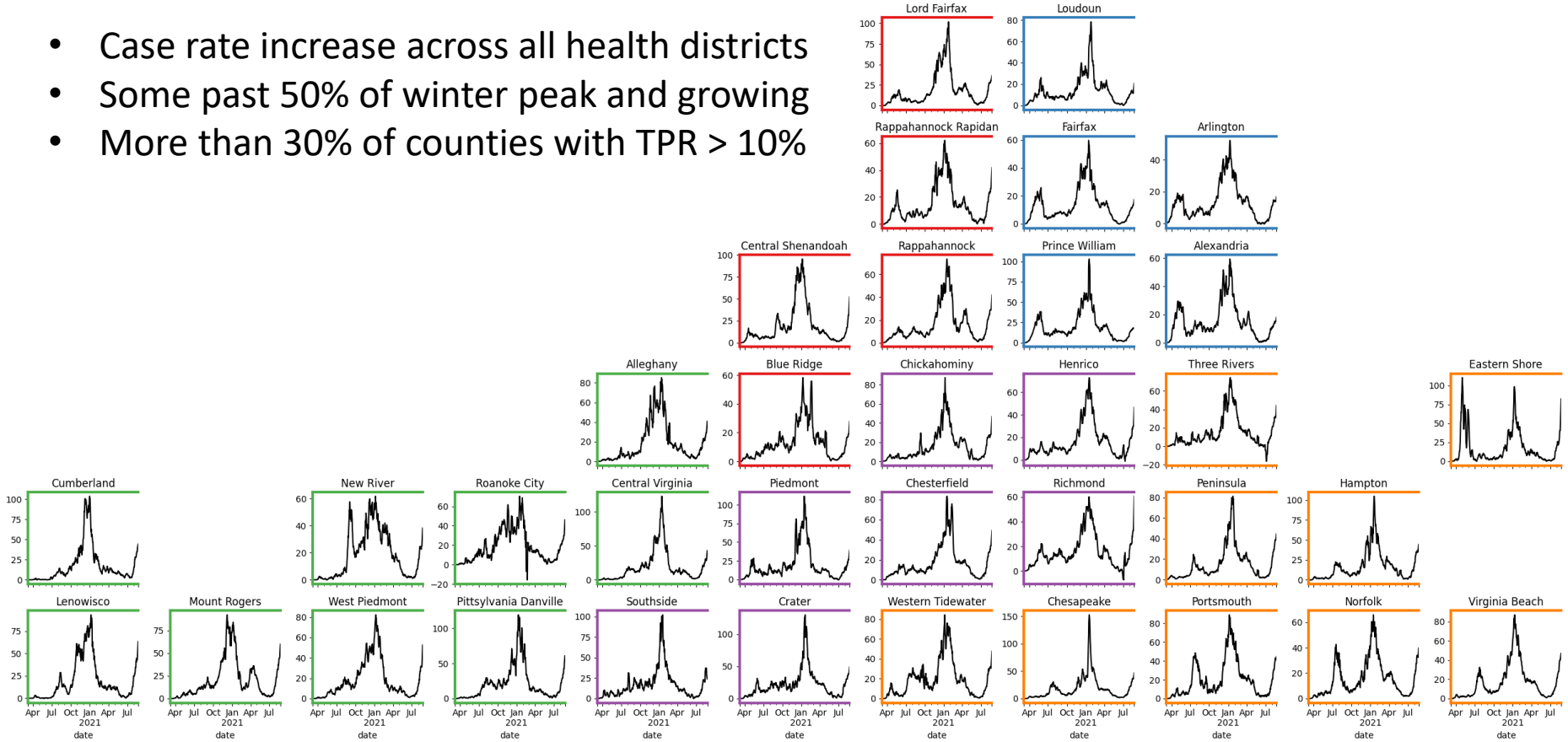
- **Case rates in Virginia continue to rise though the pace has slightly slowed, other states have plateaued, but rates remain high**
- VA mean weekly incidence up to 30/100K from 24/100K, US up to 44/100K (from 38/100K)
- Growth in vaccination rates stall, however, FDA approval may boost in coming weeks
- Projections continue to show significant uptick in activity, however, the slackened pace has decreased the overall impact
- Recent updates:
  - Updated Optimistic Vaccination to include potential inclusion of 5-11 year olds this Fall
  - Updated Surge Control scenario to commence sooner as mask use has increased recently

The situation continues to change. Models continue to be updated regularly.

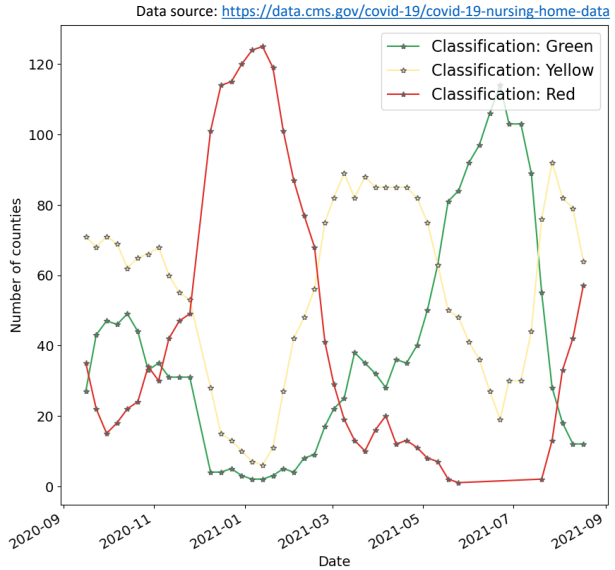
# Situation Assessment

# Case Rates (per 100k) and Test Positivity

- Case rate increase across all health districts
- Some past 50% of winter peak and growing
- More than 30% of counties with TPR > 10%




Data source: https://data.cms.gov/covid-19/covid-19-nursing-home-data




**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")

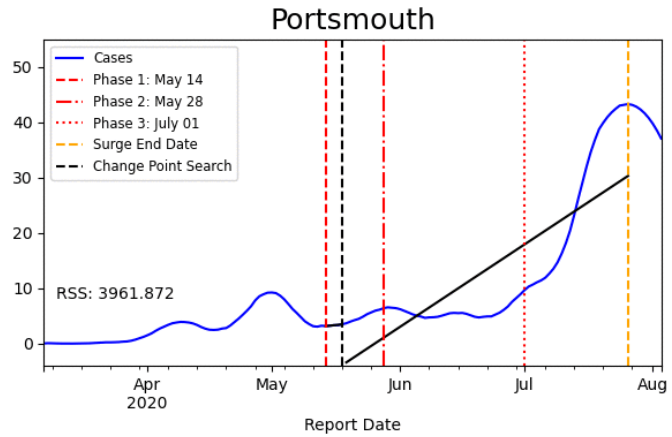
| Classification date | Green | Red | Yellow |
|---|---|---|---|
| 2021-07-20 | 55.0 | 2.0 | 76.0 |
| 2021-07-27 | 28.0 | 13.0 | 92.0 |
| 2021-08-03 | 18.0 | 33.0 | 82.0 |
| 2021-08-10 | 12.0 | 42.0 | 79.0 |

# 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

Hockey stick fit

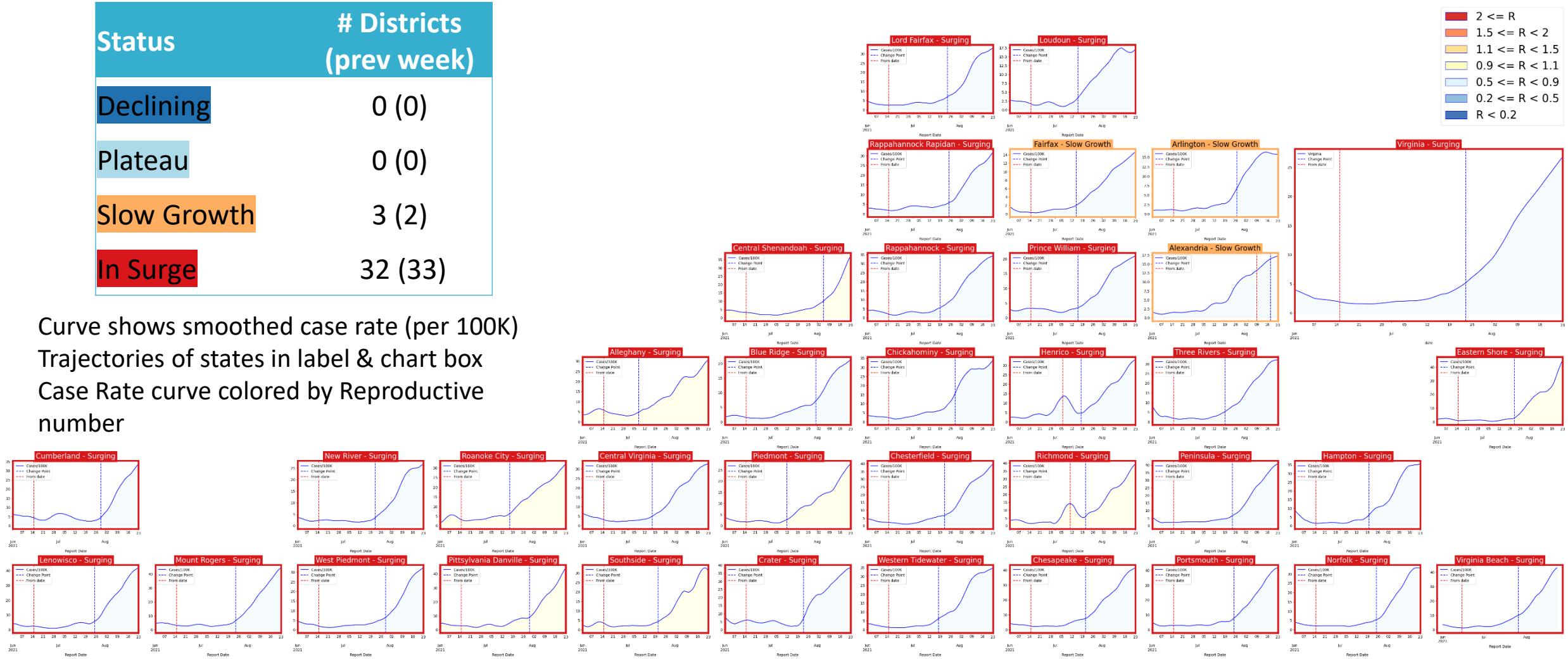



| Trajectory | Description | Weekly Case Rate (per 100K) bounds | # Districts (prev week) |
|---|---|---|---|
| **Declining** | Sustained decreases following a recent peak | below -0.9 | 0 (0) |
| **Plateau** | Steady level with minimal trend up or down | above -0.9 and below 0.5 | 0 (0) |
| **Slow Growth** | Sustained growth not rapid enough to be considered a Surge | above 0.5 and below 2.5 | 3 (2) |
| **In Surge** | Currently experiencing sustained rapid and significant growth | 2.5 or greater | 32 (33) |

# District Trajectories – last 10 weeks

| Status | # Districts (prev week) |
|---|---|
| Declining | 0 (0) |
| Plateau | 0 (0) |
| Slow Growth | 3 (2) |
| In Surge | 32 (33) |

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

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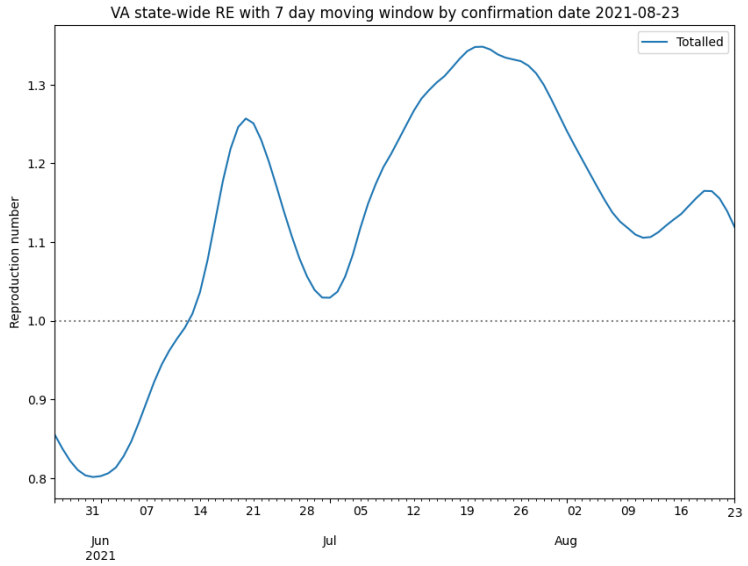
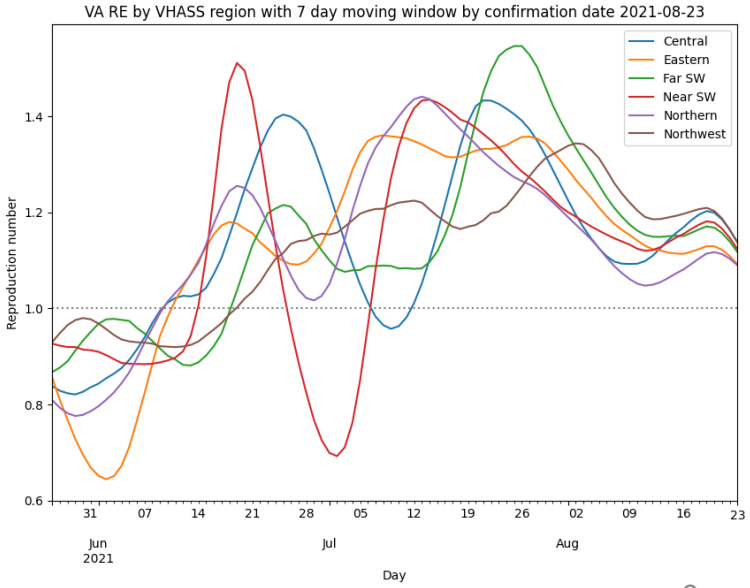
# Estimating Daily Reproductive Number

## August 23rd Estimates

| Region | Date Confirmed $R_e$ | Date Confirmed Diff Last Week |
|---|---|---|
| State-wide | 1.119 | -0.001 |
| Central | 1.137 | 0.005 |
| Eastern | 1.092 | -0.038 |
| Far SW | 1.117 | -0.017 |
| Near SW | 1.124 | 0.009 |
| Northern | 1.090 | 0.019 |
| Northwest | 1.138 | 0.007 |



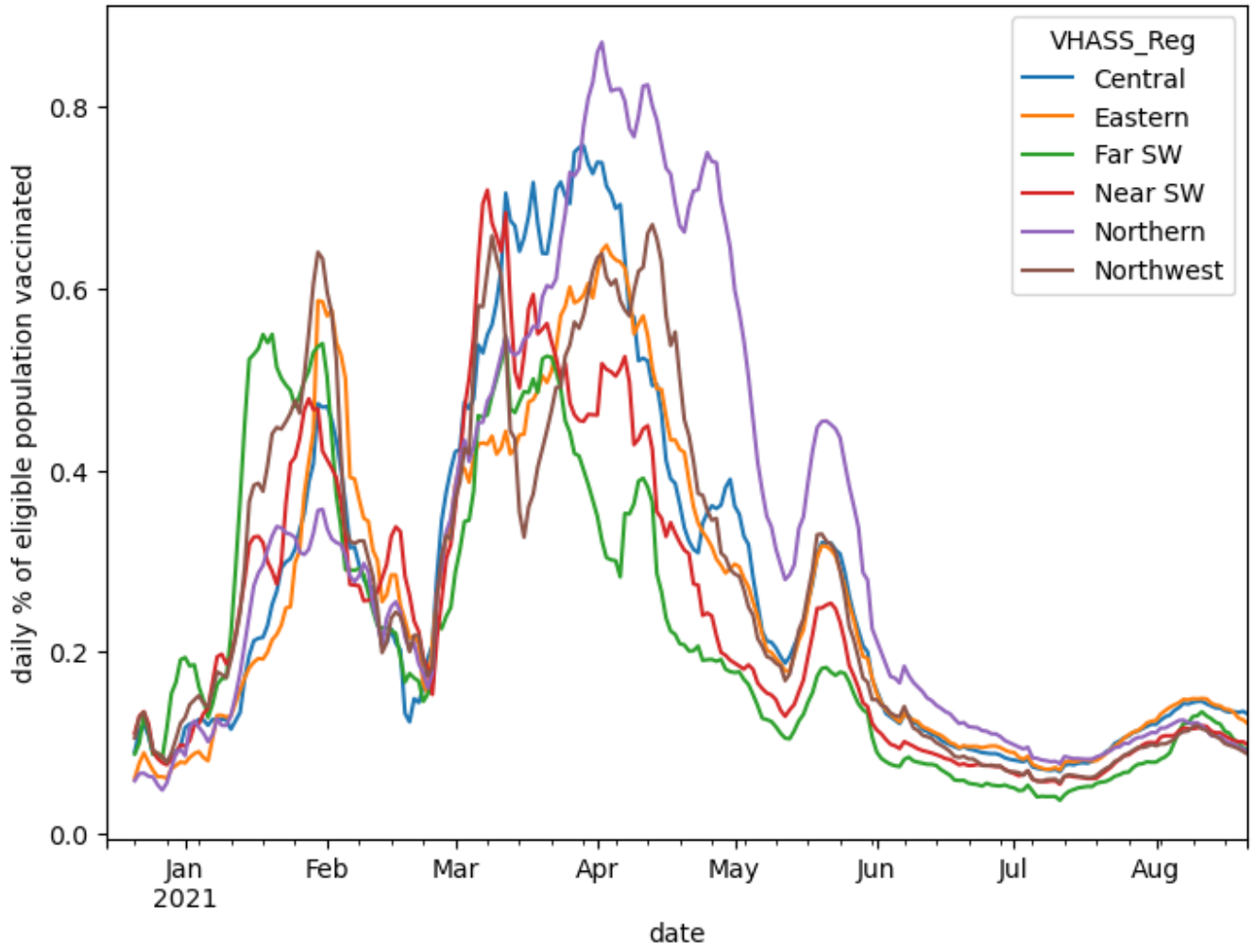




### Methodology

- Wallinga-Teunis method (EpiEstim[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

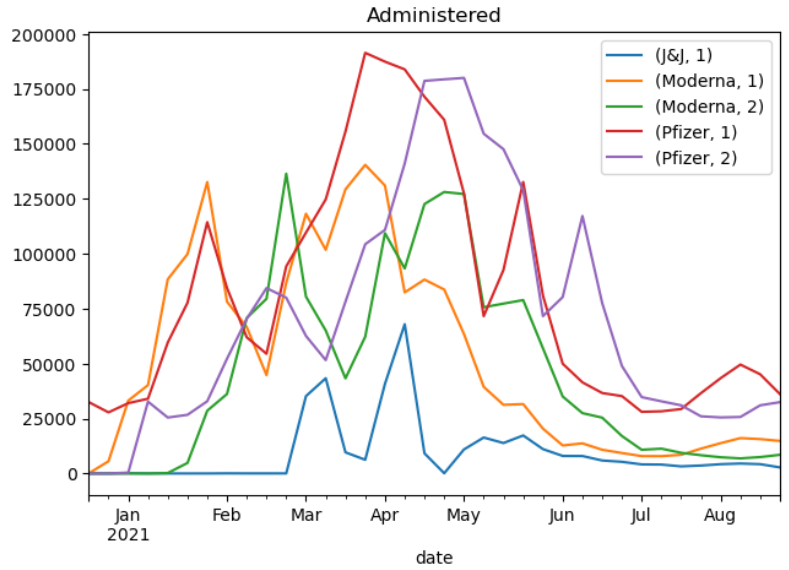

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

# Vaccination Administration Slows




**Regional Vaccine courses initiated per day:**

- Total counts of first dose of vaccines across regions
- Rise of last few weeks stalls

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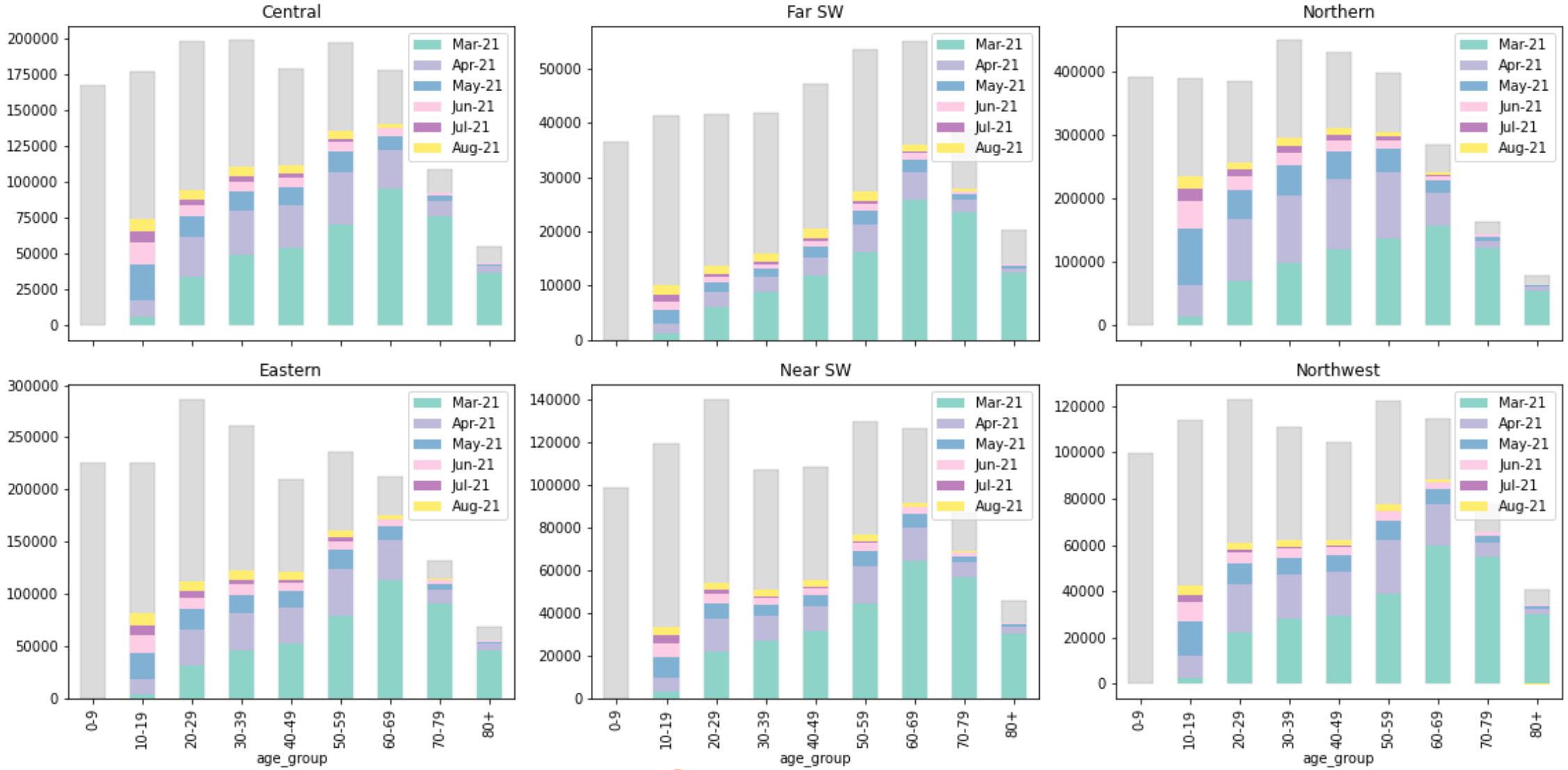
# Vaccinations Shift to Younger Populations

