Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

August 10th, 2022

(data current to August 6th – 9th)

Biocomplexity Institute Technical report: TR BI-2022-1643

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

biocomplexity.virginia.edu

About Us

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

Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Model Development, Outbreak Analytics, and Delivery Team

Przemyslaw Porebski, Joseph Outten, Brian Klahn, Alex Telionis, Srinivasan Venkatramanan, Bryan Lewis, Aniruddha Adiga, Hannah Baek, Chris Barrett, Jiangzhuo Chen, Patrick Corbett, Stephen Eubank, Galen Harrison, Ben Hurt, Dustin Machi, Achla Marathe, Madhav Marathe, Mark Orr, Akhil Peddireddy, Erin Raymond, James Schlitt, Anil Vullikanti, Lijing Wang, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

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

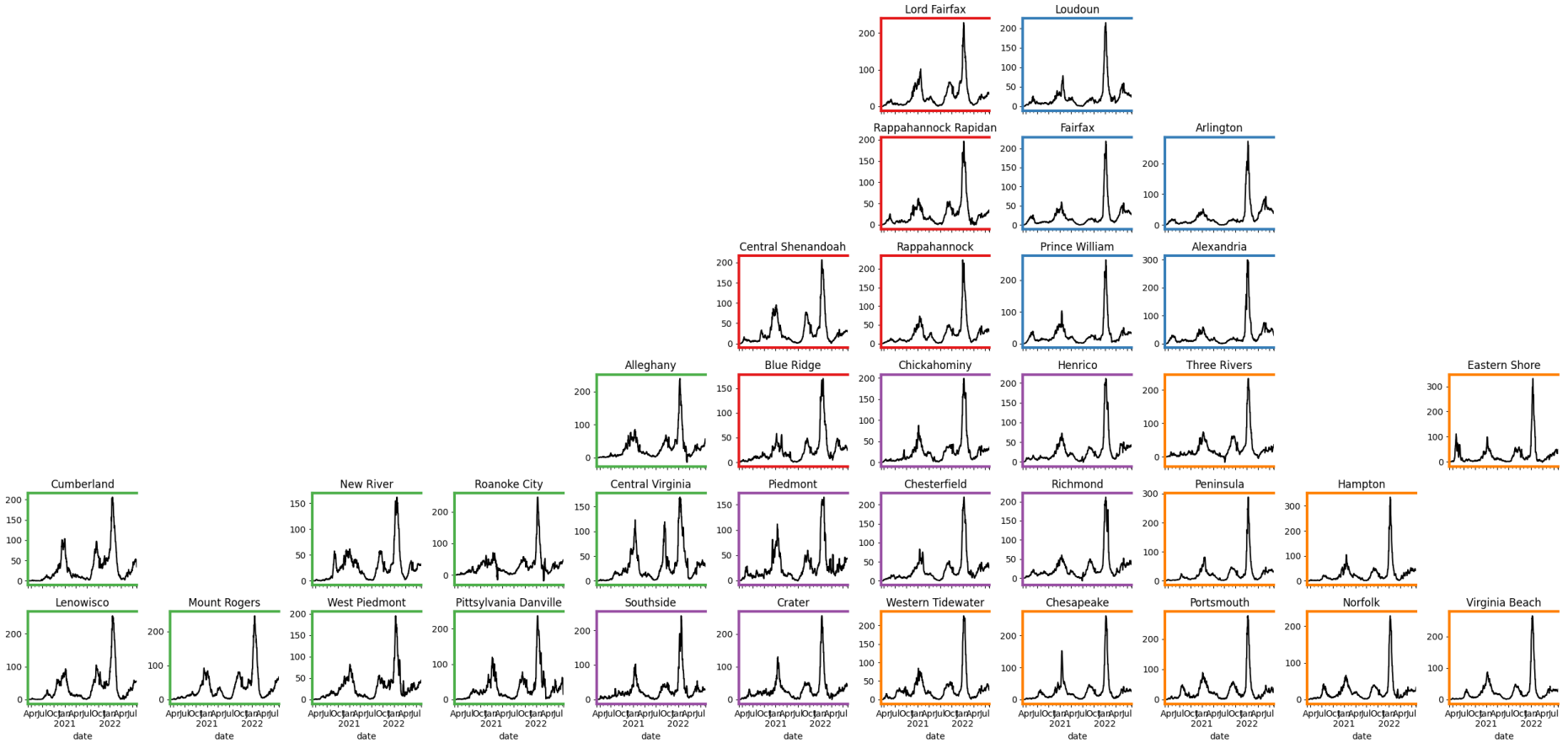
Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