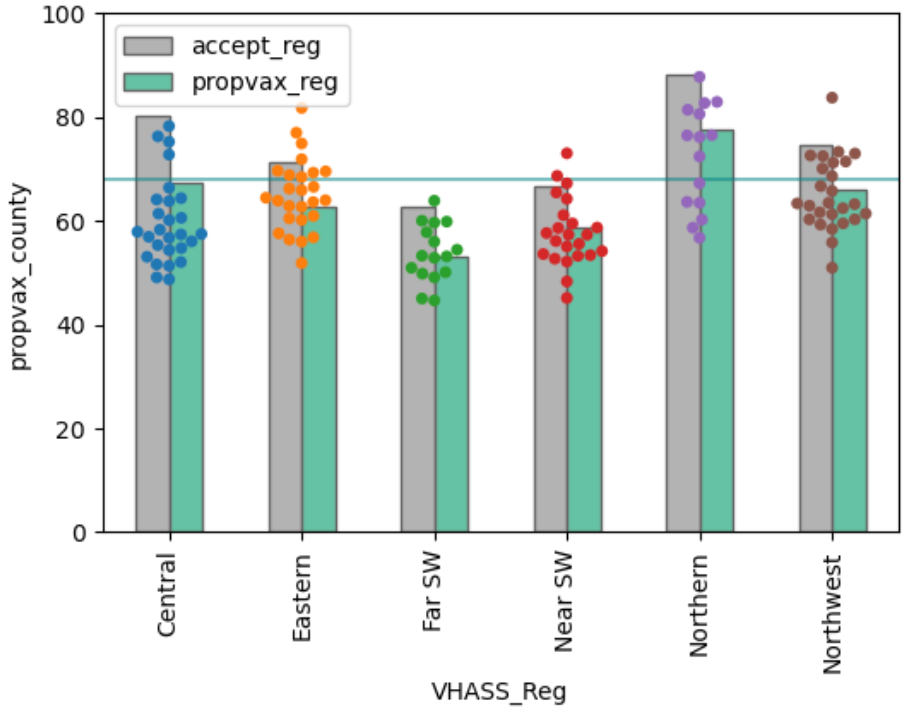


# Vaccination Acceptance by Region

**Corrections to surveys:**

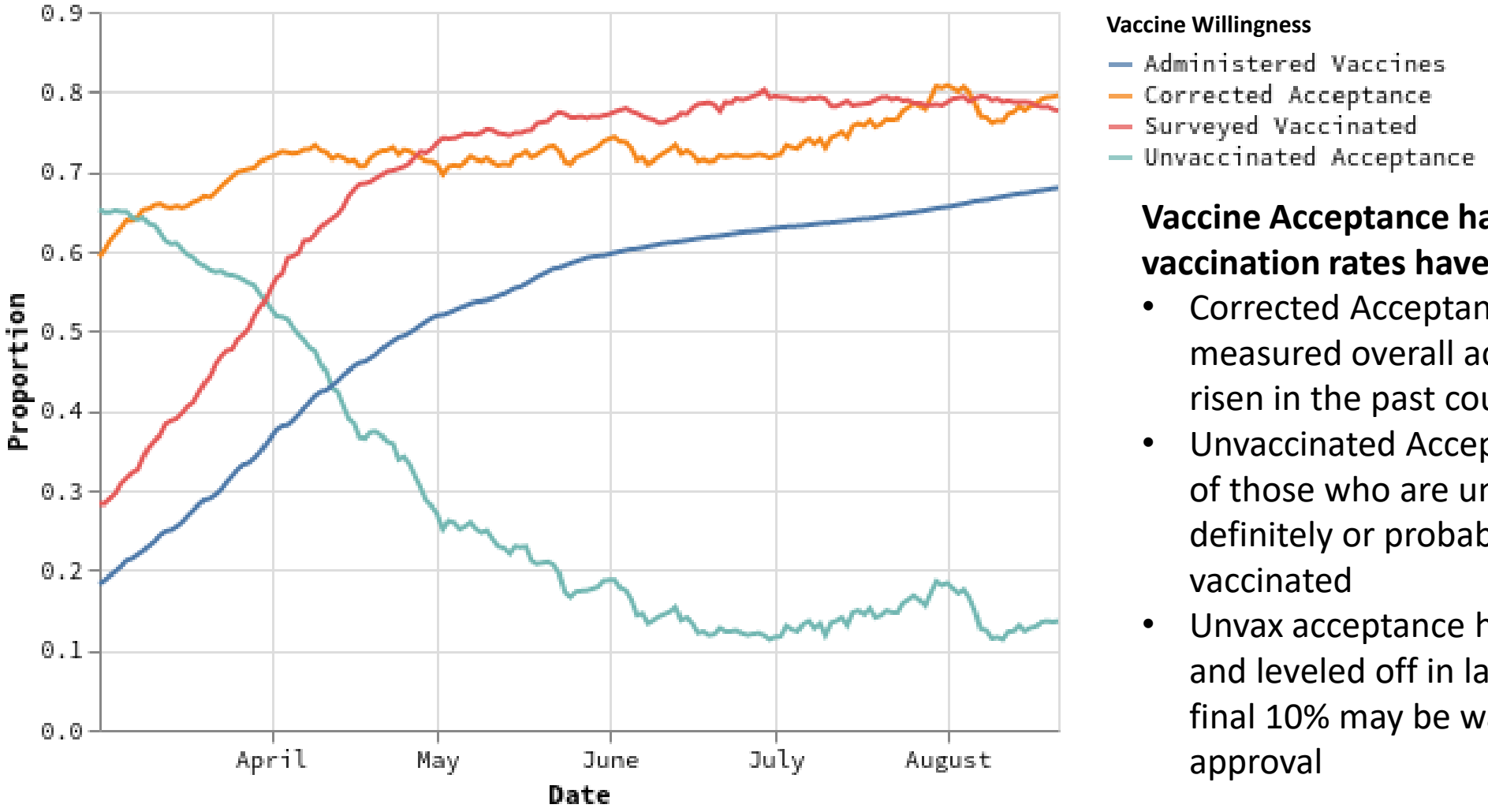
- Facebook administered survey is timely and broad, but biased by who accesses Facebook and answers the survey
- Correction approach:
  - Calculate an over-reporting fraction based on reported vaccinations compared to VDH administration data
  - Cross-validate coarse corrections against HPS survey at the state level and corrected in same manner

| Region | COVIDcast accepting corrected | VDH proportion eligible vaccinated |
|---|---|---|
| Central | 80% | 67% |
| Eastern | 75% | 63% |
| Far SW | 66% | 53% |
| Near SW | 69% | 59% |
| Northern | 88% | 77% |
| Northwest | 73% | 66% |
| **Virginia** | **80%** | **68%** |




**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




**Vaccine Acceptance has risen as vaccination rates have climbed**

- Corrected Acceptance reflects the daily measured overall acceptance and has risen in the past couple days
- Unvaccinated Acceptance shows ~10% of those who are unvaccinated are definitely or probably willing to be vaccinated
- Unvax acceptance has declined a bit and leveled off in last couple of weeks, final 10% may be waiting for FDA approval

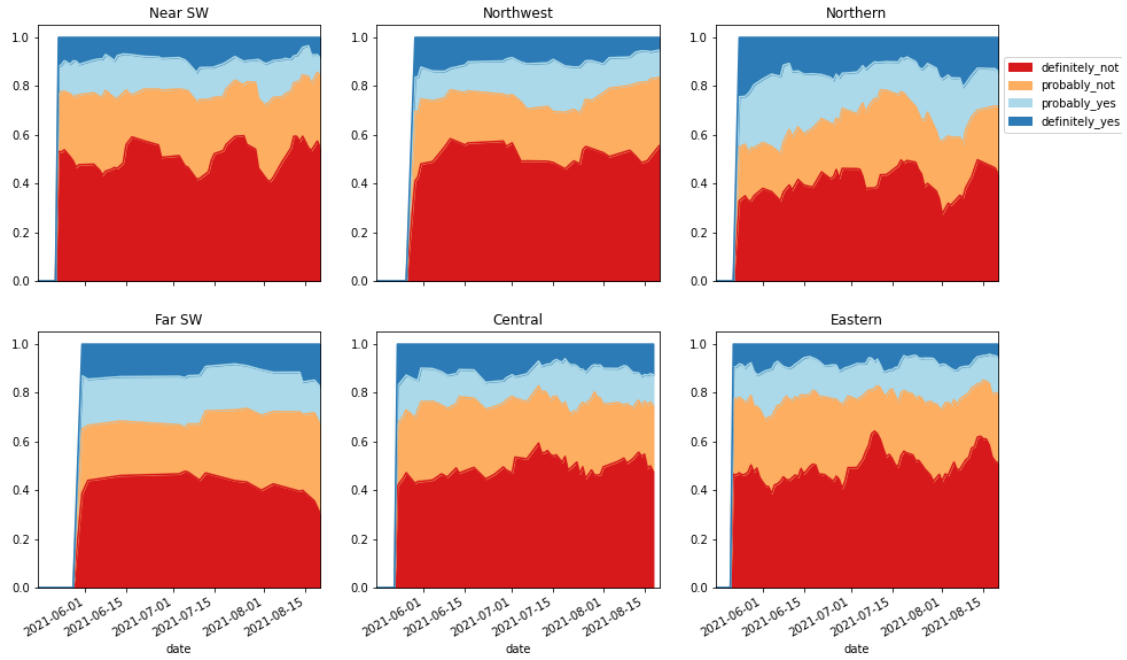
Data Source: https://covidcast.cmu.edu

# Vaccine Acceptance by Region- COVIDcast

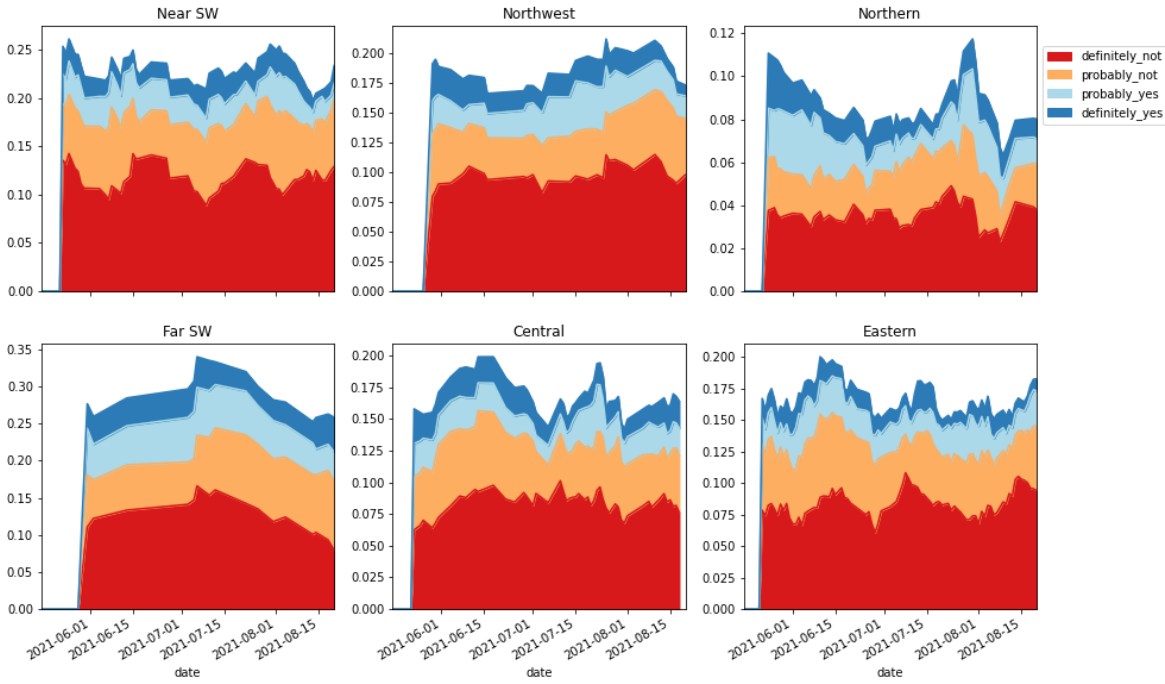
**Levels of Acceptance and potential acceptance in flux:**

- 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.

**Unvaccinated Only**



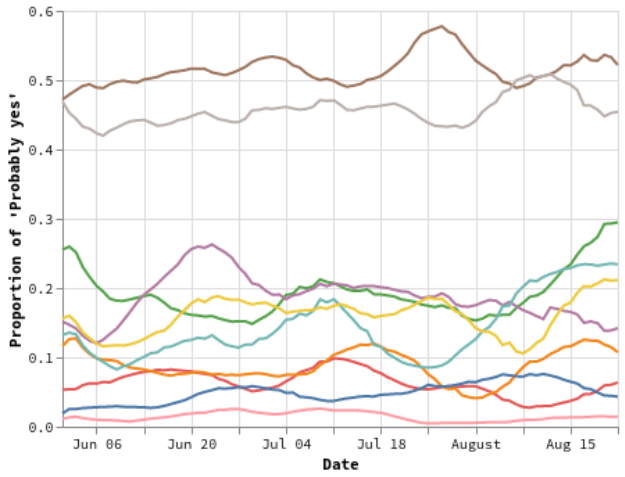

**All Respondents**



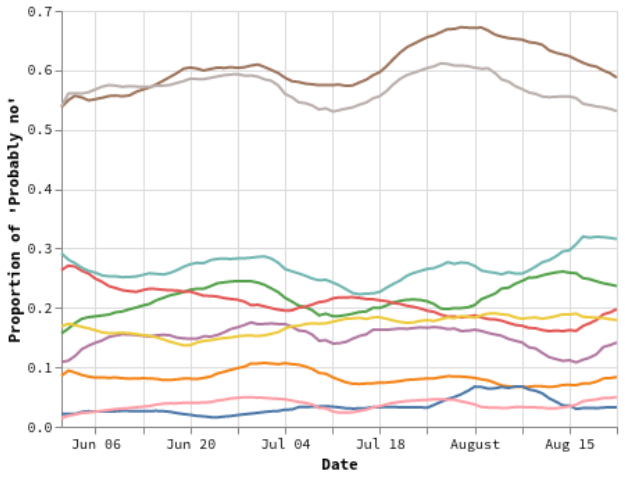

Data Source: [https://covidcast.cmu.edu](https://covidcast.cmu.edu)

# Reasons for Hesitancy by Likeliness to Accept

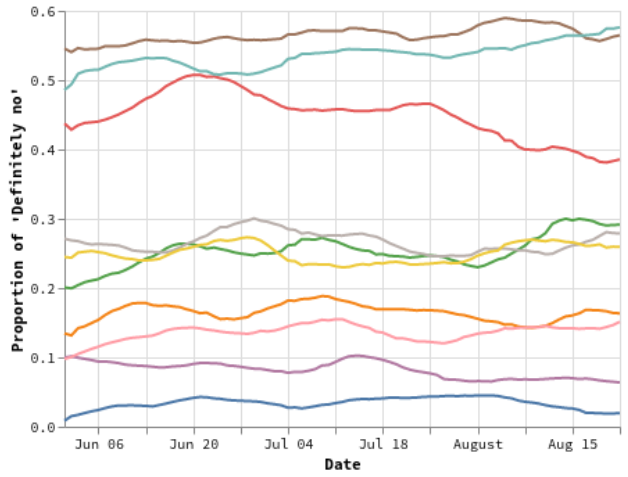
Probably Yes

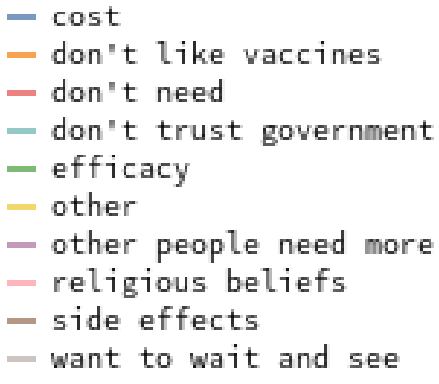



Probably No




Definitely No




**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

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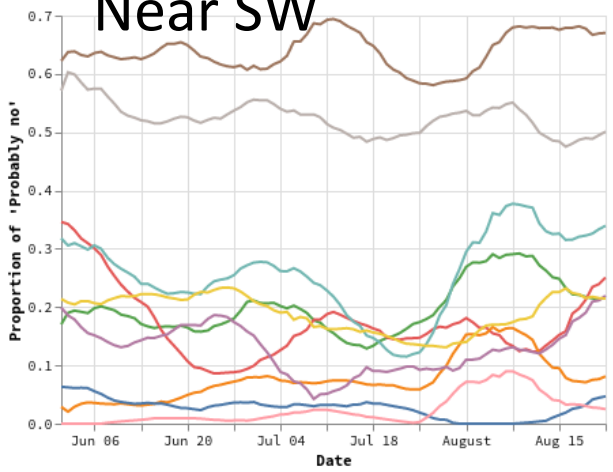
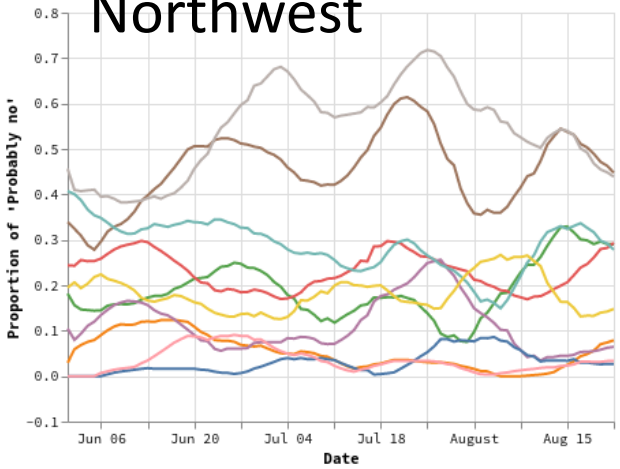
Data Source: https://covidcast.cmu.edu

# Reasons for Hesitancy of Probably No by Region

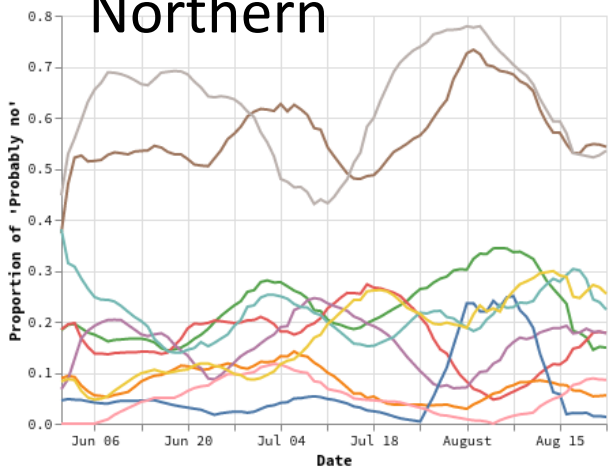
Near SW

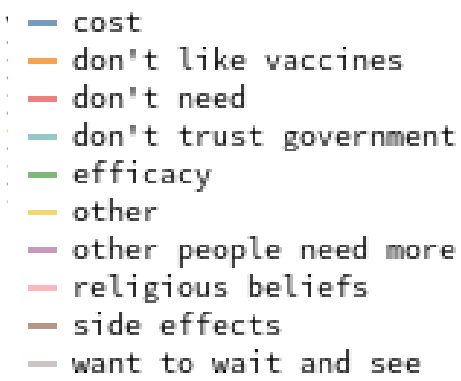



Northwest

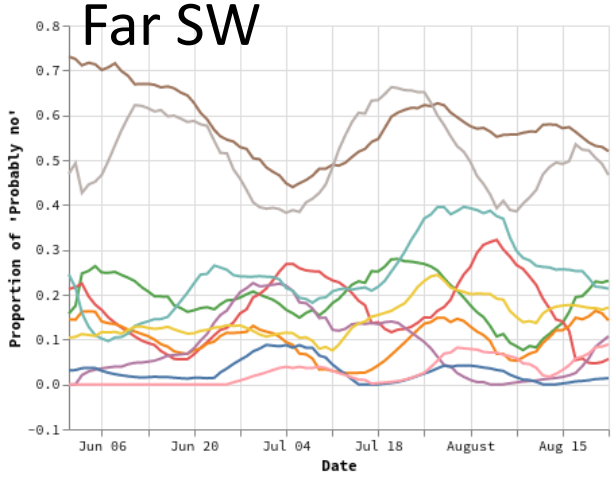



Northern

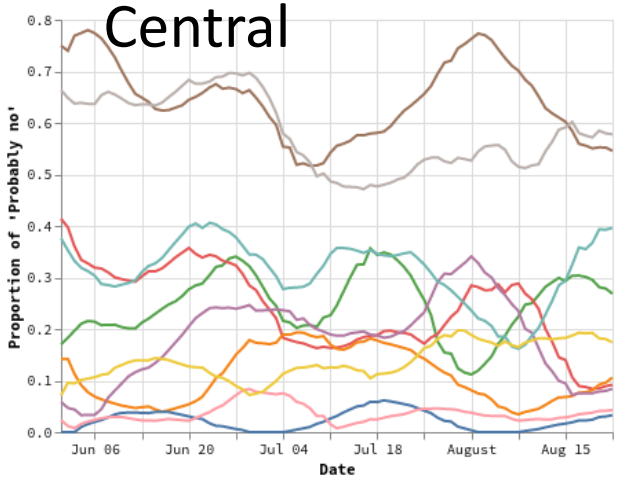


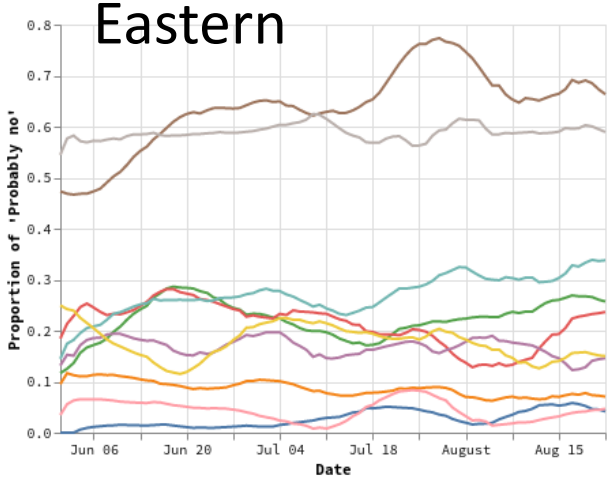

Far SW




Central




Eastern




**Reasons for Hesitancy vary across Regions**

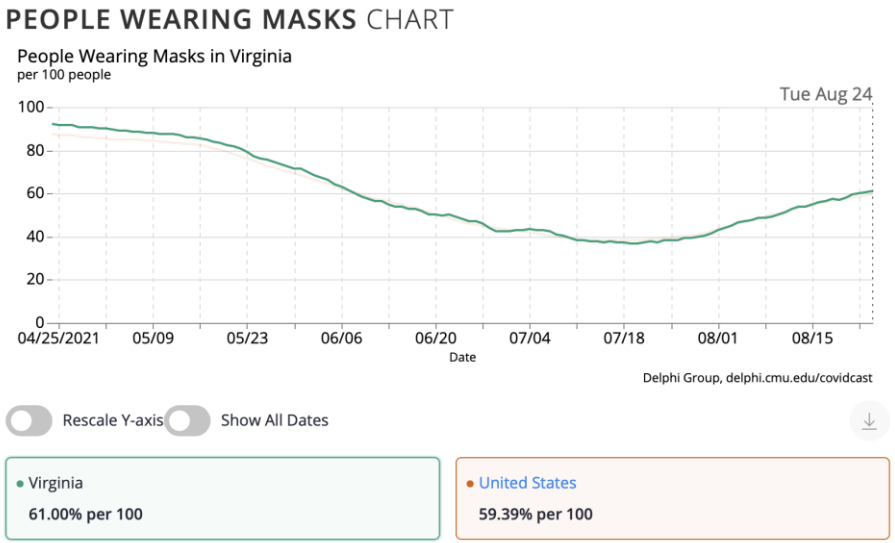
- Side effects and waiting to see safety are primary
- Most movement in last couple weeks seen in trust of govt and efficacy