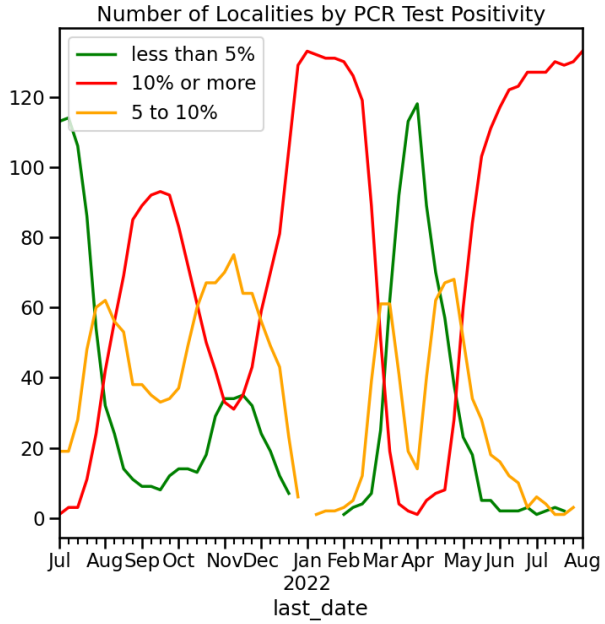
- **Case rates remain high though have continued their decline, hospitalizations have started to follow**
- VA weekly case rate down to 228/100K from 250/100K
  - US weekly case rate is relatively flat at 227/100K from 240/100K
  - VA hospital occupancy (rolling 7 day mean of 754 down from 776 a week ago) has continued to rise
- Projections anticipate continuation of these declines in cases as well as hospitalizations, but retain a potential for rebounds due to seasonal forces and/or novel sub-variants in the Fall
- Model updates:
  - Added preliminary scenarios for booster campaigns based on planned re-formulated boosters likely available this fall
  - Variant X introduction shifted back a month in the absence of any evidence of a new variant that is quickly gaining ground on BA.5

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

Situation Assessment

Case Rates (per 100k) and Test Positivity





County level RT-PCR test positivity

Green: <5.0% (or <20 tests in past 14 days)

Orange: 5.0%-10.0% (or <500 tests and <2000 tests/100k and >10% positivity over 14 days)

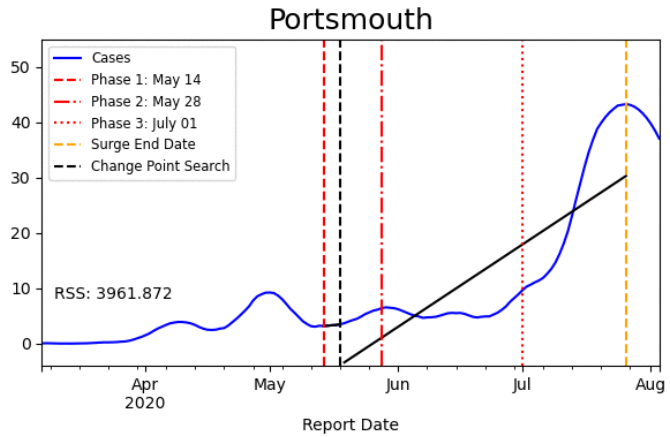
Red: >10.0% (and not "Green" or "Yellow")