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
- Progress in some counties has stalled or declined


| | | |
|---|---|---|
| Virginia | ↑ +8.12% | 57.12% /100 |
| Spotsylvania County, VA | ↓ −18.49% | 49.87% /100 |
| Virginia Beach, VA | ↑ +11.63% | 51.00% /100 |
| Chesterfield County, VA | ↑ +8.97% | 57.08% /100 |
| Chesapeake, VA | ↑ +9.06% | 58.48% /100 |
| Norfolk, VA | ↑ +10.81% | 59.93% /100 |
| Albemarle County, VA | ↓ −12.16% | 61.70% /100 |
| Henrico County, VA | ↑ +5.38% | 62.74% /100 |
| Hampton, VA | ↓ −5.15% | 63.18% /100 |
| Newport News, VA | → −4.65% | 63.73% /100 |
| Loudoun County, VA | ↑ +20.04% | 66.12% /100 |
| Arlington County, VA | ↑ +17.52% | 66.64% /100 |
| Stafford County, VA | ↑ +24.79% | 66.93% /100 |
| Prince William County, VA | ↑ +20.53% | 68.09% /100 |
| Richmond, VA | → −3.34% | 69.13% /100 |
| Fairfax, VA | ↑ +8.11% | 75.08% /100 |

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

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# 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
- “Probably Not” rebounds, though lags the ”yes”
- All other vaccine willingness levels have similar mask wearing levels


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

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# SARS-CoV2 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

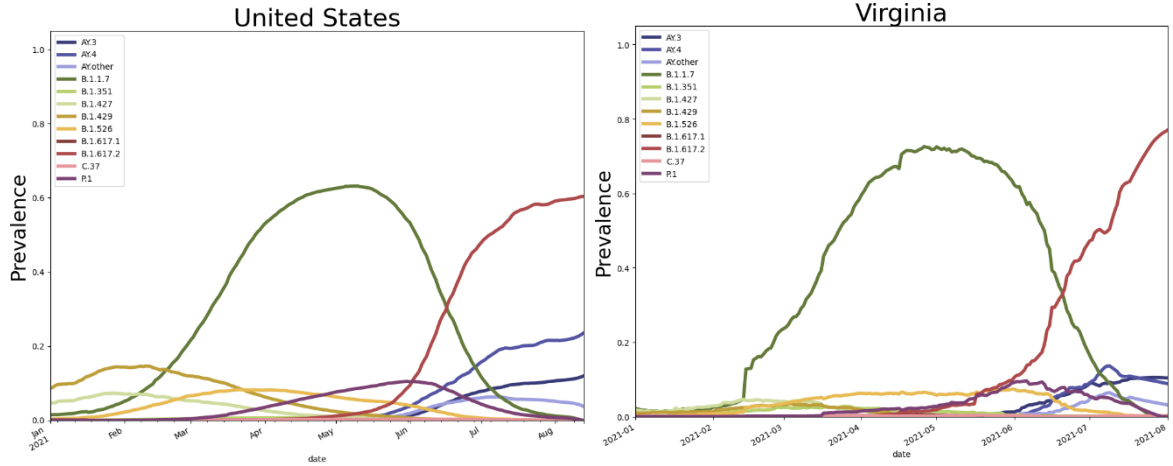
| | New WHO Name | Transmissibility | Immune Evasiveness | Vaccine Effectiveness^ |
|---|---|---|---|---|
| Ancestral | | — | — | ✓ |
| D614G | | + | — | ✓ |
| B.1.1.7 | Alpha | +++ | — | ✓ |
| B.1.351 | Beta | + | ++++ | ✓ |
| P.1 | Gamma | ++ | ++ | ✓ |
| B.1.429 | Epsilon | + | + | ✓ |
| B.1.526 | Iota | + | + | ✓ |
| B.1.617.2 | Delta | ++++* | ++# | ✓ |

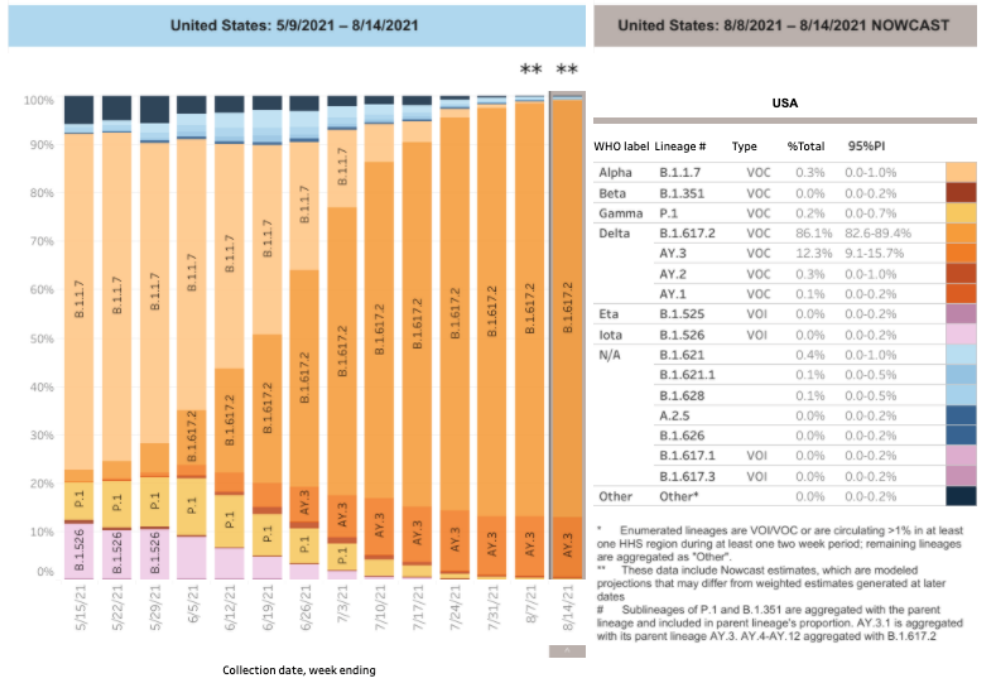
*Relative transmissibility to B.1.1.7 yet to be fully defined
^Effectiveness from real world evidence vs. severe illness, not all vaccines are effective vs all variants, and importance of 2-doses, especially for B.1.617.2 for which 1 dose of mRNA or AZ is only ~30% effective # May carry more immune escape than P.1, to be determined

World Health Organization

WHO and Eric Topol

GISAID outbreak.info




CDC Variant Tracking

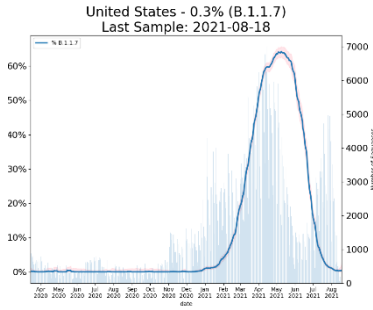
# SARS-CoV2 Variants of Concern

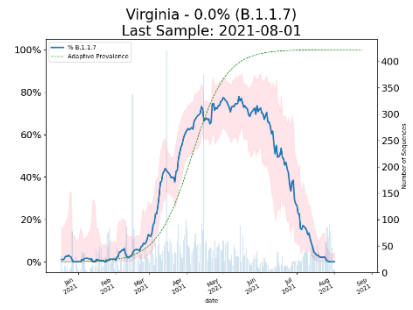
## Alpha α - Lineage B.1.1.7

**Prevalence:** Nationally low, decline from a high of 60% (VA reached about 80%)

**Transmissibility:** Estimated increase of 50% compared to previous variants. B.1.1.7's mutations boost its overall levels of viremia; study from Public Health England shows contacts of B.1.1.7 cases are more likely (50%) to test positive

**Severity:** Increased risk of hospitalization (60%) and mortality (60%). Danish study shows B.1.1.7 to have a 64% higher risk of hospitalization, while Public Health Scotland studies showed a range of 40% to 60%; Study in Nature estimates 60% higher mortality

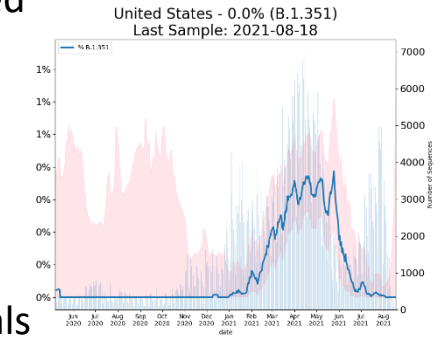


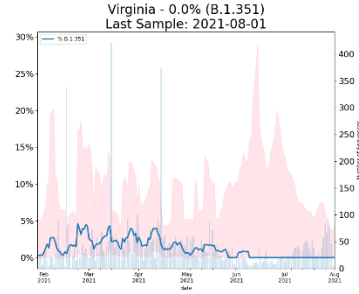




## Beta β - Lineage B.1.351

**Prevalence**: Levels have remained low, as this variant's transmissibility can't compete with B.1.1.7, however, as more of the population becomes immune it may gain an advantage

**Immune Escape:** Many studies show that convalescent sera from previously infected individuals does not neutralize B.1.351 virus well which is predictive of protection, however, vaccine induced immunity shows signs of effectiveness

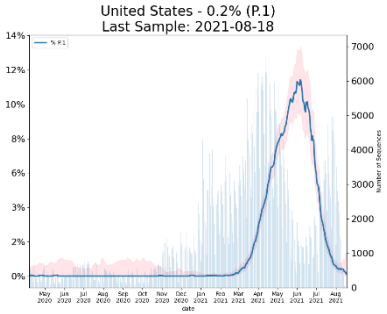


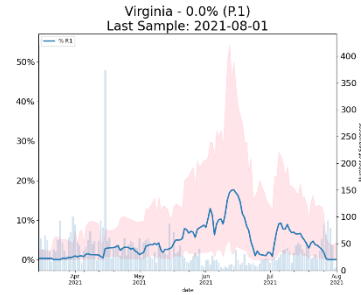




## Gamma γ - Lineage P.1

**Prevalence:** Nationally low, declining from a high of 12%

Study estimates 17-32% of all infections in Manaus in 2021 were reinfections, which helps explain data from Brazil demonstrating P.1's continued dominance in Rio despite presence of B.1.1.7

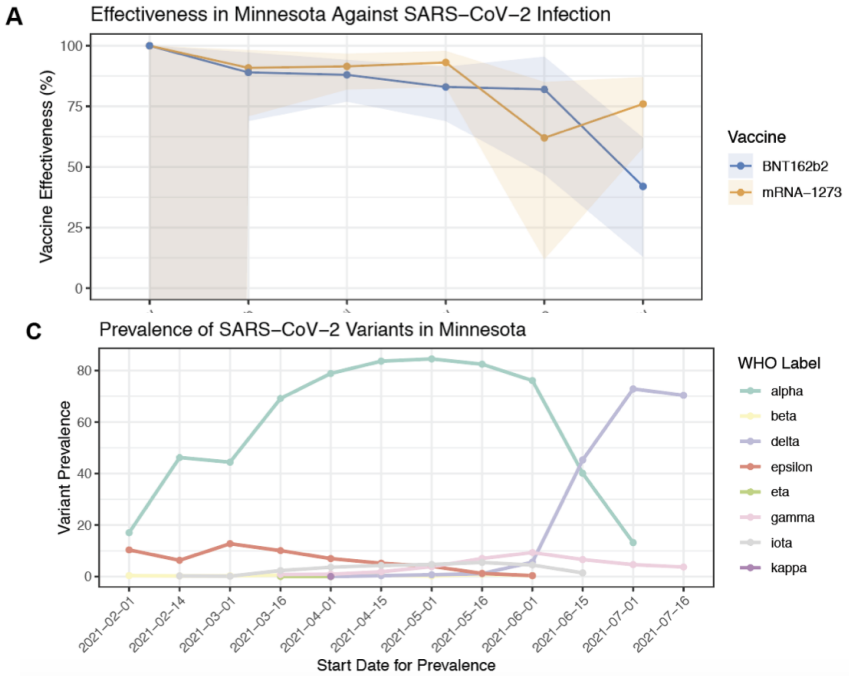


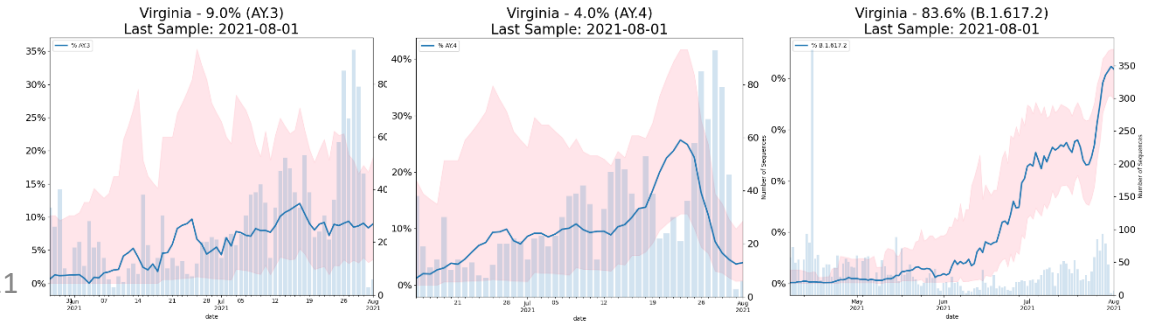
# SARS-CoV2 Variants of Concern

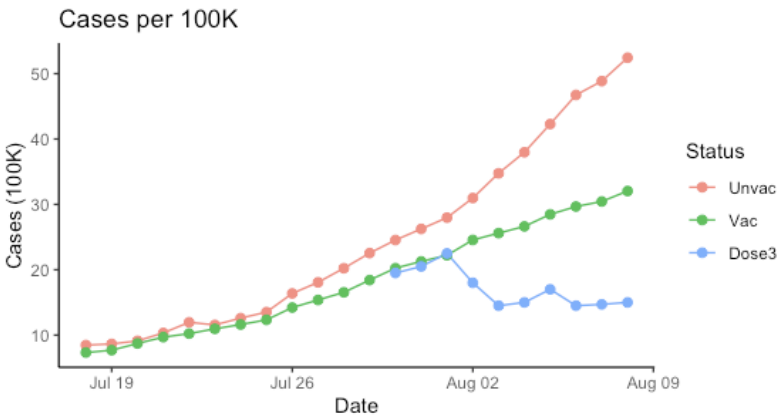
**Delta δ - Lineage B.1.617.2 and related subvariants**

- 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 (9%) and AY.4 (4%) of Delta are more prevalent, may be more transmissible than Delta itself




**Vax effectiveness drops as Delta rises.**
Measured effectiveness of Pfizer (BNT162b2) and Moderna (mRNA-1273) over time in the Mayo Clinic health system. BioRxiv




**3rd dose of Vax seems to be more effective even against Delta**
Preliminary data on third dose against Delta in Israel
Eric Topol
Israeli gov data

# Variants & Vaccines

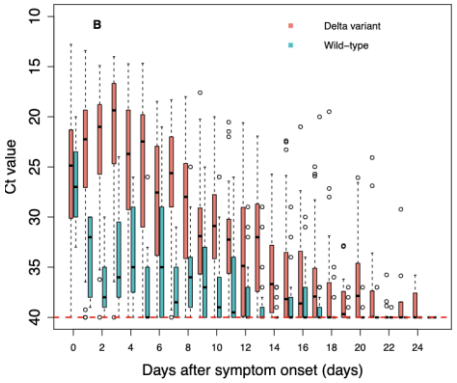
1. Sentinel surveillance of frontline healthcare workers shows reduced efficacy (MMWR)
2. Latent period shorter in Delta infections and higher viral loads
3. Pfizer based study of 3.3M suggests protection against infection reduction may be due to waning at 6 months more than vax escape of Delta
4. UK suffering weaker hospital wave than US mainly due to vaccination
5. Simpson's paradox explains misestimation of efficacy if not controlled by age
6. Specific mutations that may cause immune escape being identified in Delta

1

| | | | | | |
|---|---|---|---|---|---|
| Pre-Delta variant predominance | | | | | |
| Unvaccinated | 4,137 | 156,626 | 19 (8–43) | 175 | N/A |
| Fully vaccinated | 2,875 | 329,865 | 124 (95–149) | 10 | 91 (81–96) |
| Delta variant predominance | | | | | |
| Unvaccinated | 488 | 24,871 | 43 (37–69) | 19 | N/A |
| Fully vaccinated | 2,352 | 119,218 | 49 (35–56) | 24 | 66 (26–84) |

**Effectiveness of COVID-19 Vaccines in Preventing SARS-CoV-2 Infection Among Frontline Workers Before and During B.1.617.2 (Delta) Variant Predominance** Health care personnel, first responders, and other essential and frontline workers in eight U.S. locations across six states were tested weekly for SARS-CoV-2 infection by RT-PCR and upon the onset of any COVID-19–like illness.
https://www.cdc.gov/mmwr/volumes/70/wr/mm7034e4.htm?s_cid=mm7034e4_w

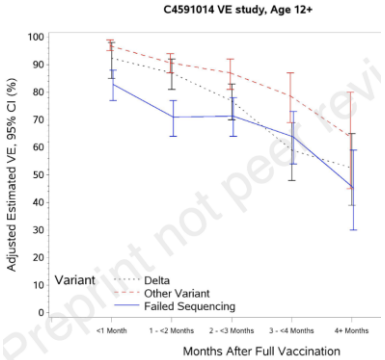
2



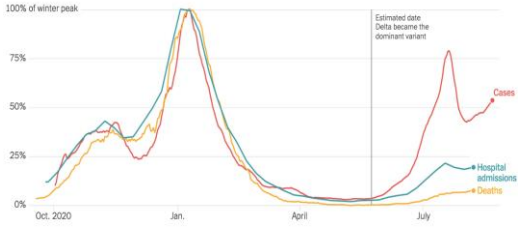

Identified 167 patients infected with the Delta variant in the Guangdong outbreak. **The mean estimates of the latent period and the incubation period were 4.0 days and 5.8 days, respectively. Comparatively pre-delta had a latent period of 5.5 days (testing negative) and an incubation period of 6.3 days (symptom onset) resulting in a smaller period for presymptomatic transmission.** A relatively higher viral load was observed in Delta cases than in wild-type infections. The secondary attack rate among close contacts of Delta cases was 1.4%, and 73.9% (95% confidence interval: 67.2%, 81.3%) of the transmissions occurred before onset.
https://www.nature.com/articles/d41586-021-02259-2
https://www.medrxiv.org/content/10.1101/2021.08.12.21261991v1.full.pdf

3

Pfizer retrospective study of **large cohort 3.3 million, between Dec 14, 2020 – Aug 8, 2021**. Confirm **high effectiveness of BNT162b2 against hospitalizations** through roughly six months after being fully vaccinated. Show **reductions in effectiveness against SARS-CoV-2 infections over time are likely primarily due to waning rather than Delta escaping vaccine protection.**
https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3909743




4

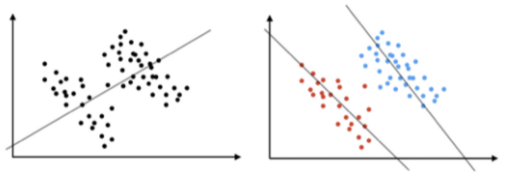




5

**Simpso's Paradox Explained** https://www.covid-datascience.com/post/israeli-data-how-can-efficacy-vs-severe-disease-be-strong-when-60-of-hospitalized-are-vaccinated

**Simpson's paradox explained**

There are various nice explanations of Simpson's paradox online, including here and here.
I will borrow a plot from the latter reference and give a simple illustration:

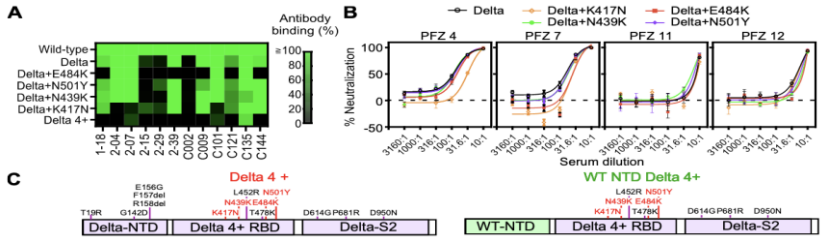


A visual example: the overall trend reverses when data is grouped by some colour-represented category.

Vaccine efficacy vs. severe disease for younger (<50yr) = 1 - 0.3/3.9 = ***91.8%***
Vaccine efficacy vs. severe disease for older (>50yr) = 1- 13.6/90.9 = ***85.2%***

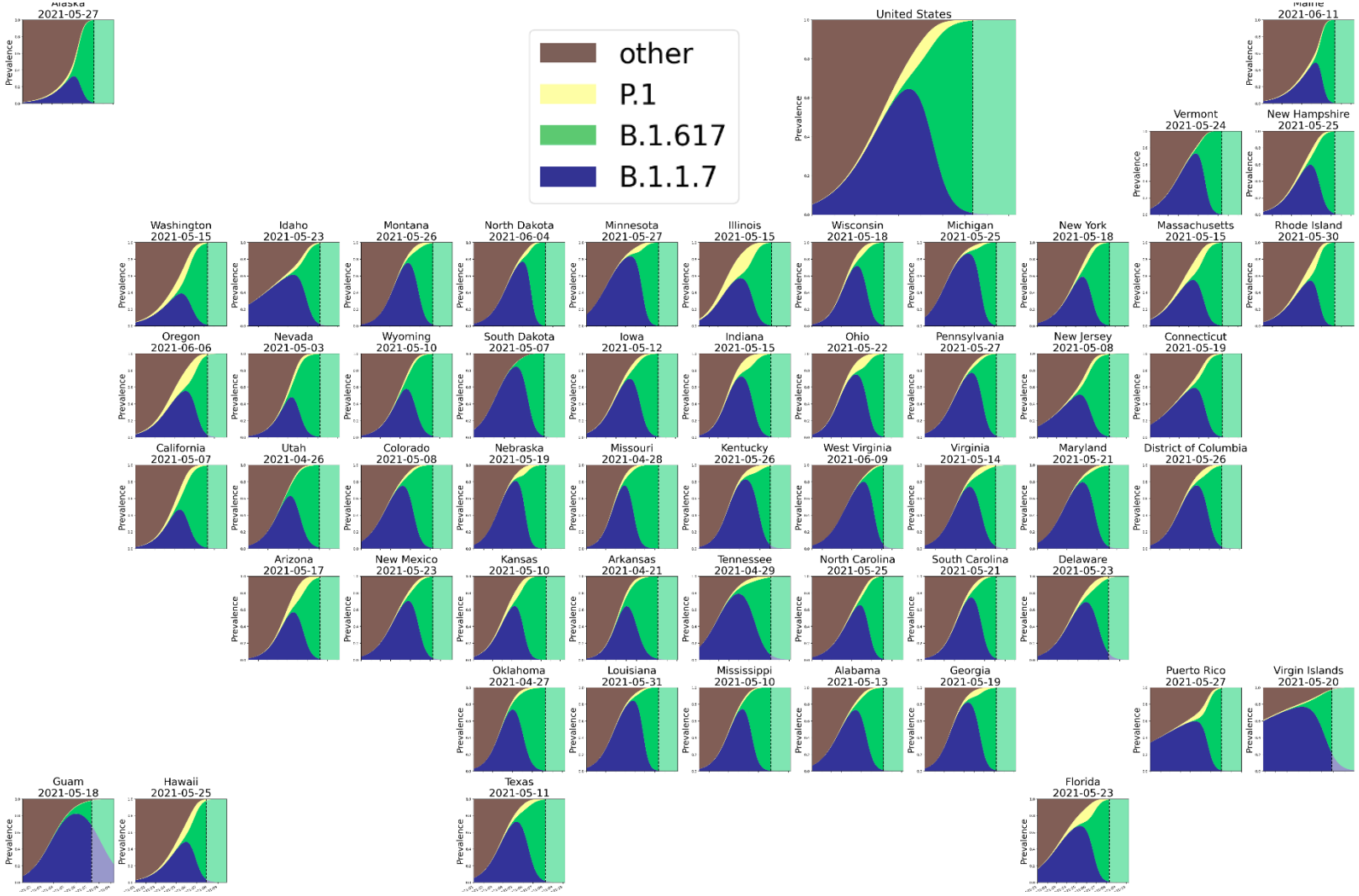
| Age | Population (%) | | Severe cases | | Efficacy |
|---|---|---|---|---|---|
| | Not Vax % | Fully Vax % | Not Vax per 100k | Fully Vax per 100k | vs. severe disease |
| All ages | 1,302,912 18.2% | 5,634,634 78.7% | 214 16.4 | 301 5.3 | **67.5%** |
| <50 | 1,116,834 23.3% | 3,501,118 73.0% | 43 3.9 | 11 0.3 | **91.8%** |
| >50 | 186,078 7.9% | 2,133,516 90.4% | 171 91.9 | 290 13.6 | **85.2%** |

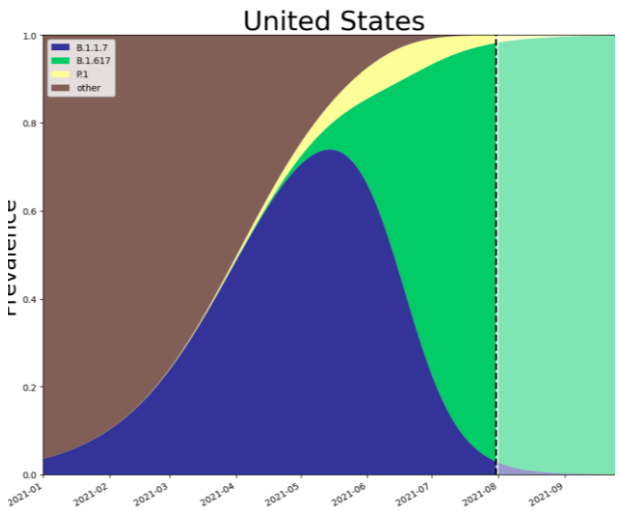
6

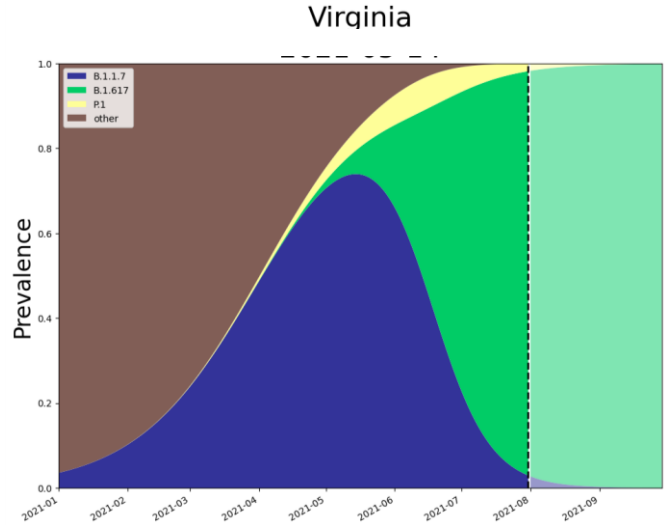



A recent study from Osaka University showed that Pfizer-BioNTech BNT162b2-immune sera neutralized the Delta variant, **when four common mutations were introduced into the receptor binding domain (RBD) of the Delta variant (Delta 4+), some BNT162b2-immune sera lost neutralizing activity**
https://www.biorxiv.org/content/10.1101/2021.08.22.457114v1.full.pdf

# Variant of Concern Trajectories

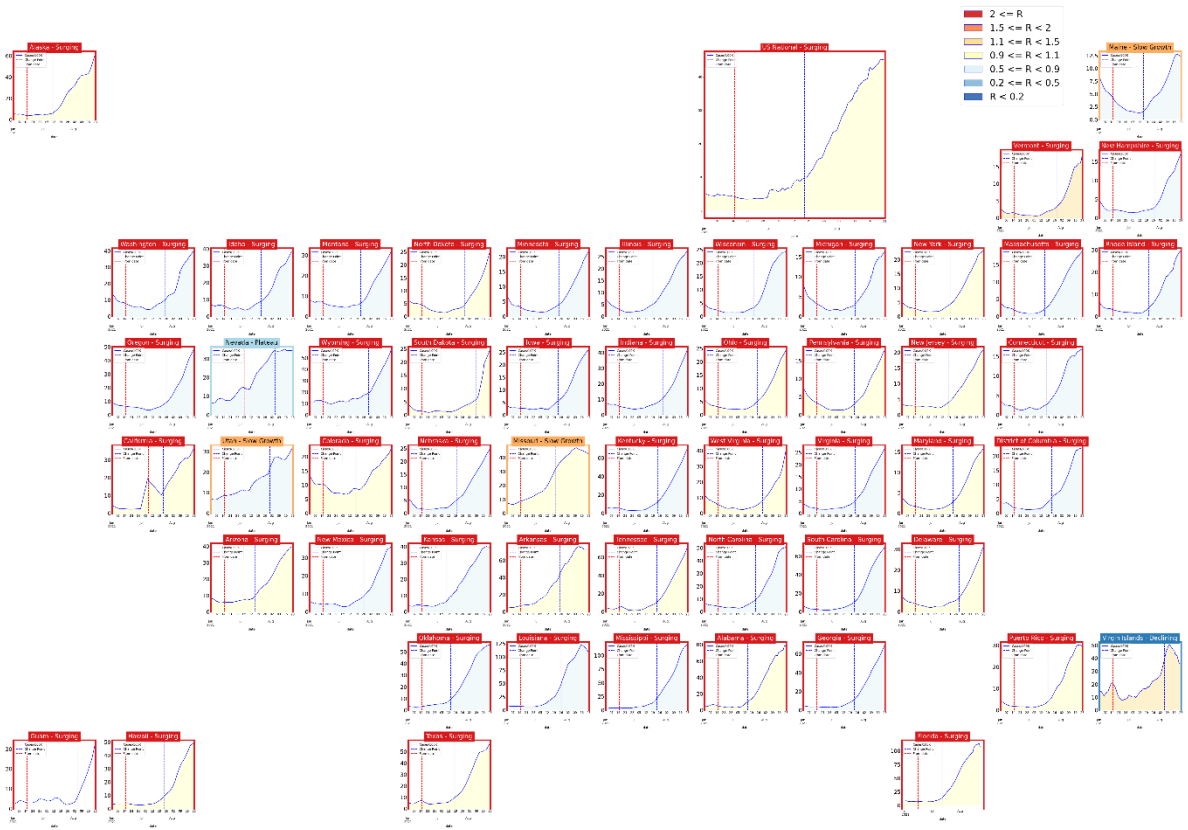


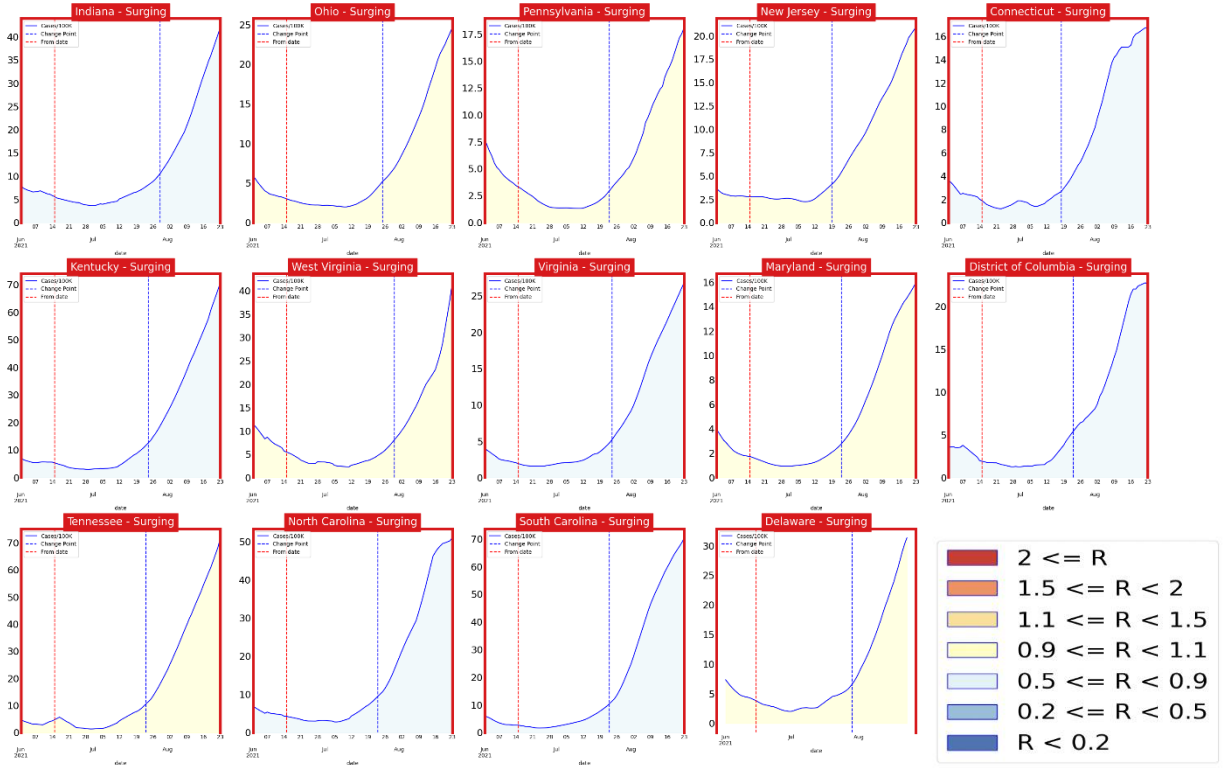
# Other State Comparisons

## Trajectories of States




- Most of the country is in Surge, some with very high case rates
- Early surges show some signs of slowing, but continue rapid growth

## Virginia and her neighbors

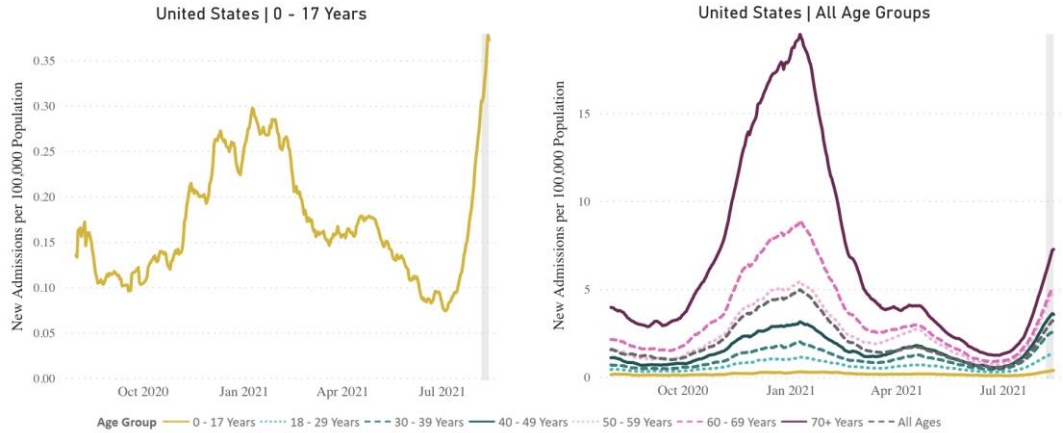



- VA and many neighbors show slight upward trends
- Many neighbors are in surge and/or have returned to rates above 10/100K

# Hospitalizations across the US

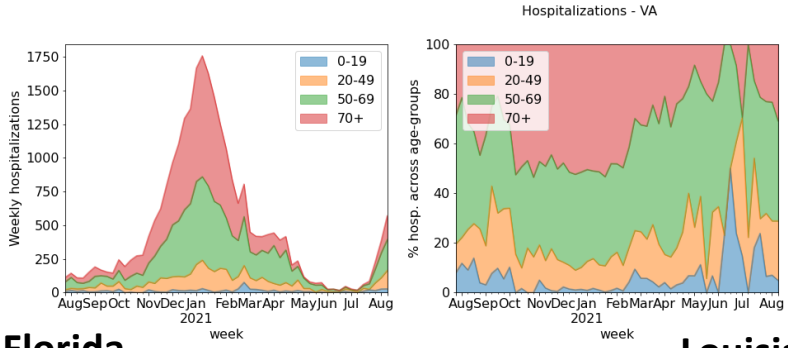
**Hospitalization rates remain low in VA, but rapid change is possible as seen in other states**

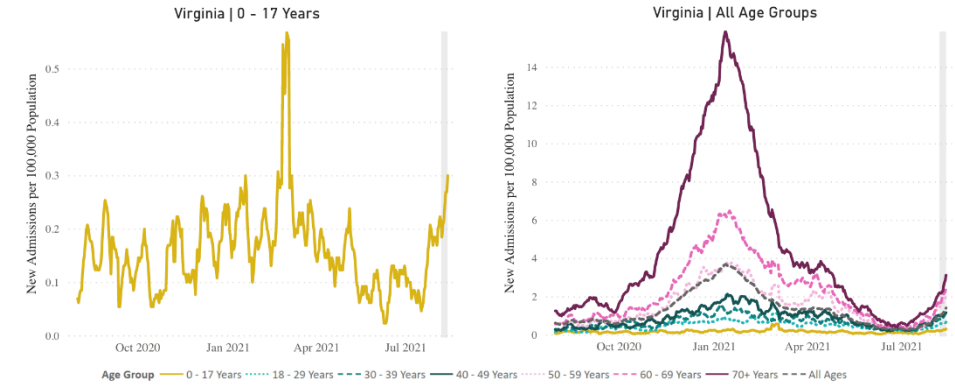
- Hotspot states see rapid rise in hospitalizations especially among the younger age groups
- Nationally pediatric hospitalizations are at an all time high since the pandemic began



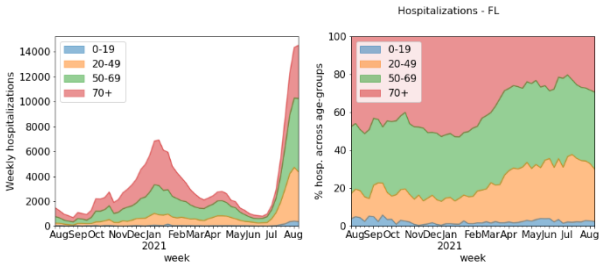

Source: https://covid.cdc.gov/covid-data-tracker/#new-hospital-admissions

**Virginia**

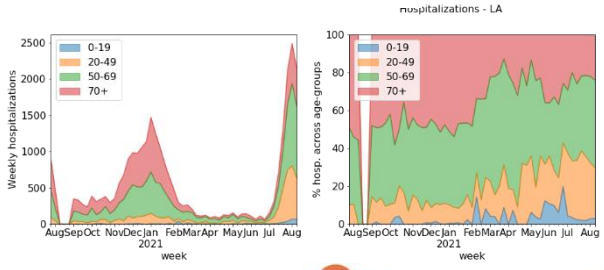


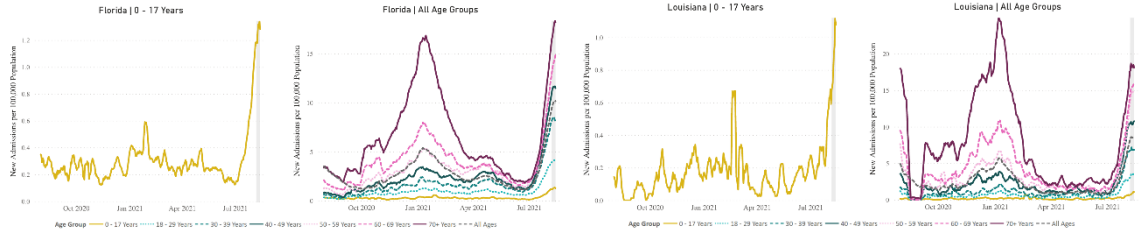




**Florida**




**Louisiana**

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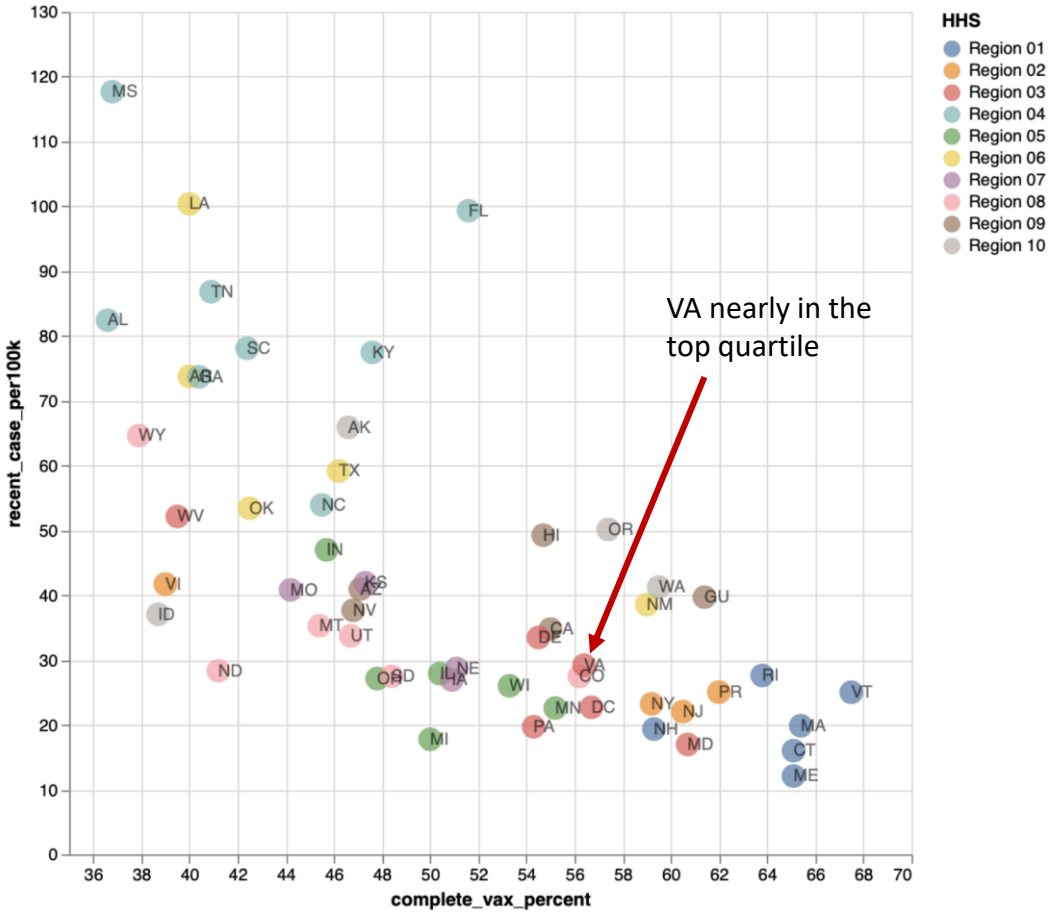
# Recent Cases Correlate with Vax Coverage

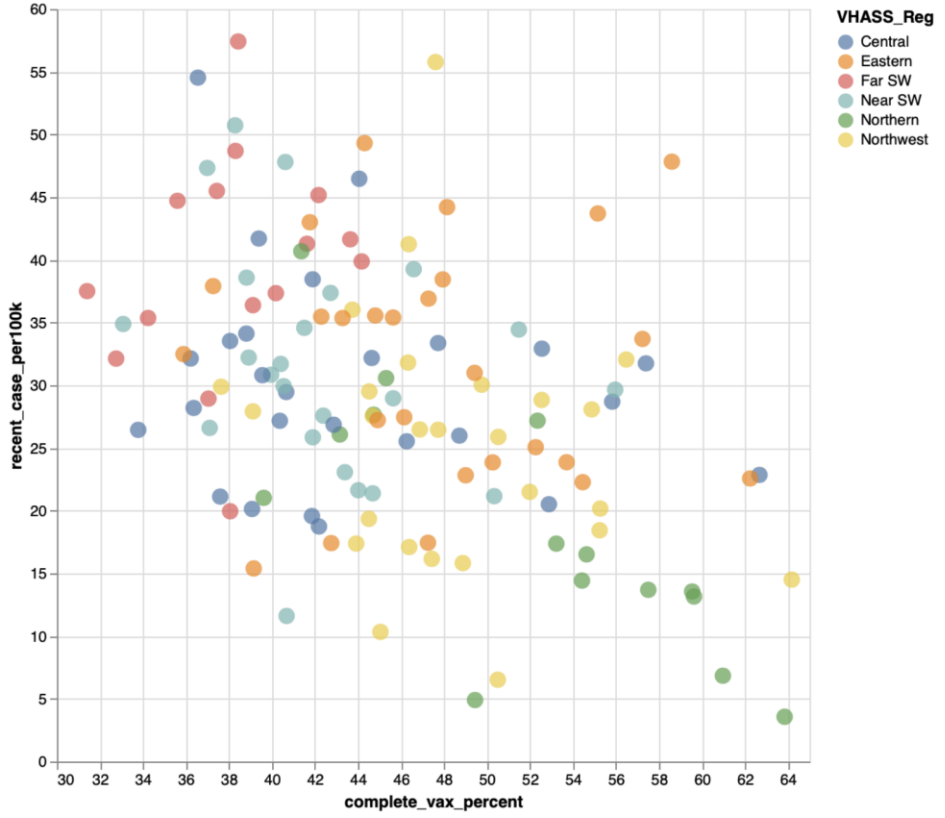
**Mean cases per 100K vs. vaccine coverage**

- States with lower vax coverage have had the worst case spikes
- Virginia 14th out of 51 states in fully vaccinated coverage

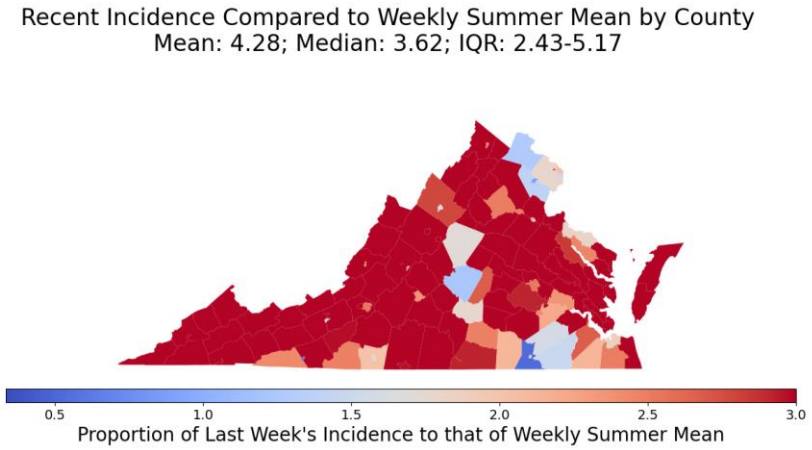


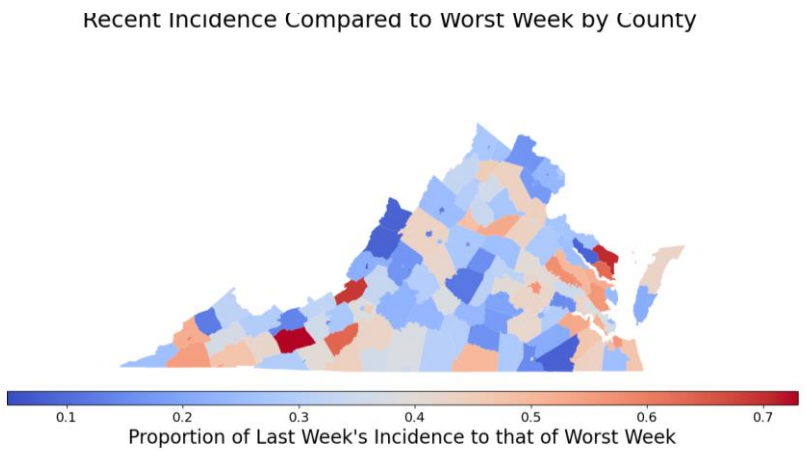

**Virginia Counties**

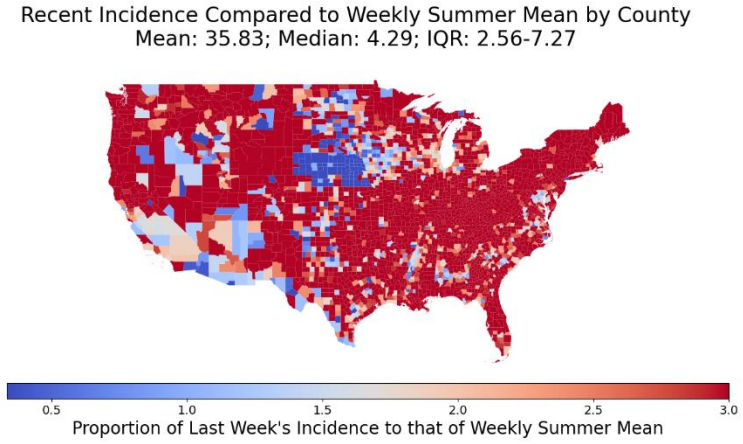
- Counties with higher vax coverage are maintaining lower case rates (e.g., Albemarle, Fairfax city)
- Many counties with low vax coverage starting to rise as Delta surge reaches more remote areas of state