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

Hockey stick fit

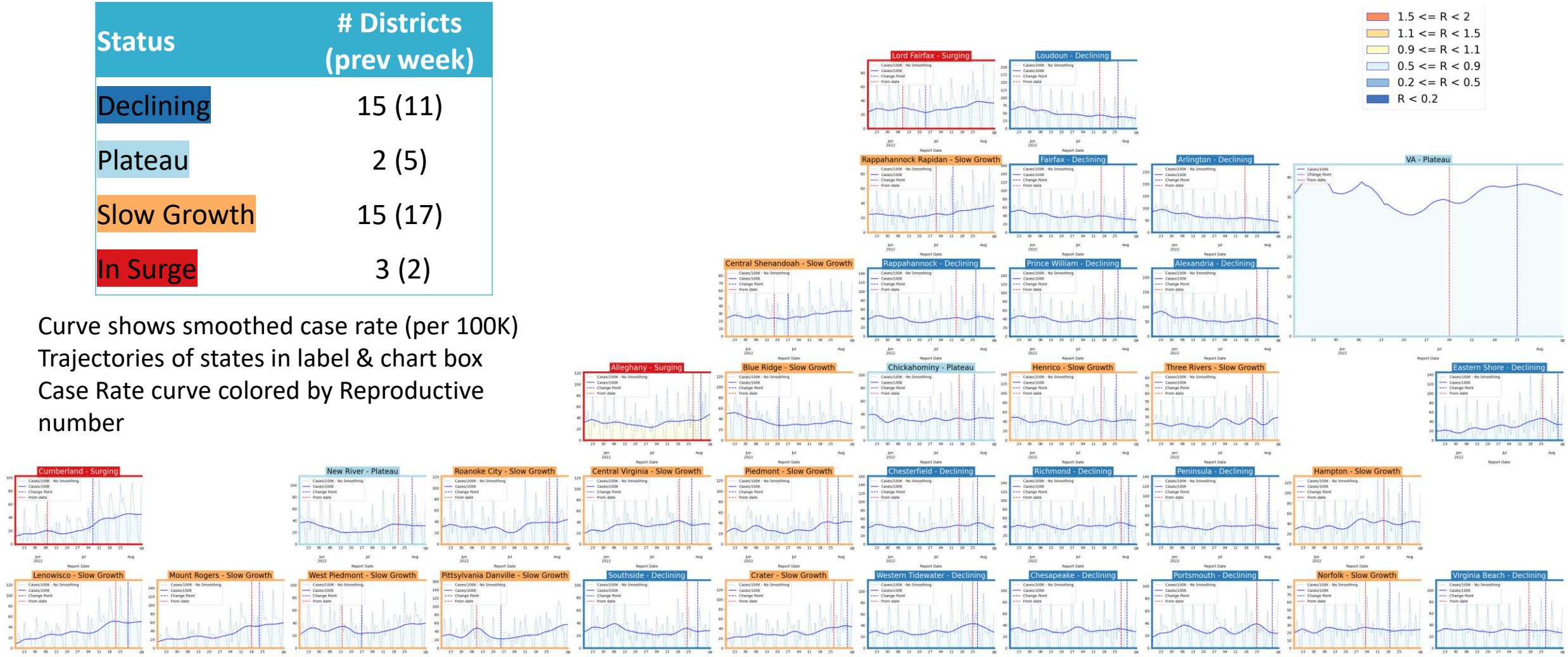


Trajectory	Description	Weekly Case Rate (per 100K) bounds
Declining	Sustained decreases following a recent peak	below -0.9
Plateau	Steady level with minimal trend up or down	above -0.9 and below 0.5
Slow Growth	Sustained growth not rapid enough to be considered a Surge	above 0.5 and below 2.5
In Surge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