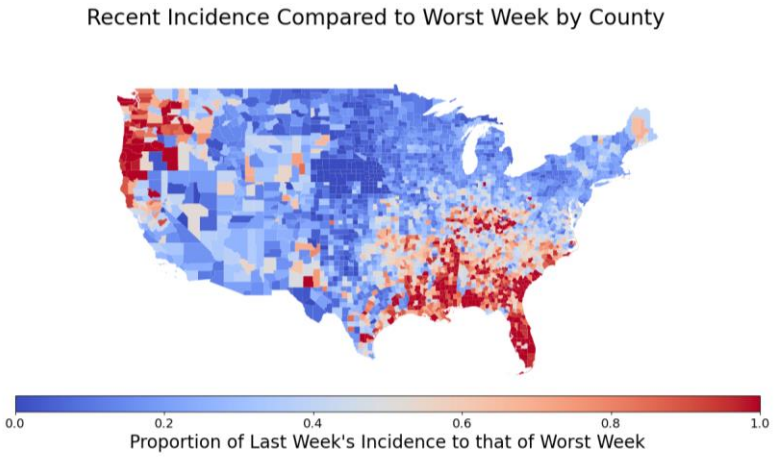


# Recent Incidence Compared to Worst Week




**Percentage of counties with Higher case rates**

| Region | Above Summer'20 Mean | Above 50% of Worst Week |
|---|---|---|
| Virginia | 97% | 14% |
| United States | 93% | 32% |

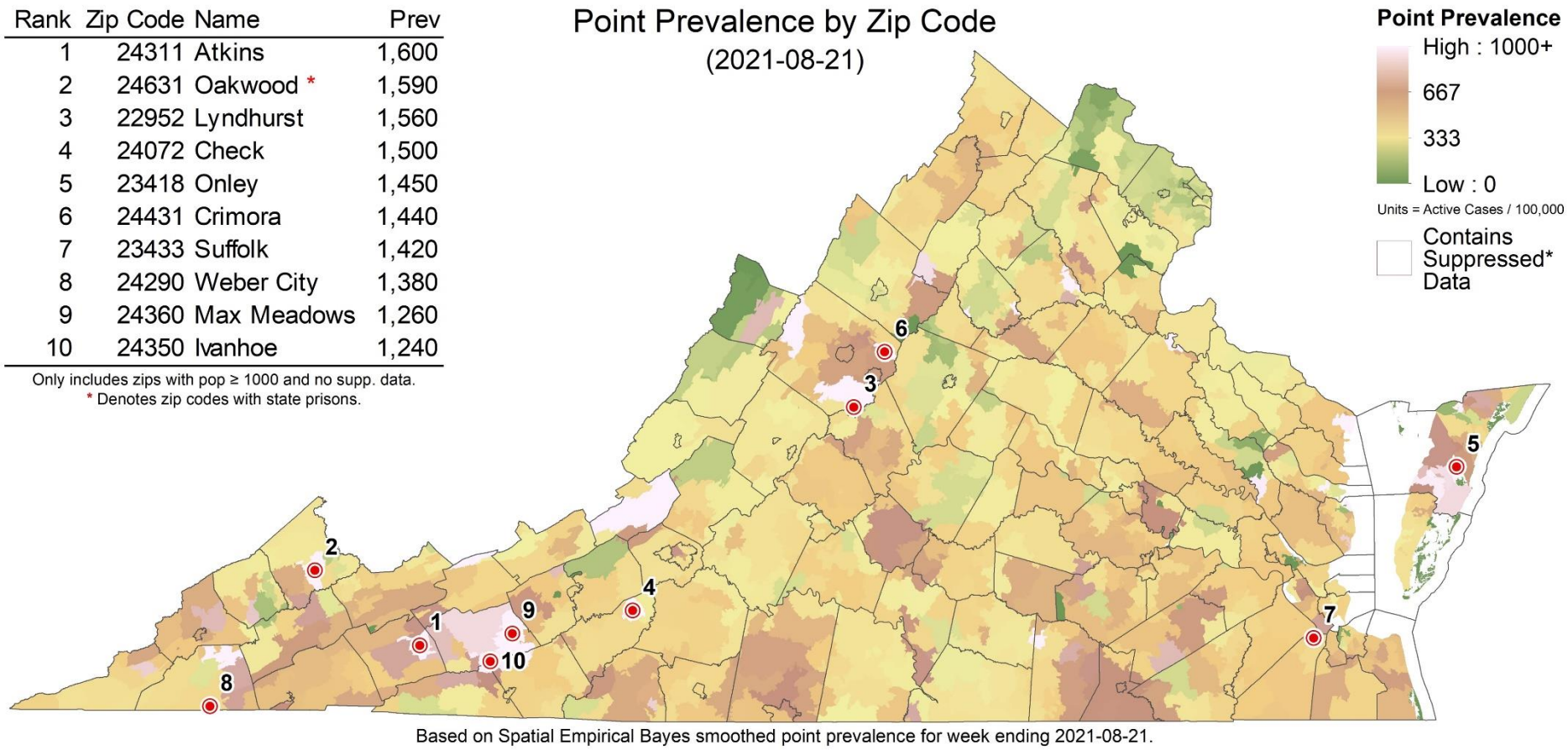
# Zip code level weekly Case Rate (per 100K)

**Case Rates in the last week by zip code**

- Clusters of high prevalence in Southwest and Eastern
- Some counts are low and suppressed to protect anonymity, those are shown in white

| Rank | Zip Code | Name | Prev |
|---|---|---|---|
| 1 | 24311 | Atkins | 1,600 |
| 2 | 24631 | Oakwood * | 1,590 |
| 3 | 22952 | Lyndhurst | 1,560 |
| 4 | 24072 | Check | 1,500 |
| 5 | 23418 | Onley | 1,450 |
| 6 | 24431 | Crimora | 1,440 |
| 7 | 23433 | Suffolk | 1,420 |
| 8 | 24290 | Weber City | 1,380 |
| 9 | 24360 | Max Meadows | 1,260 |
| 10 | 24350 | Ivanhoe | 1,240 |

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




Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-08-21.

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# Risk of Exposure by Group Size

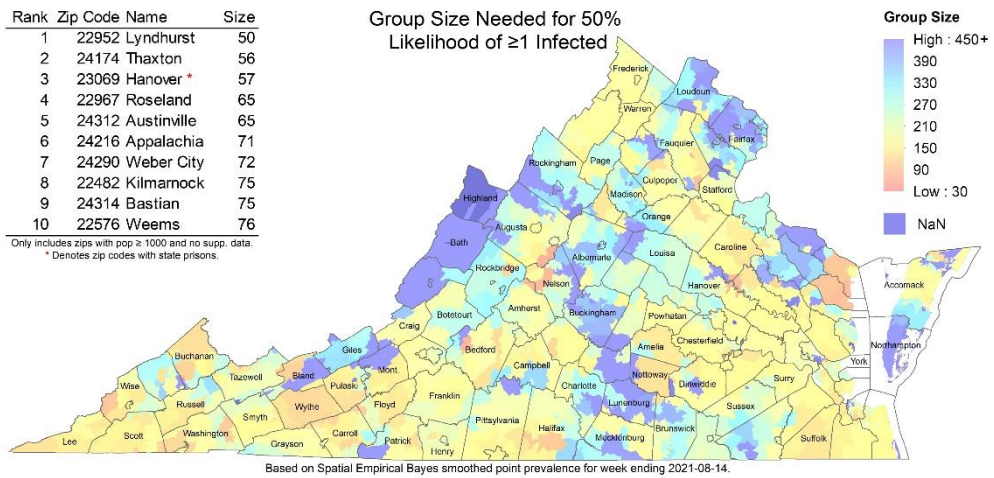
**Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)**

- **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 (eg in a group of 50 in Atkins, there is a 50% chance someone will be infected)

**From Last Week**

| Rank | Zip Code | Name | Size |
|---|---|---|---|
| 1 | 22952 | Lyndhurst | 50 |
| 2 | 24174 | Thaxton | 56 |
| 3 | 23069 | Hanover * | 57 |
| 4 | 22967 | Roseland | 65 |
| 5 | 24312 | Austinville | 65 |
| 6 | 24216 | Appalachia | 71 |
| 7 | 24290 | Weber City | 72 |
| 8 | 22482 | Kilmarnock | 75 |
| 9 | 24314 | Bastian | 75 |
| 10 | 22576 | Weems | 76 |

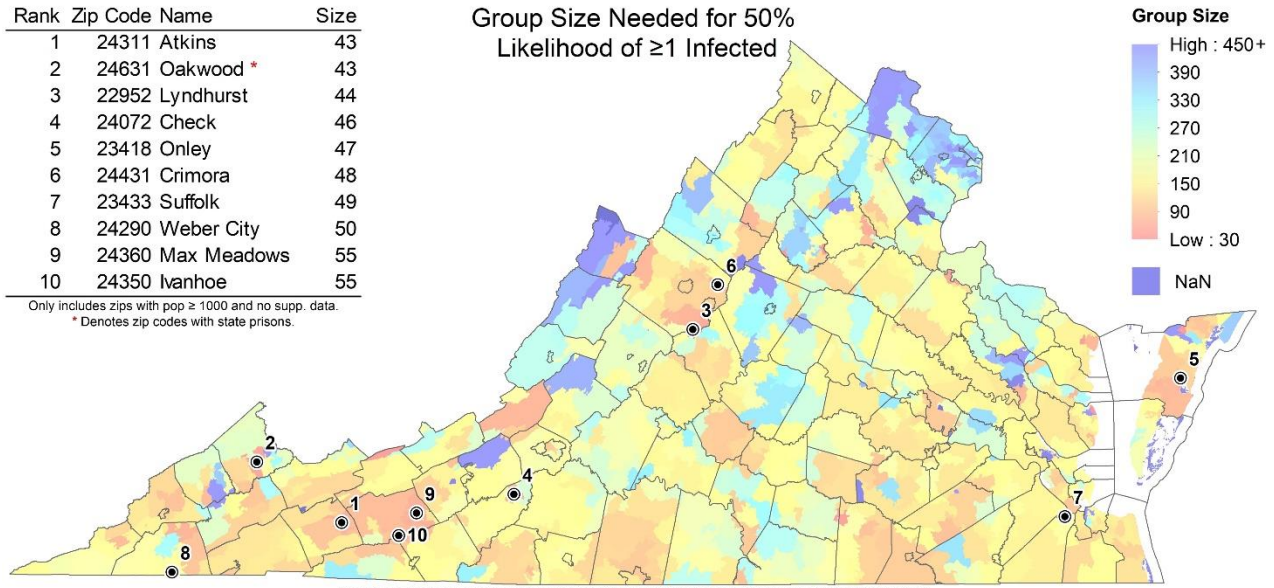
Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.




Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-08-14.

| Rank | Zip Code | Name | Size |
|---|---|---|---|
| 1 | 24311 | Atkins | 43 |
| 2 | 24631 | Oakwood * | 43 |
| 3 | 22952 | Lyndhurst | 44 |
| 4 | 24072 | Check | 46 |
| 5 | 23418 | Onley | 47 |
| 6 | 24431 | Crimora | 48 |
| 7 | 23433 | Suffolk | 49 |
| 8 | 24290 | Weber City | 50 |
| 9 | 24360 | Max Meadows | 55 |
| 10 | 24350 | Ivanhoe | 55 |

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



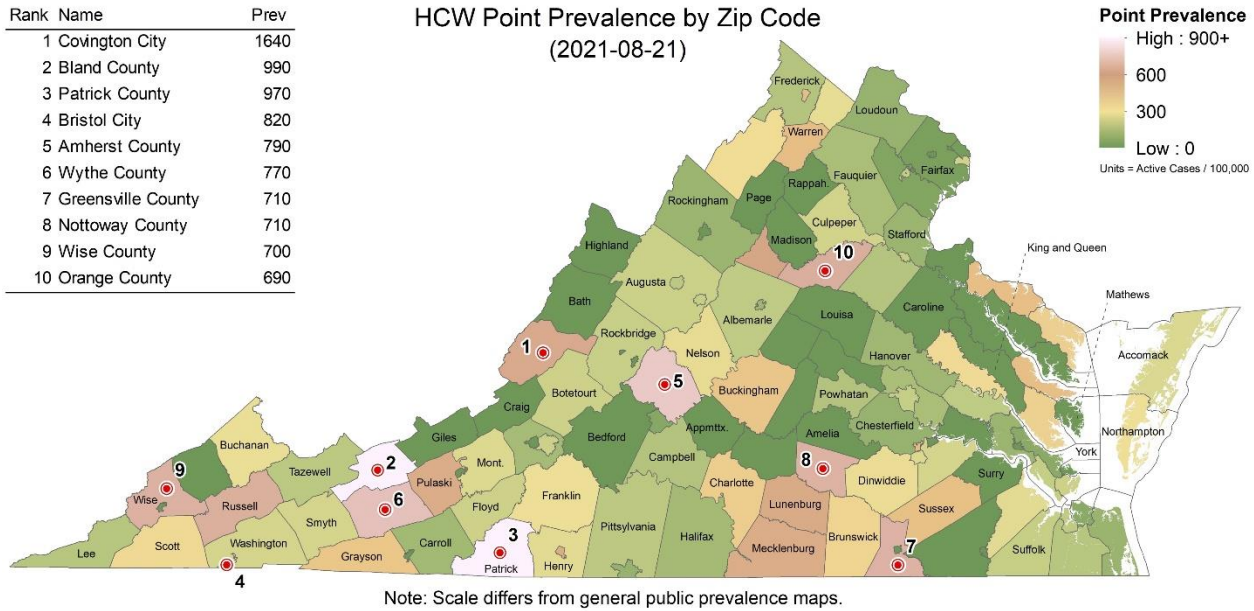

Based on Spatial Empirical Bayes smoothed point prevalence for week ending 2021-08-21.

# 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)

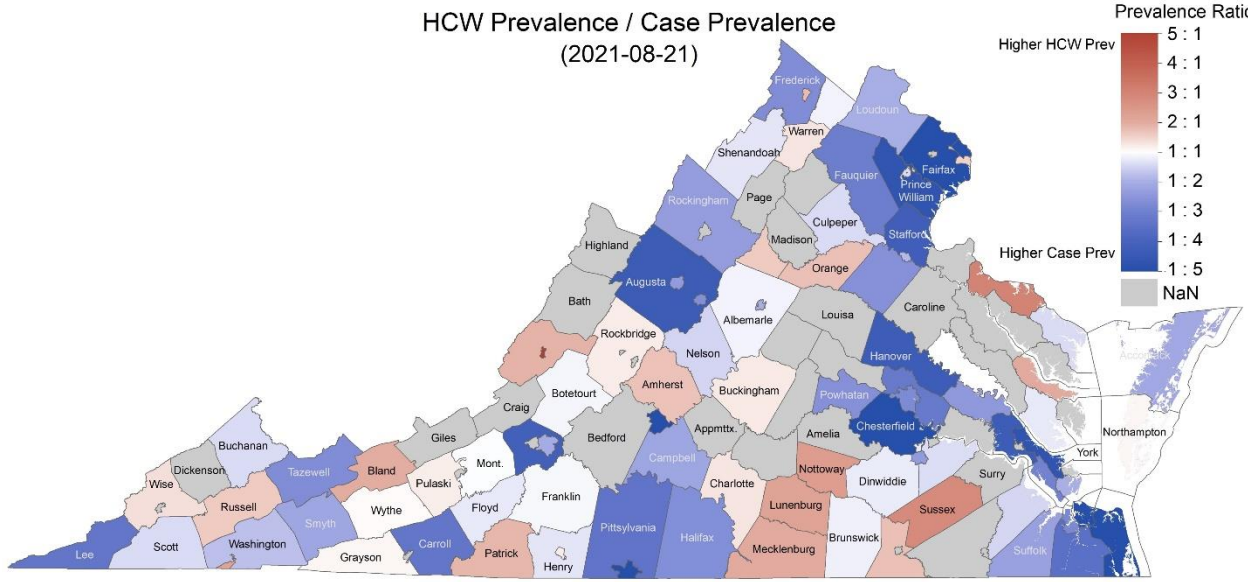
**HCW Prevalence**

| Rank | Name | Prev |
|---|---|---|
| 1 | Covington City | 1640 |
| 2 | Bland County | 990 |
| 3 | Patrick County | 970 |
| 4 | Bristol City | 820 |
| 5 | Amherst County | 790 |
| 6 | Wythe County | 770 |
| 7 | Greensville County | 710 |
| 8 | Nottoway County | 710 |
| 9 | Wise County | 700 |
| 10 | Orange County | 690 |




Note: Scale differs from general public prevalence maps.

**HCW to Public Prevalence Ratio**



# Current Hot-Spots

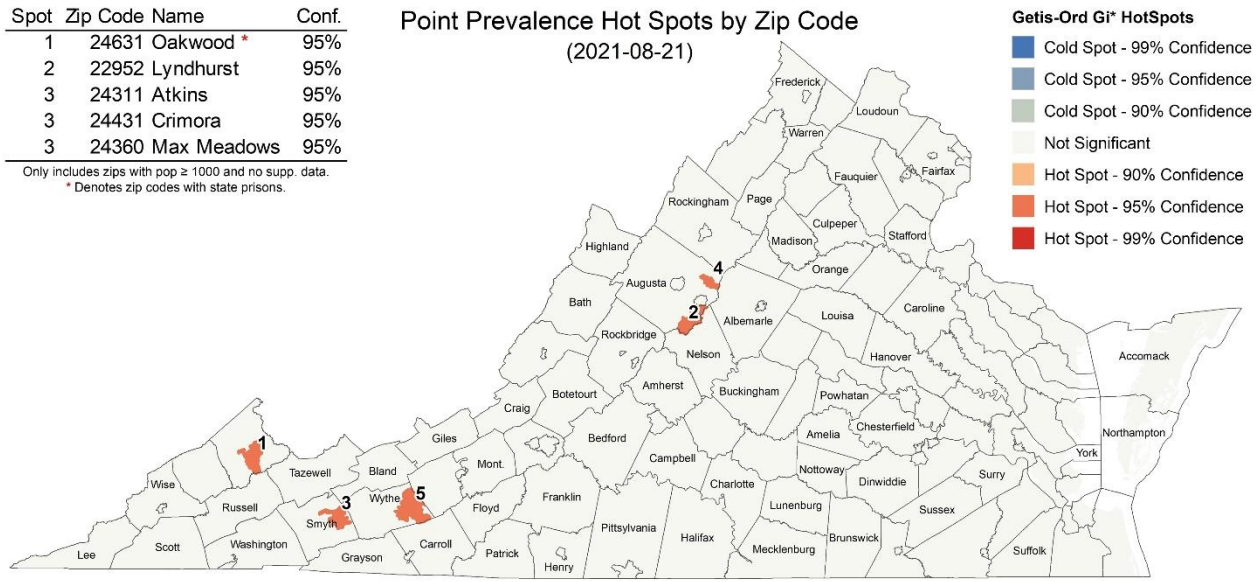
**Case rates that are significantly different from neighboring areas or model projections**

- **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

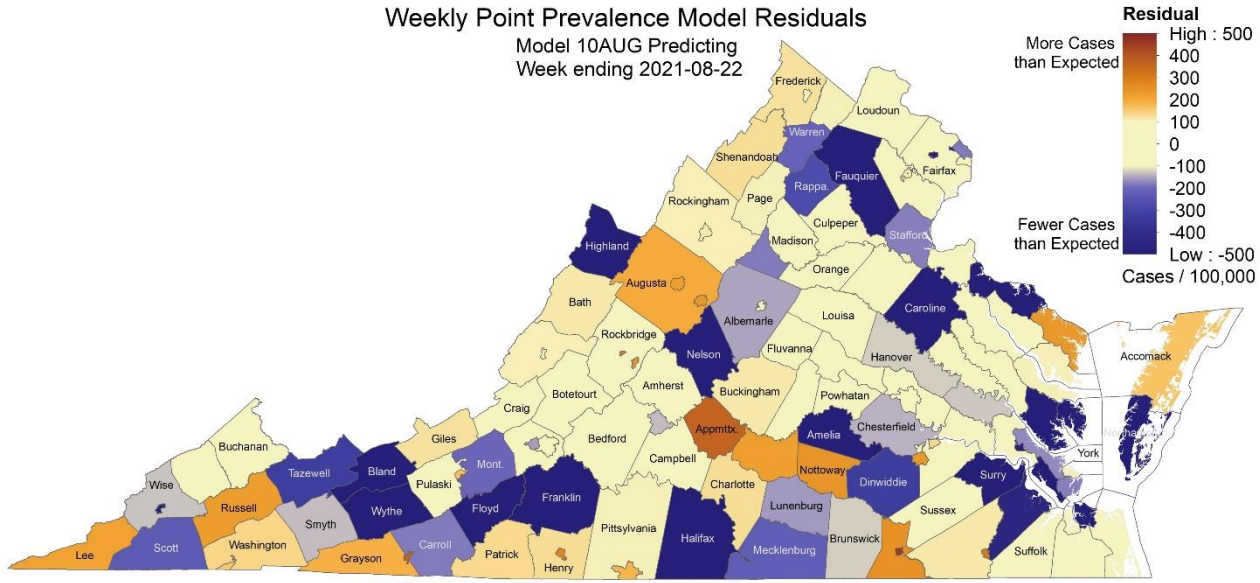
| Spot | Zip Code | Name | Conf. |
|---|---|---|---|
| 1 | 24631 | Oakwood * | 95% |
| 2 | 22952 | Lyndhurst | 95% |
| 3 | 24311 | Atkins | 95% |
| 3 | 24431 | Crimora | 95% |
| 3 | 24360 | Max Meadows | 95% |

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




Based on Global Empirical Bayes smoothed point prevalence for week ending 2021-08-21.

## Clustered Temporal Hotspots



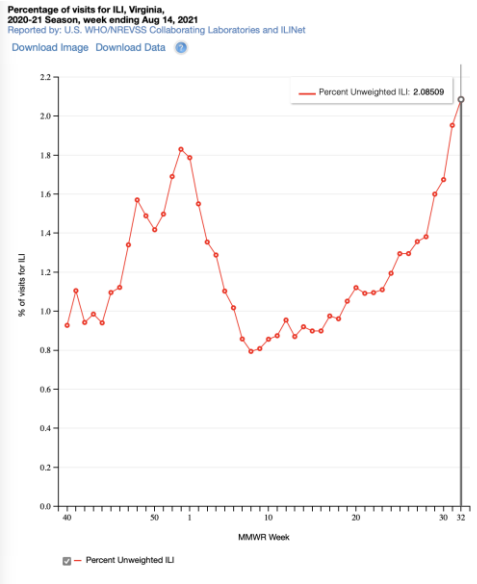

Moran's I = 0.011122, Z-Score = 0.84404, P-Value = 0.398647
No Residual Autocorrelation Detected

# Influenza-like Illnesses Update

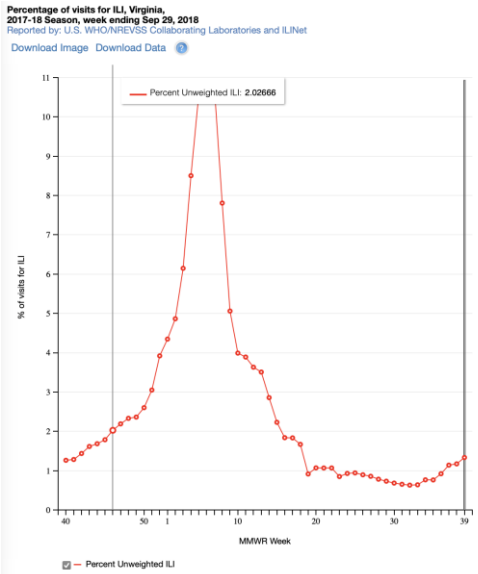
**Other Respiratory Viruses on the rise and are on way towards a much earlier than usual influenza season**

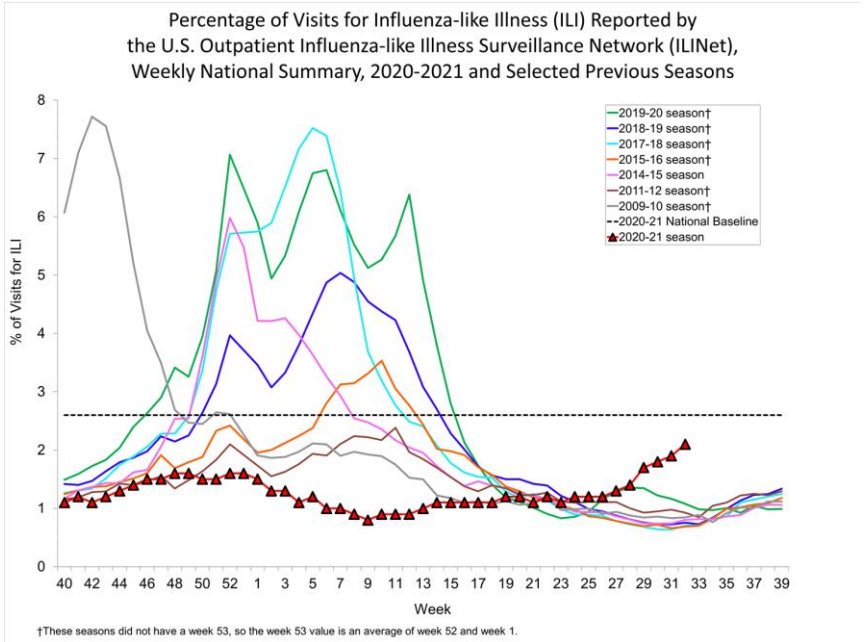
- Much higher non-COVID ILI activity now compared to previous decade
- Southeast is already above ILI season threshold
- Virginia is currently at ~2% ILI activity which is similar to early Nov 2017 (last very strong influenza season)

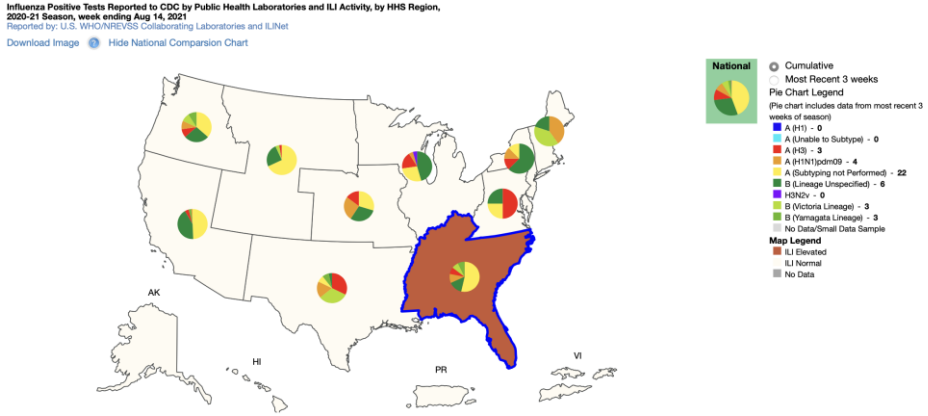
Virginia 2021-22




Virginia 2017-18



# Model Update – Adaptive Fitting

# Adaptive Fitting Approach

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

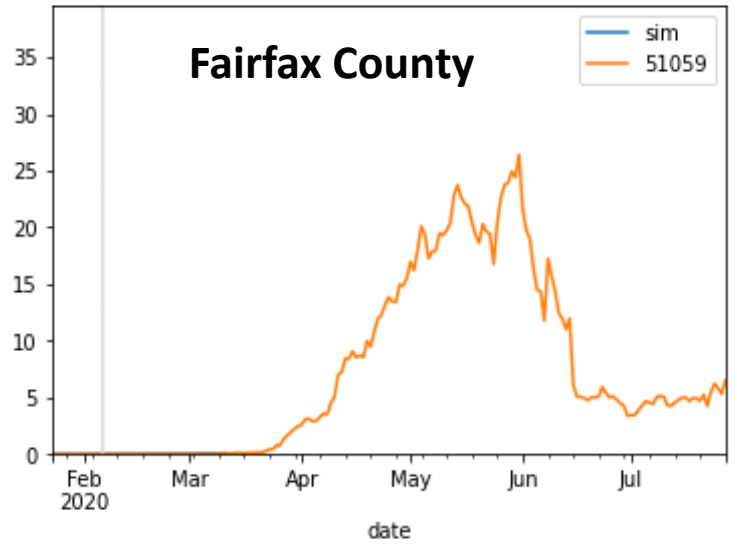
- Allows history to be precisely captured, and used to guide bounds on projections

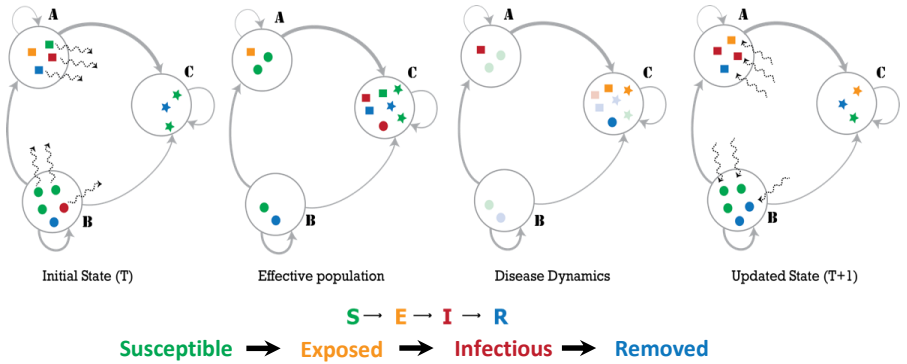
**Model:** An alternative use of the same meta-population model, PatchSim

- 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

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# Using Ensemble Model to Guide Projections

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

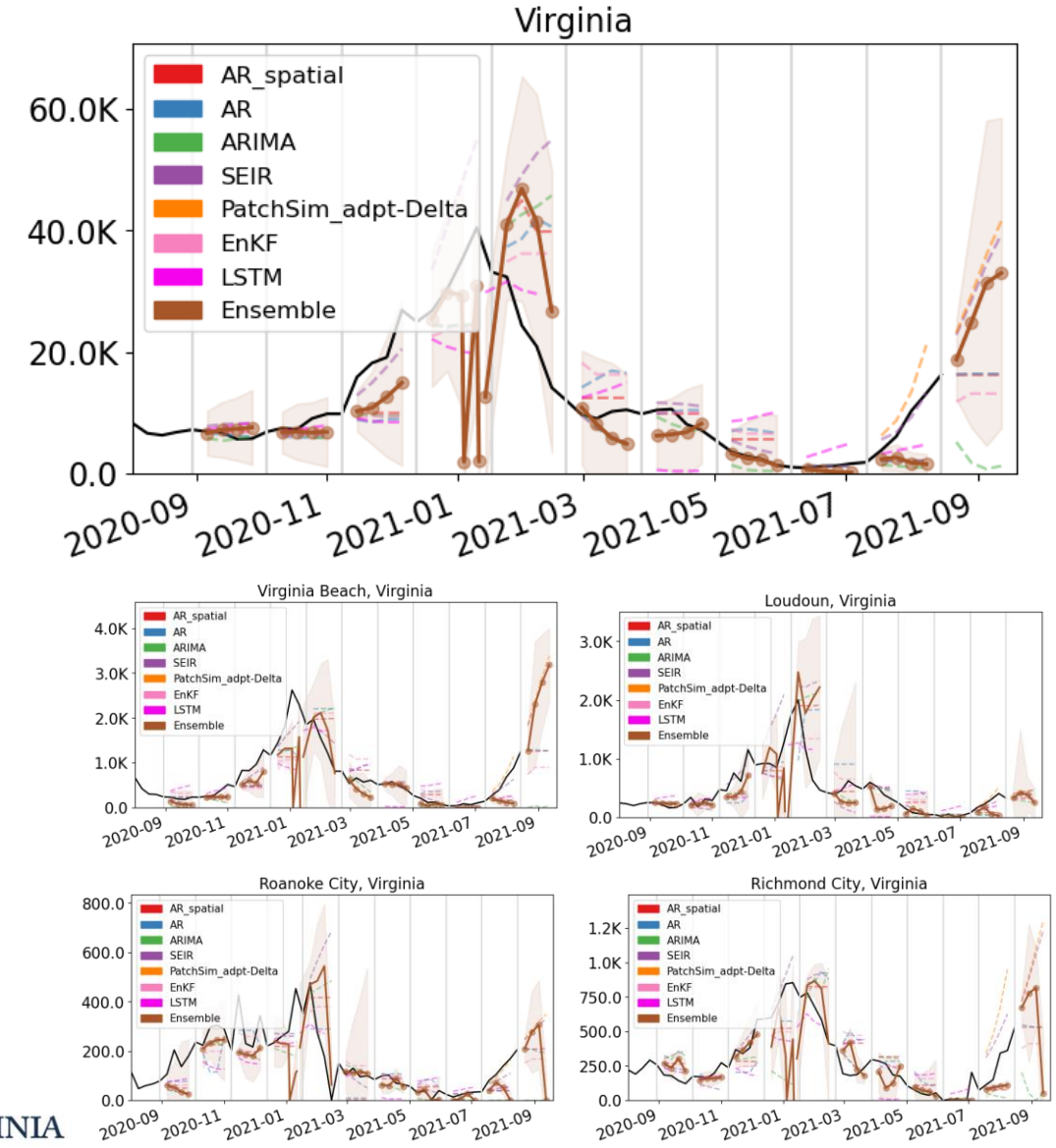
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

<u>Weekly forecasts</u> 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.

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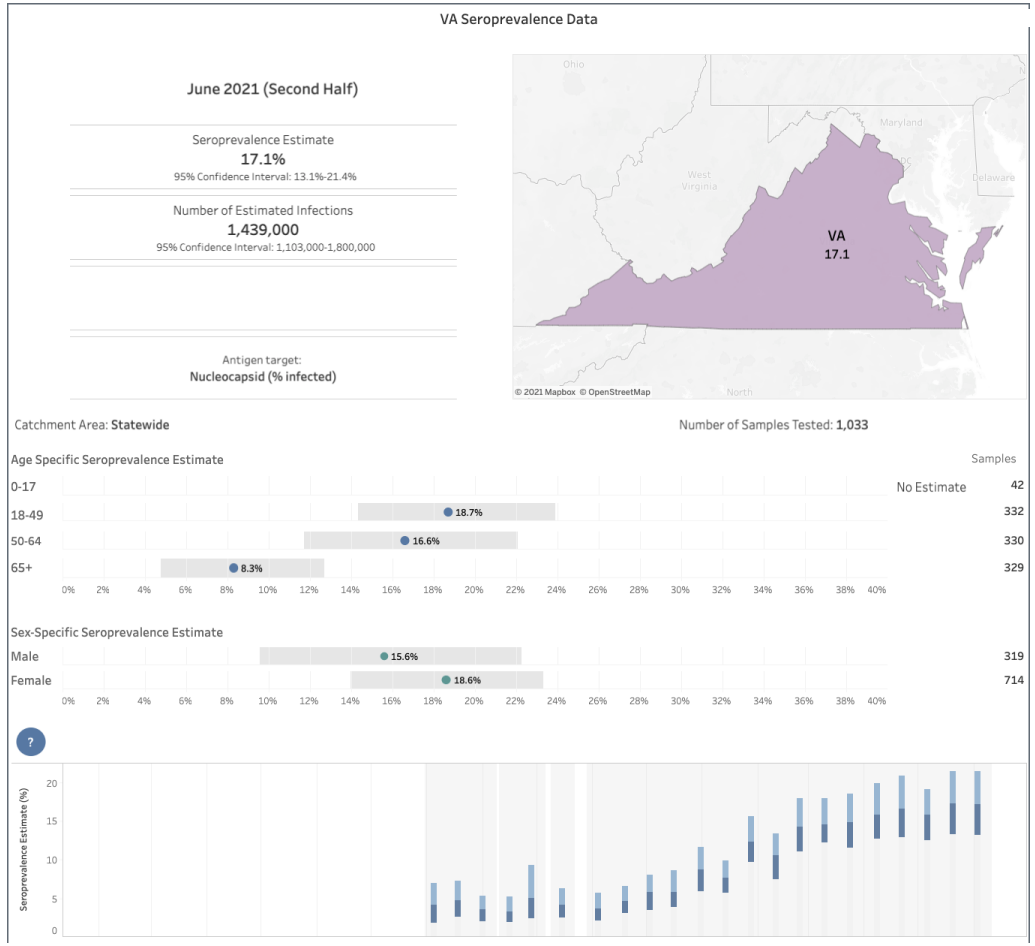
# Seroprevalence updates to model design

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

- CDC Nationwide Commercial Laboratory Seroprevalence Survey estimated 17.1% [13.1% – 21.4%] seroprevalence as of June 15th – 30th up from 15.8% a month earlier

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

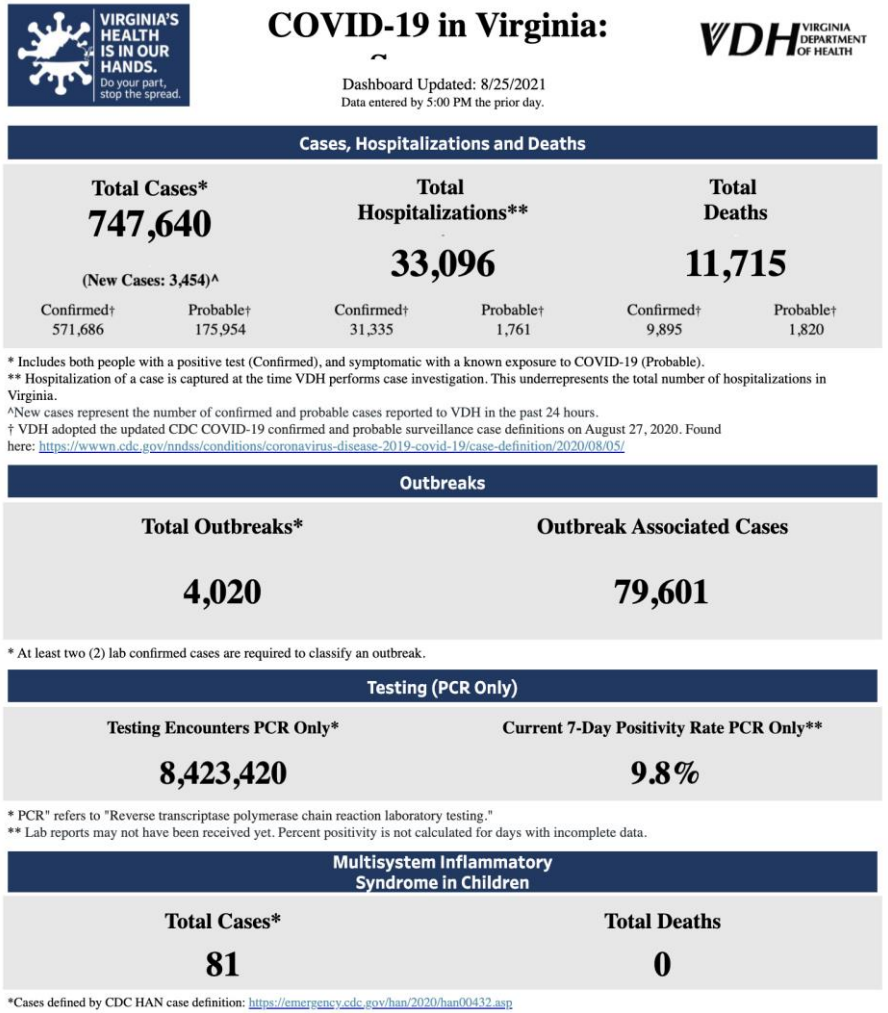
- Thus for 2x there are 2 total infections in the population for every confirmed case recently
- This measure now fully tracks the estimated ascertainment over time
- Uncertainty design has been shifted to these bounds (previously higher ascertainments as was consistent earlier in the pandemic were being 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



VIRGINIA'S HEALTH IS IN OUR HANDS. Do your part, stop the spread.

**COVID-19 in Virginia:**

VDH VIRGINIA DEPARTMENT OF HEALTH

Dashboard Updated: 8/25/2021
Data entered by 5:00 PM the prior day.

**Cases, Hospitalizations and Deaths**

| Total Cases* | Total Hospitalizations** | Total Deaths |
|---|---|---|
| 747,640 | 33,096 | 11,715 |
| (New Cases: 3,454)^ | | |

| Confirmed† | Probable† | Confirmed† | Probable† | Confirmed† | Probable† |
|---|---|---|---|---|---|
| 571,686 | 175,954 | 31,335 | 1,761 | 9,895 | 1,820 |

* Includes both people with a positive test (Confirmed), and symptomatic with a known exposure to COVID-19 (Probable).
** Hospitalization of a case is captured at the time VDH performs case investigation. This underrepresents the total number of hospitalizations in Virginia.
^New cases represent the number of confirmed and probable cases reported to VDH in the past 24 hours.
† VDH adopted the updated CDC COVID-19 confirmed and probable surveillance case definitions on August 27, 2020. Found here: https://wwwn.cdc.gov/nndss/conditions/coronavirus-disease-2019-covid-19/case-definition/2020/08/05/

**Outbreaks**

| Total Outbreaks* | Outbreak Associated Cases |
|---|---|
| 4,020 | 79,601 |

* At least two (2) lab confirmed cases are required to classify an outbreak.

**Testing (PCR Only)**

| Testing Encounters PCR Only* | Current 7-Day Positivity Rate PCR Only** |
|---|---|
| 8,423,420 | 9.8% |

* PCR" refers to "Reverse transcriptase polymerase chain reaction laboratory testing."
** Lab reports may not have been received yet. Percent positivity is not calculated for days with incomplete data.

**Multisystem Inflammatory Syndrome in Children**

| Total Cases* | Total Deaths |
|---|---|
| 81 | 0 |

*Cases defined by CDC HAN case definition: https://emergency.cdc.gov/han/2020/han00432.asp

Accessed 9:00am August 25, 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
- Plausible levels of transmission can be bounded by past experience
  - Assess transmission levels at the county level from May 1, 2020 – Sept 1, 2020 or current, whichever is highest
- Projection Scenario:
  - **Adaptive-Delta:** Control remains as is currently experienced into the future with assumption that Delta continues to become more dominant
  - **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-SpringControl:** Immediate return to the mean levels of transmission experienced in May 2021

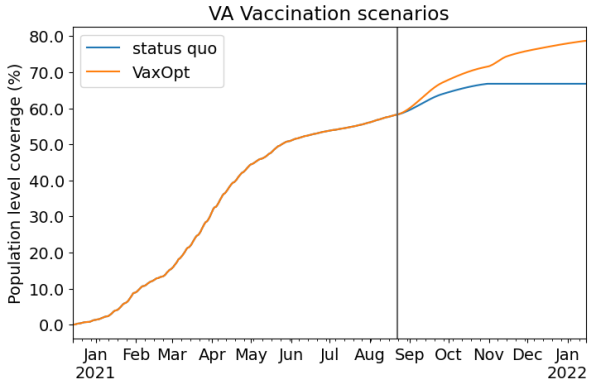
# Scenarios – Vaccination Conditions

## 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 rollout starting in November further boosting 10% of population by end of January. Also, all counties reaching 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)




**Monthly first doses**

| Date | status quo | VaxOpt |
|---|---|---|
| 2020-12-31 | 108.8K | 108.8K |
| 2021-01-31 | 644.0K | 644.0K |
| 2021-02-28 | 557.0K | 557.0K |
| 2021-03-31 | 1.3M | 1.3M |
| 2021-04-30 | 1.2M | 1.2M |
| 2021-05-31 | 573.1K | 573.1K |
| 2021-06-30 | 241.8K | 241.8K |
| 2021-07-31 | 196.1K | 196.1K |
| 2021-08-31 | 287.8K | 326.1K |
| 2021-09-30 | 424.4K | 676.3K |
| 2021-10-31 | 207.5K | 322.2K |
| 2021-11-30 | 0.0 | 369.2K |
| 2021-12-31 | 0.0 | 177.0K |
| 2022-01-31 | 0.0 | 66.3K |

**Cumulative**

| Date | status quo | VaxOpt |
|---|---|---|
| 2020-12-31 | 108.8K | 108.8K |
| 2021-01-31 | 752.8K | 752.8K |
| 2021-02-28 | 1.3M | 1.3M |
| 2021-03-31 | 2.6M | 2.6M |
| 2021-04-30 | 3.8M | 3.8M |
| 2021-05-31 | 4.3M | 4.3M |
| 2021-06-30 | 4.6M | 4.6M |
| 2021-07-31 | 4.8M | 4.8M |
| 2021-08-31 | 5.1M | 5.1M |
| 2021-09-30 | 5.5M | 5.8M |
| 2021-10-31 | 5.7M | 6.1M |
| 2021-11-30 | 5.7M | 6.5M |
| 2021-12-31 | 5.7M | 6.7M |
| 2022-01-31 | 5.7M | 6.7M |

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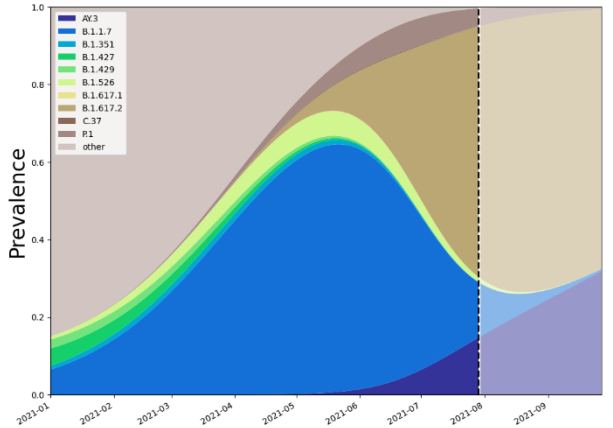
# Scenarios – Delta δ Variant Condition

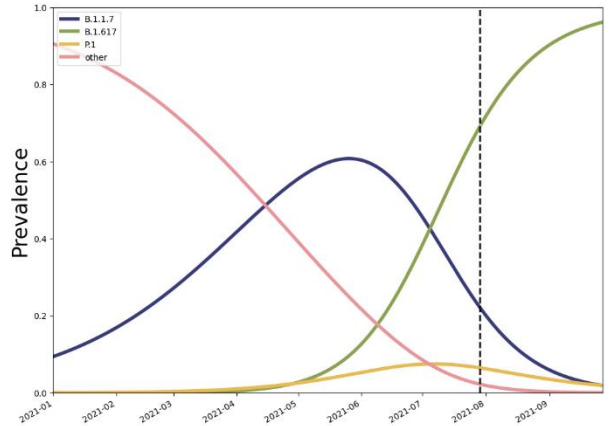
Variant Delta δ has exhibited ability to outcompete other variants and now is dominant in the US and most states

**Transmissibility:** Delta's relative transmissibility compared to Alpha is better understood (60% more transmissible) and its weighted growth fits a 60% growth advantage well

**Immune Escape:** Delta has been observed to evade immunity, both natural and vaccine-induced, however, uncertainty remains high thus this is **NOT** factored into the model

**Severity**: Delta, similar to Alpha, appears to cause more severe illness with estimates ranging from 50% to 200%, at the moment assume 60%




## Delta Variant Scenario:

- Continues to grow on 60% more transmissible trajectory, reached 50% prevalence on June 29th and is also 60% more severe than Alpha

# Projection Scenarios – Combined Conditions

| Name | Txm Controls | Variant Boosting | Vax | Description |
|---|---|---|---|---|
| Adaptive-Delta | C | 60% | SQ | Likely trajectory based on conditions remaining similar to now, but with increasing prevalence of Delta variant |
| Adaptive-Delta-VaxOpt | C | 60% | VO | Vaccination through October reaches an optimistically high level of expanded coverage (85%), with increasing prevalence of Delta variant |
| Adaptive-SurgeControl | 25% | 60% | SQ | Transmission rates in the next month reduced through increased control from non-pharmaceutical interventions, with status quo vax and Delta |
| Adaptive-SpringControl | Spring | 60% | SQ | Transmission rates return to rates experienced in May 2021 with status quo vaccination and increasing prevalence of Delta |

**Transmission Controls:** C = Current levels persist into the future
25% = Transmission rates are reduced by 25% with a gradual introduction, concluding in 4 weeks
Spring = Transmission rates return to May 2021 levels

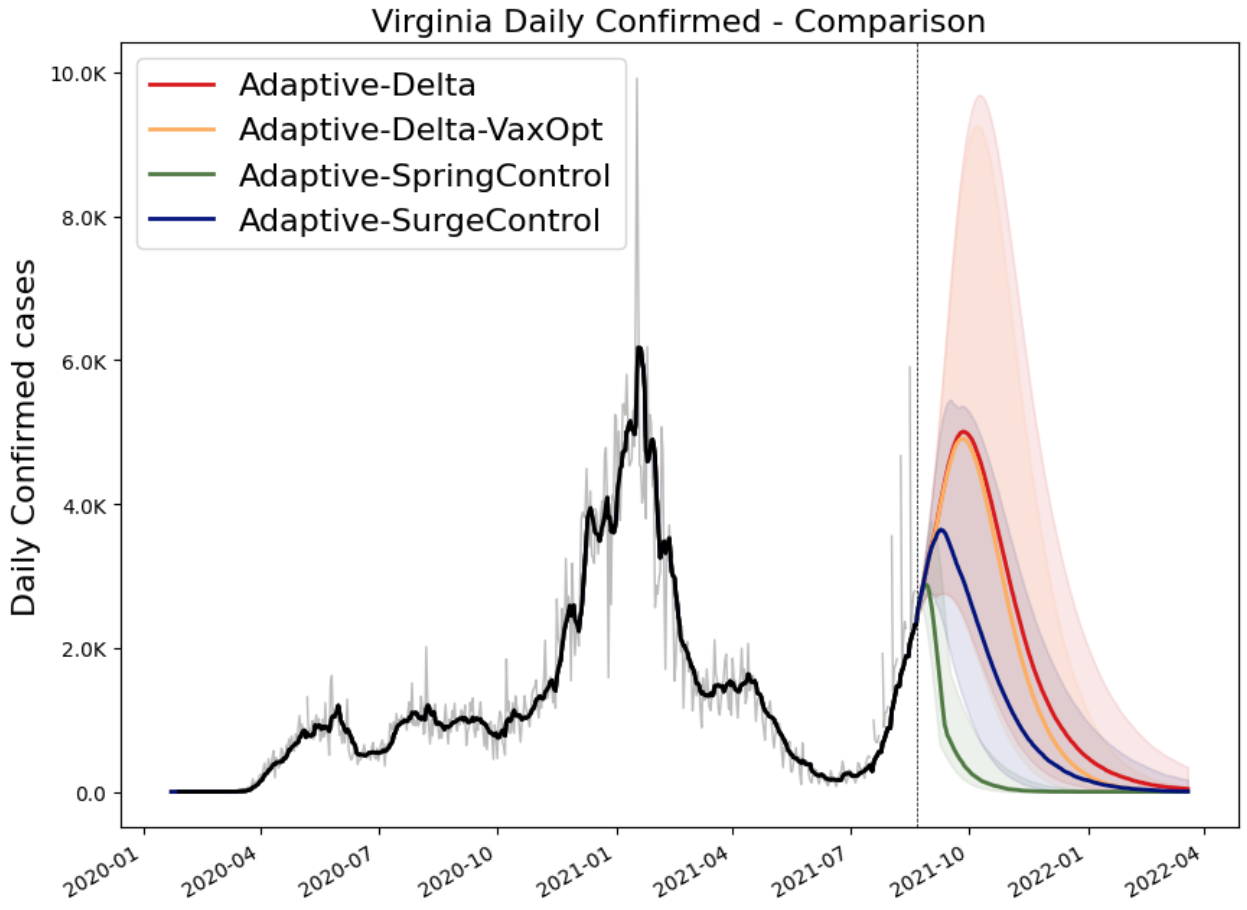
**Variant Boosting:** None = Variety of variants, no future txm boosting, but with severity impacts from current levels
60% = Prevalence of Delta ramps up according to logistic growth and is 60% more transmissible

**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

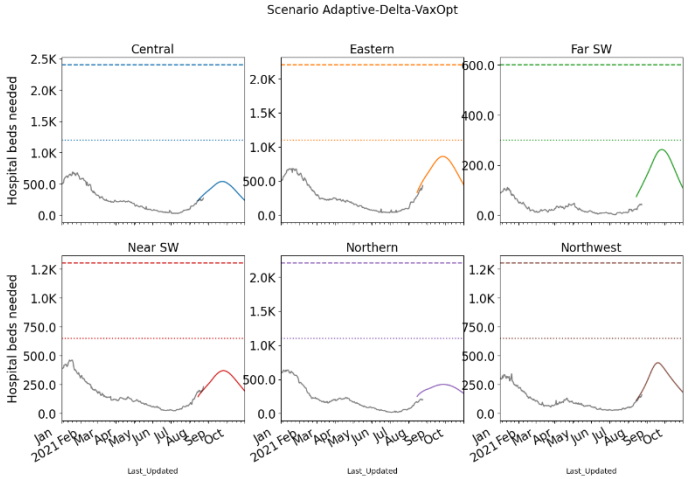
# Model Results

# Outcome Projections

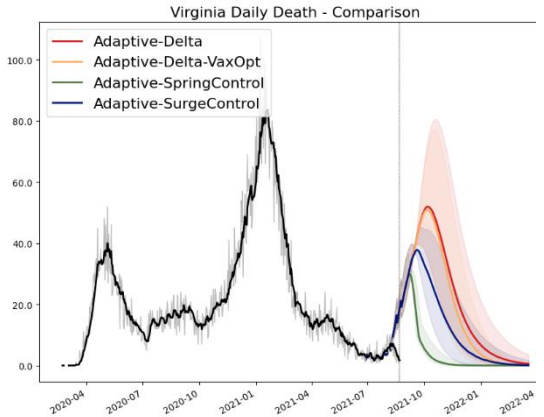
## Confirmed cases




## Estimated Hospital Occupancy

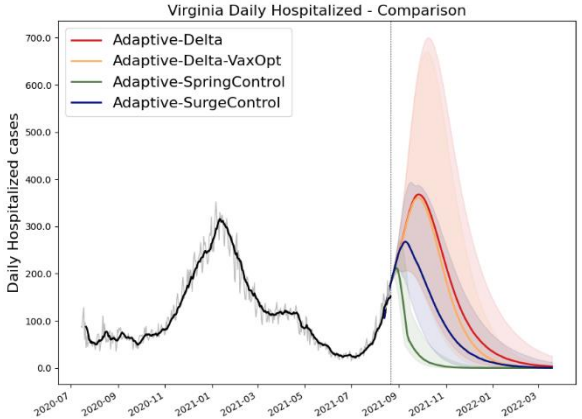



## Daily Deaths




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

## Daily Hospitalized

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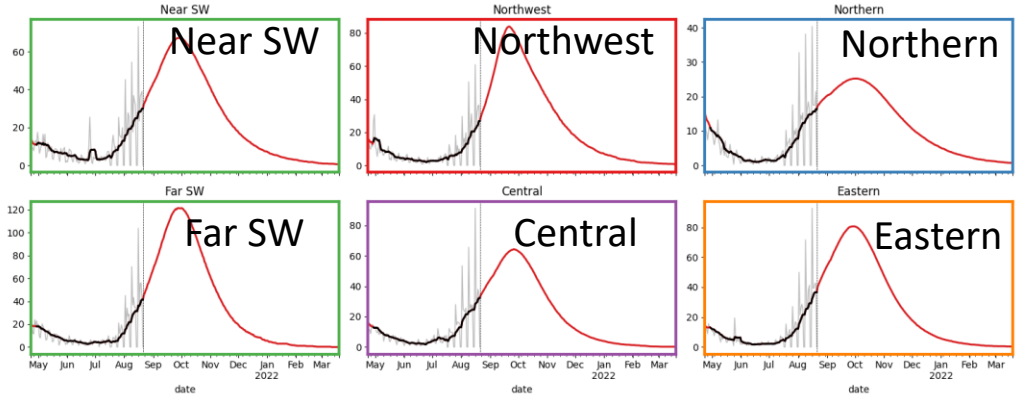
# District Level Projections: Adaptive-Delta

## Projections by Region



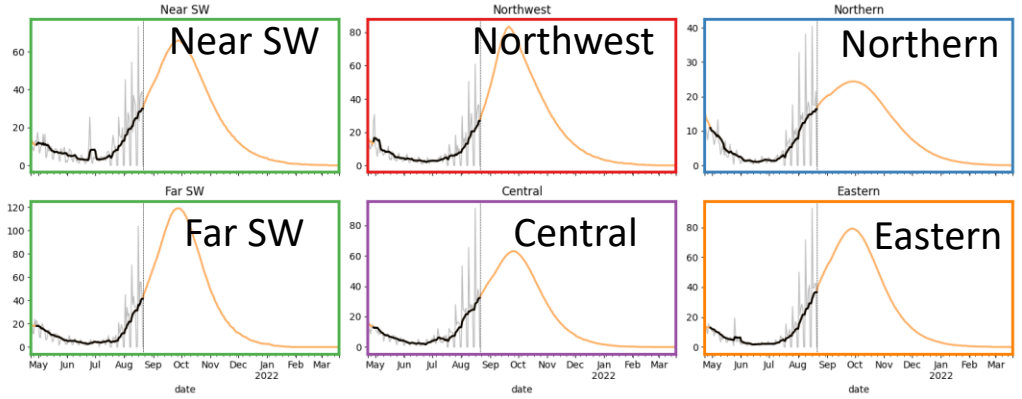

## Projections by District




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

# District Level Projections: Adaptive-Delta-VaxOpt

## Projections by Region



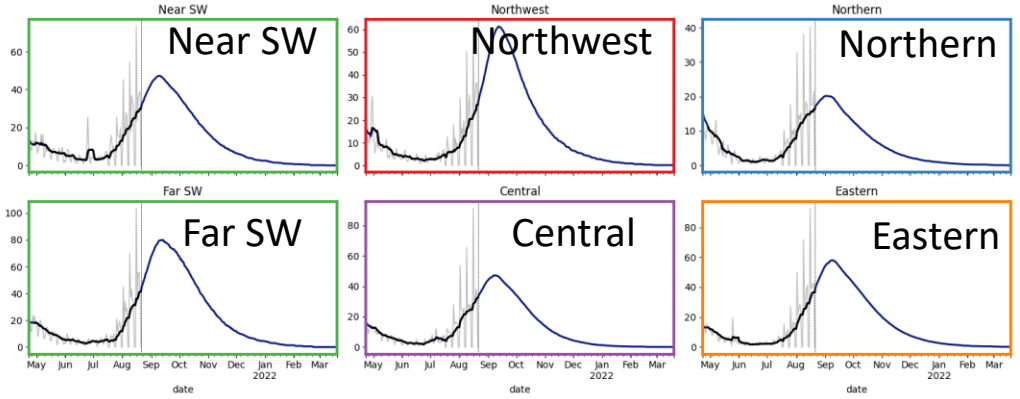

## Projections by District




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

# District Level Projections: SurgeControl

## Projections by Region



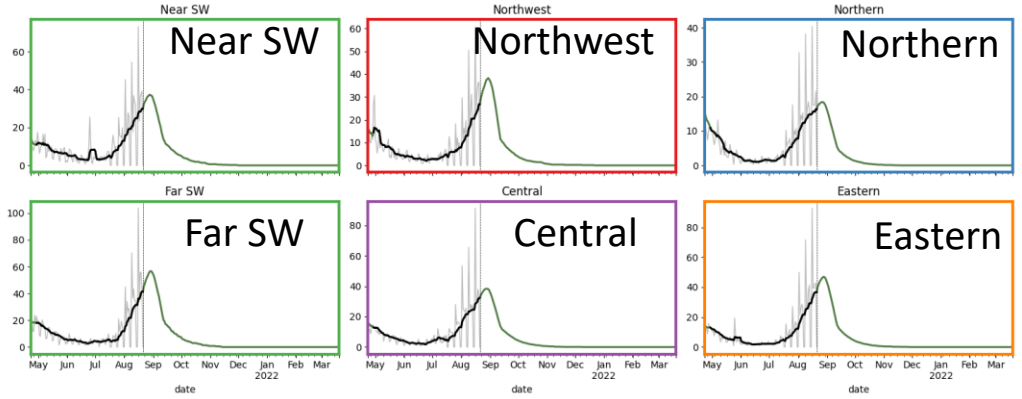

## Projections by District




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

# District Level Projections: SpringControl

## Projections by Region




## Projections by District

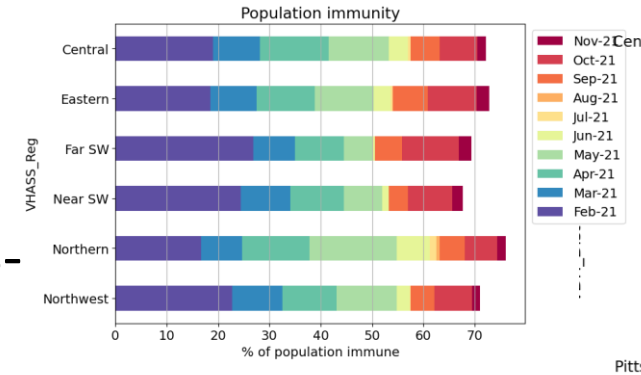


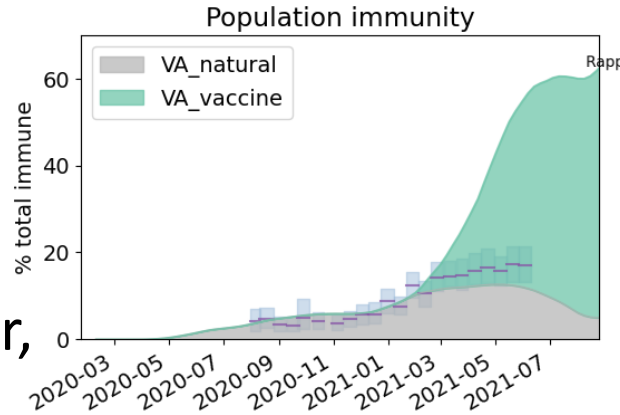

Daily confirmed cases rate (per 100K) by District (grey with 7-day average in black) with simulation colored by scenario

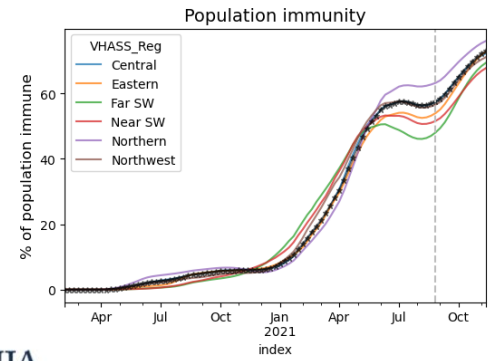
# Virginia's Progress on Population Immunity

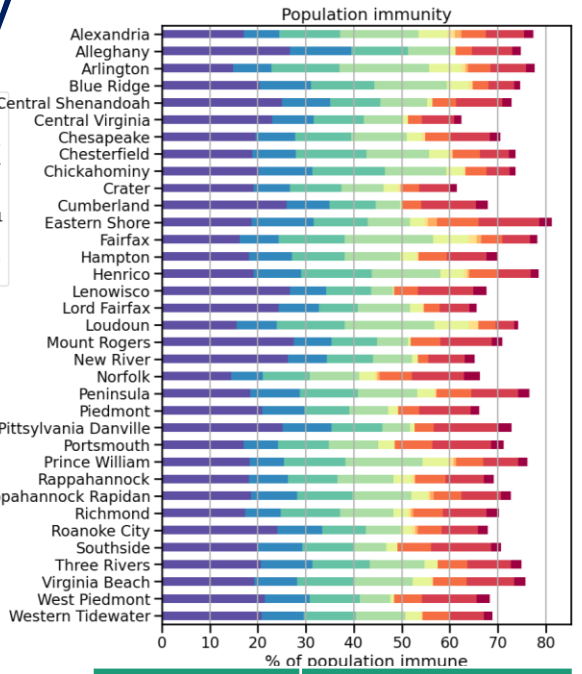
**Natural Immunity and Vaccines combine to produce a population level of immunity**

- 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




| Region | % pop immune (est.)* |
|---|---|
| Central | 57% |
| Eastern | 54% |
| Far SW | 48% |
| Near SW | 52% |
| Northern | 63% |
| Northwest | 56% |
| Virginia | 57% |

* As of August 22, 2021 (updated to account for entire population)

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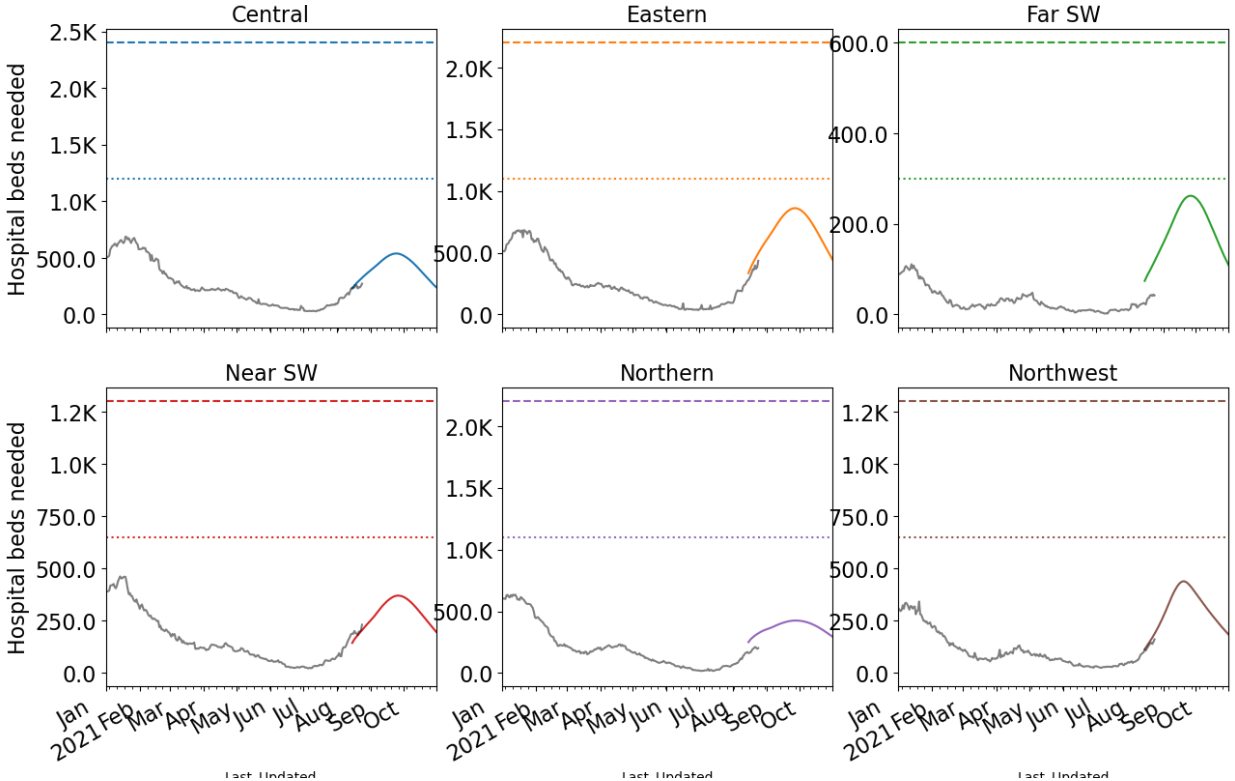
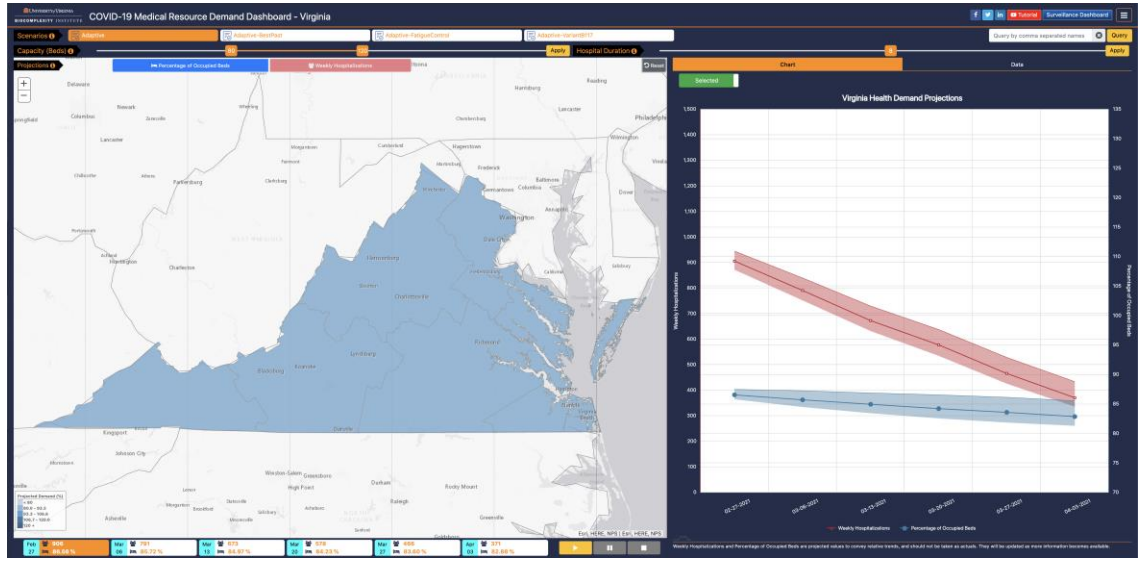
# Hospital Demand and Bed Capacity by Region

**Capacities* by Region – Adaptive-Delta**

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




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

**Adaptive-Delta scenario shows that if the Delta-fueled surge continues unabated:**

- Eastern, Southwest and Northwest could approach initial capacities

* Assumes average length of stay of 8 days

# 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 has slightly slowed, other states have plateaued, but rates remain high**
- VA mean weekly incidence up to 30/100K from 24/100K, US up to 44/100K (from 38/100K)
- Growth in vaccination rates stall, however, FDA approval may boost in coming weeks
- Projections continue to show significant uptick in activity, however, the slackened pace has decreased the overall impact
- Recent updates:
  - Updated Optimistic Vaccination to include potential inclusion of 5-11 year olds this Fall
  - Updated Surge Control scenario to commence sooner as mask use has increased recently
- The situation continues to change. Models continue to be updated regularly.

# Additional Analyses

# 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

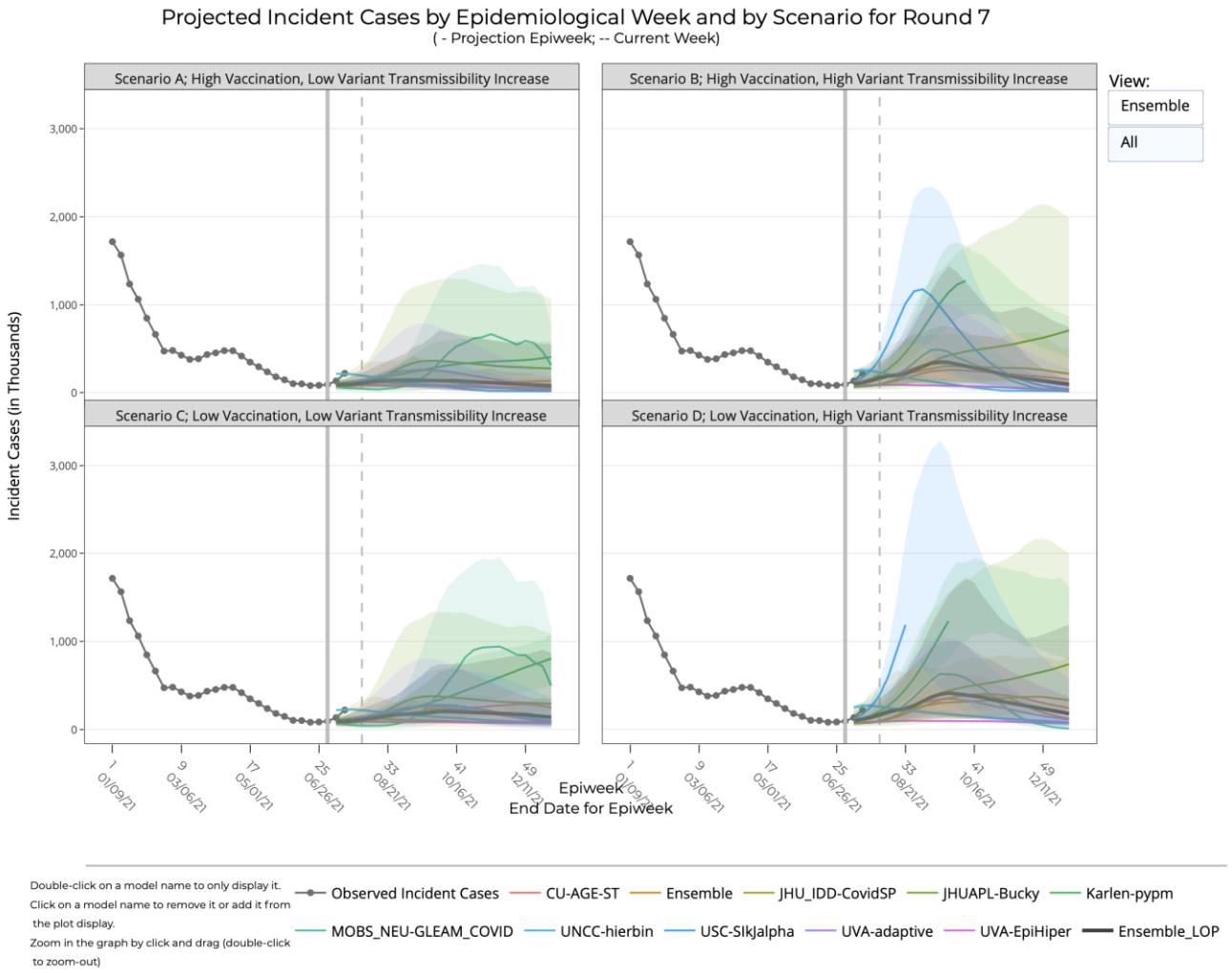
# COVID-19 Scenario Modeling Hub

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

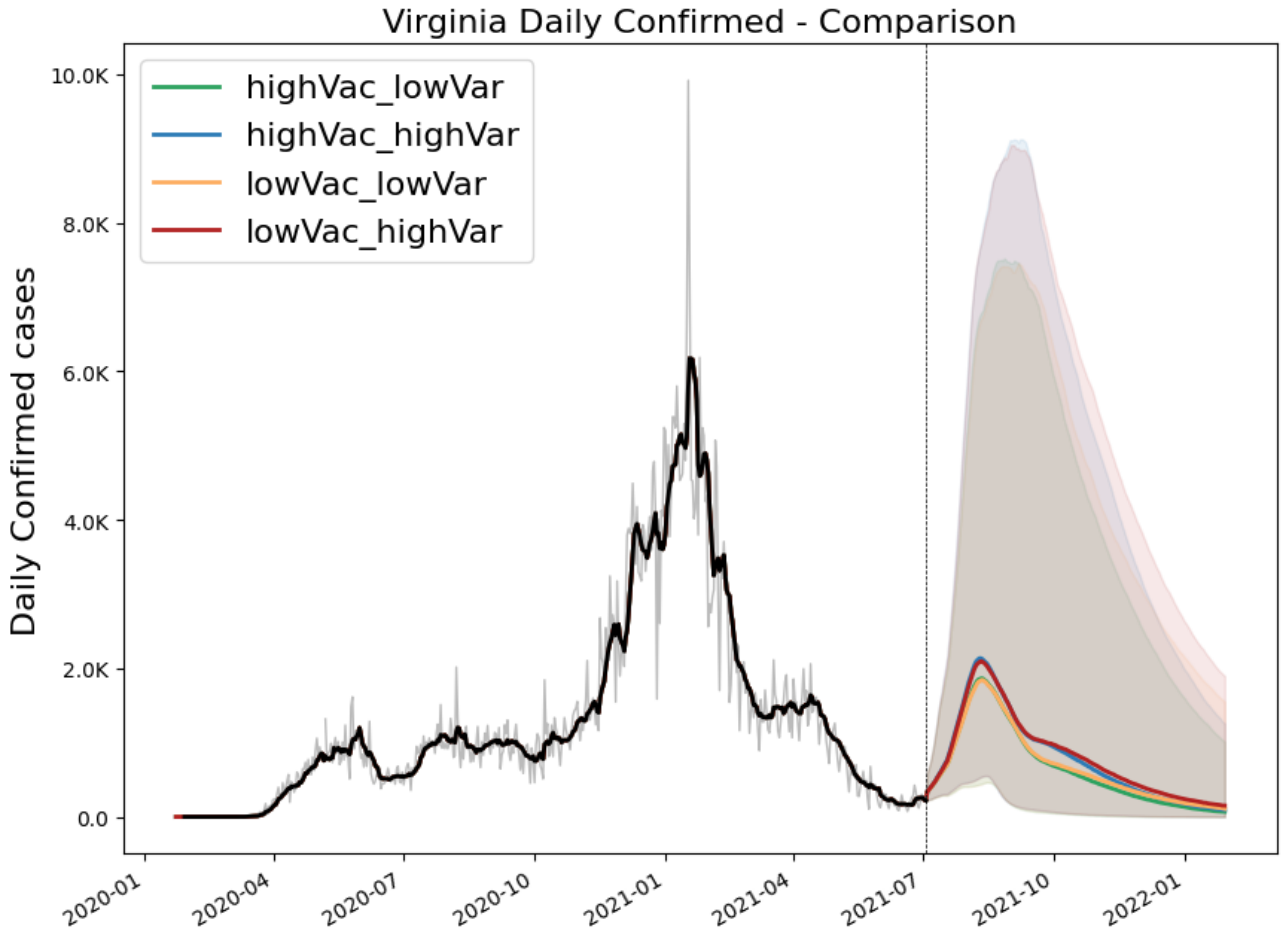
## Emerging Variant Impact (5% prevalence on May 29th)

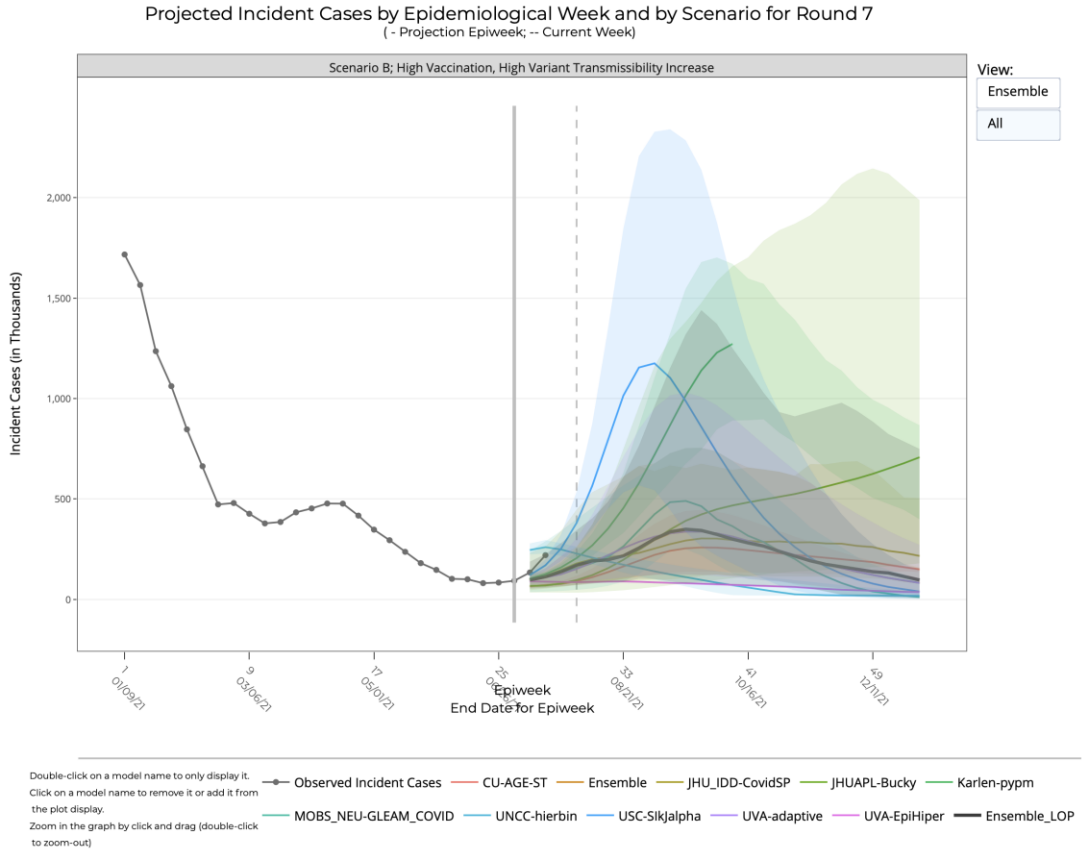
- LowVar – 40% more transmissible
- HighVar – 60% more transmissible

https://covid19scenariomodelinghub.org/viz.html

| | LowVar | HighVar |
|---|---|---|
| See more detailed notes for each scenario below | **Low Impact Variant** *(low transmissibility increase, no immune escape)* | **High Impact Variant** *(high transmissibility increase, no immune escape)* |
| **High Vaccination** *(Low hesitancy)* **HighVacc** | ***Scenario A***<br>Vaccination:<br>- Coverage saturates at **80% nationally** among the vaccine-eligible population* by December 31, 2021**<br>- VE is **50%/90%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose)<br>- J&J no longer used<br>Variant:<br>- **40% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams. | ***Scenario B***<br>Vaccination:<br>- Coverage saturates at **80% nationally** among the vaccine-eligible population* by December 31, 2021**<br>- VE is **35%/85%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose)<br>- J&J no longer used<br>Variant:<br>**60% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams. |
| **Low Vaccination** *(High hesitancy)* **LowVacc** | ***Scenario C***<br>Vaccination:<br>- Coverage saturates at **70% nationally** among the vaccine-eligible population* by December 31, 2021**<br>- VE is **50%/90%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose)<br>- J&J no longer used<br>Variant:<br>- **40% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams. | ***Scenario D***<br>Vaccination:<br>- Coverage saturates at **70% nationally** among the vaccine-eligible population* by December 31, 2021**<br>- VE is **35%/85%** for Pfizer/Moderna against the Delta variant, against symptoms (1st /2nd dose)<br>- J&J no longer used<br>Variant:<br>**60% increased transmissibility** as compared with Alpha for Delta variant. Initial prevalence estimated at state-level by teams. |

# Modeling Hub – Round 7 Prelim Results




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**

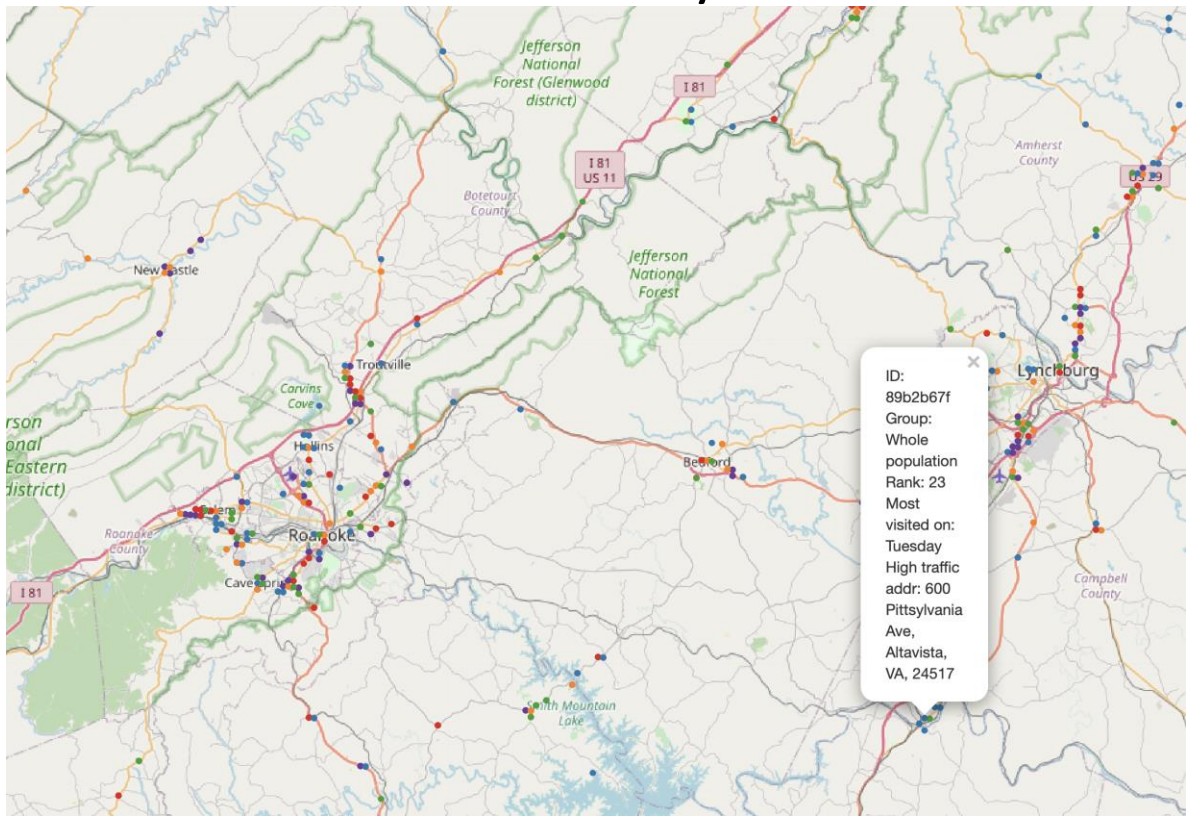
- Age stratified protection from infection
- 80% or 90% protection from hosp/death

| | | **Slow Waning** | **Fast Waning** |
|---|---|---|---|
| See detailed notes on each scenario below | | **Slow waning of natural and vaccine-induced immunity** *(from no waning to exponential waning with mean of 3 yrs)* | **Fast waning of natural and vaccine-induced immunity** *(exponential waning with mean of 1 year)* |
| **High protection against infection and severe disease after waning** | **High Protection** | ***Scenario A***<br><br>No Waning:<br>- Vaccine-induced and natural immunity retain their initial protection throughout the simulation period | ***Scenario B***<br><br>Waning:<br>- **Exponentially distributed immune waning with mean of 1 year** (time to transition to partially immune state)<br><br>In partially immune state:<br>- Protection from infection is:<br>**- 70% ≤ 65yrs**<br>**- 35% > 65yrs**<br>- Protection from hospitalization and death is **90%** |
| **Low protection against infection and severe disease after waning** | **Low Protection** | ***Scenario C***<br><br>Waning:<br>- **Exponentially distributed immune waning with mean of 3 years** (time to transition to partially immune state)<br><br>In partially immune state:<br>- Protection from infection is:<br>**- 50% ≤ 65yrs**<br>**- 25% > 65yrs**<br>- Protection from hospitalization and death is **80%** | ***Scenario D***<br><br>Waning:<br>- **Exponentially distributed immune waning with mean of 1 year** (time to transition to partially immune state)<br><br>In partially immune state:<br>- Protection from infection is:<br>**- 50% ≤ 65yrs**<br>**- 25% > 65yrs**<br>- Protection from hospitalization and death is **80%** |

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

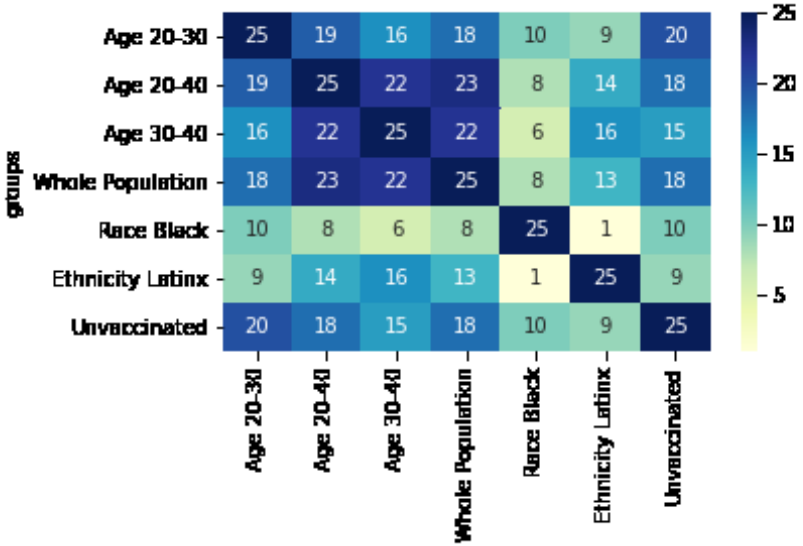
**Goal:** Provide frequently visited locations based on populations and vaccination levels one desires to reach

**Example:** List of location in the Southside frequented by 20-40 year olds

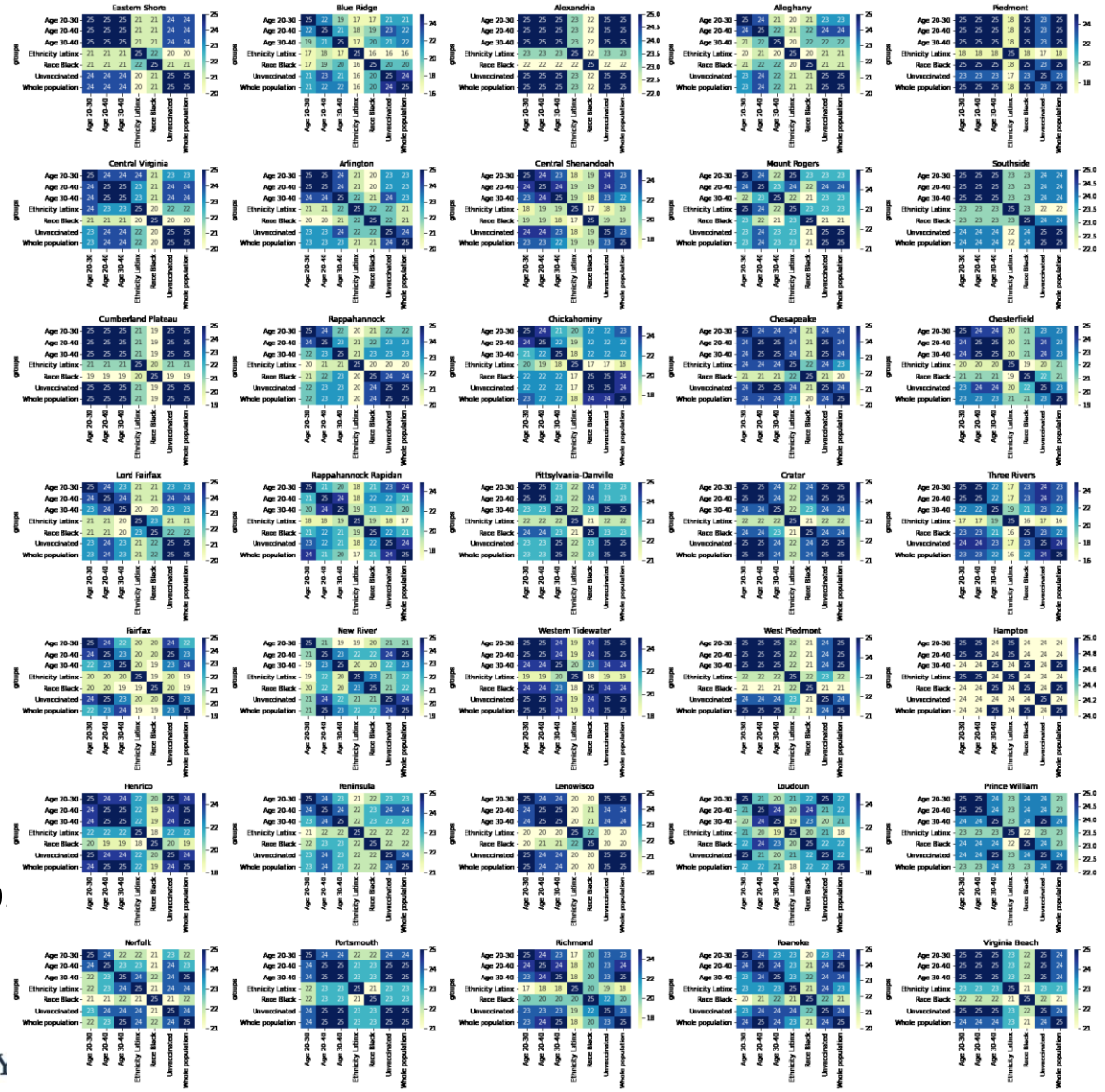
# Data Recommended Mobile Vax Clinic Sites

## Overlap of locations between groups

**State Level**




**Within VDH Health Districts**




**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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NSSAC. PatchSim: Code for simulating the metapopulation SEIR model. https://github.com/NSSAC/PatchSim

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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/


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

# Questions?

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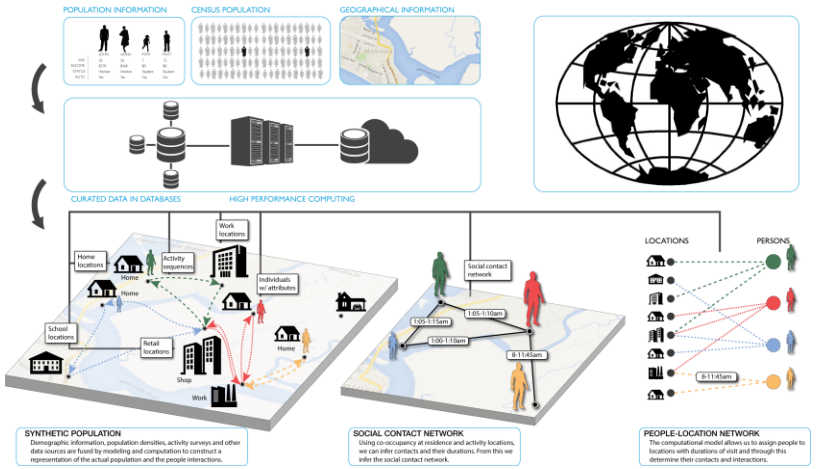
# Supplemental Slides

# Agent-based Model (ABM )

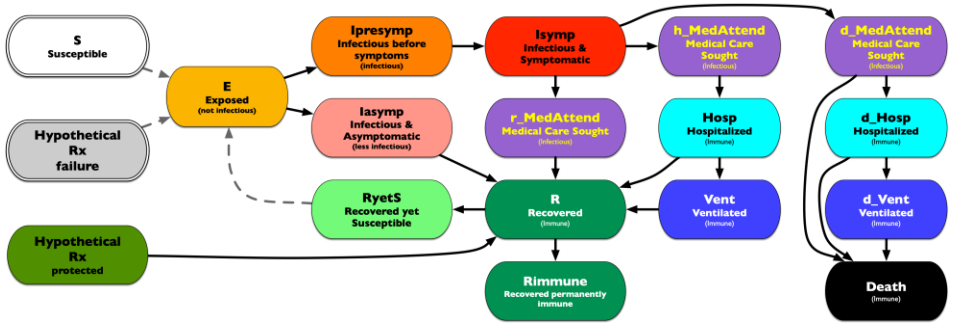
**EpiHiper: Distributed network-based stochastic disease transmission simulations**

- 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