District Case Trajectories – last 10 weeks

Status	# Districts (prev week)
Declining	15 (11)
Plateau	2 (5)
Slow Growth	15 (17)
In Surge	3 (2)

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



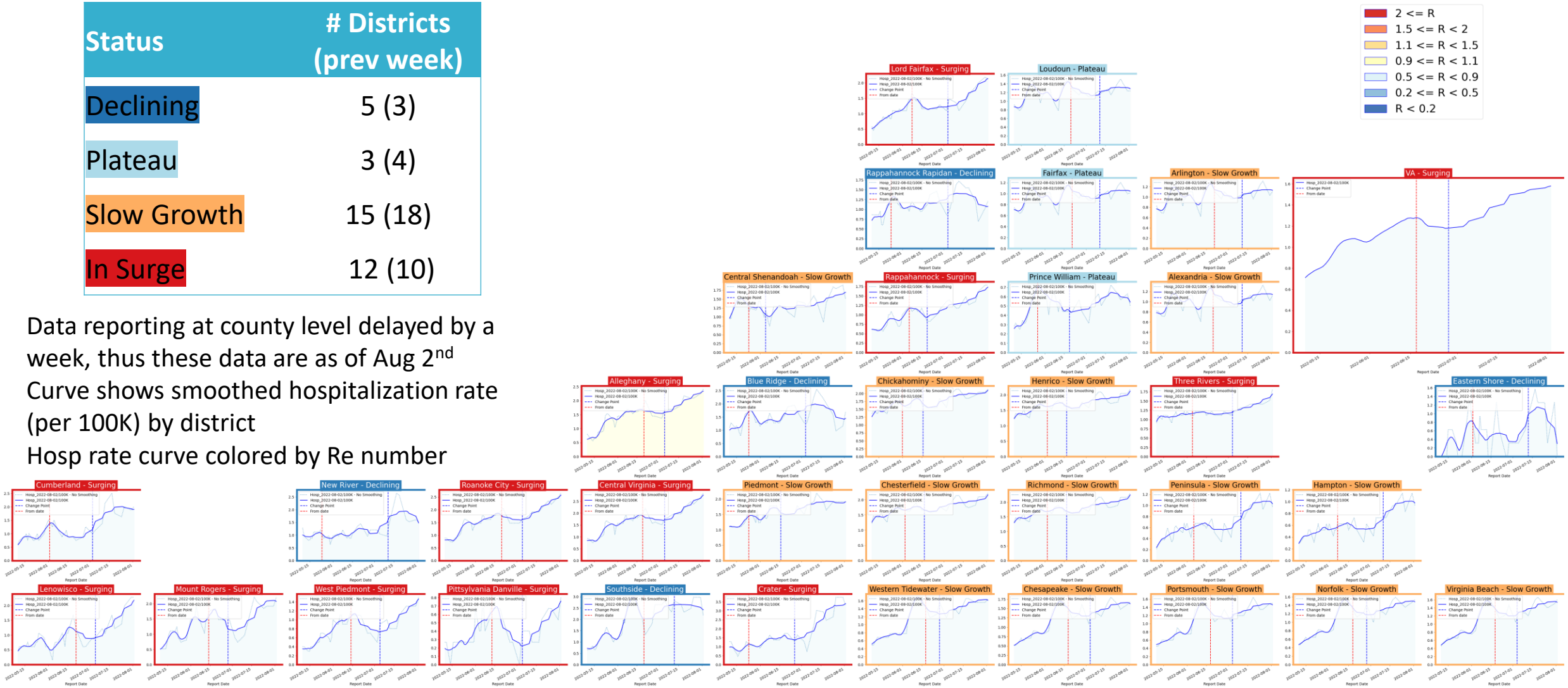
District Hospital Trajectories – last 10 weeks (as of Aug 2nd)

Status	# Districts (prev week)
Declining	5 (3)
Plateau	3 (4)
Slow Growth	15 (18)
In Surge	12 (10)

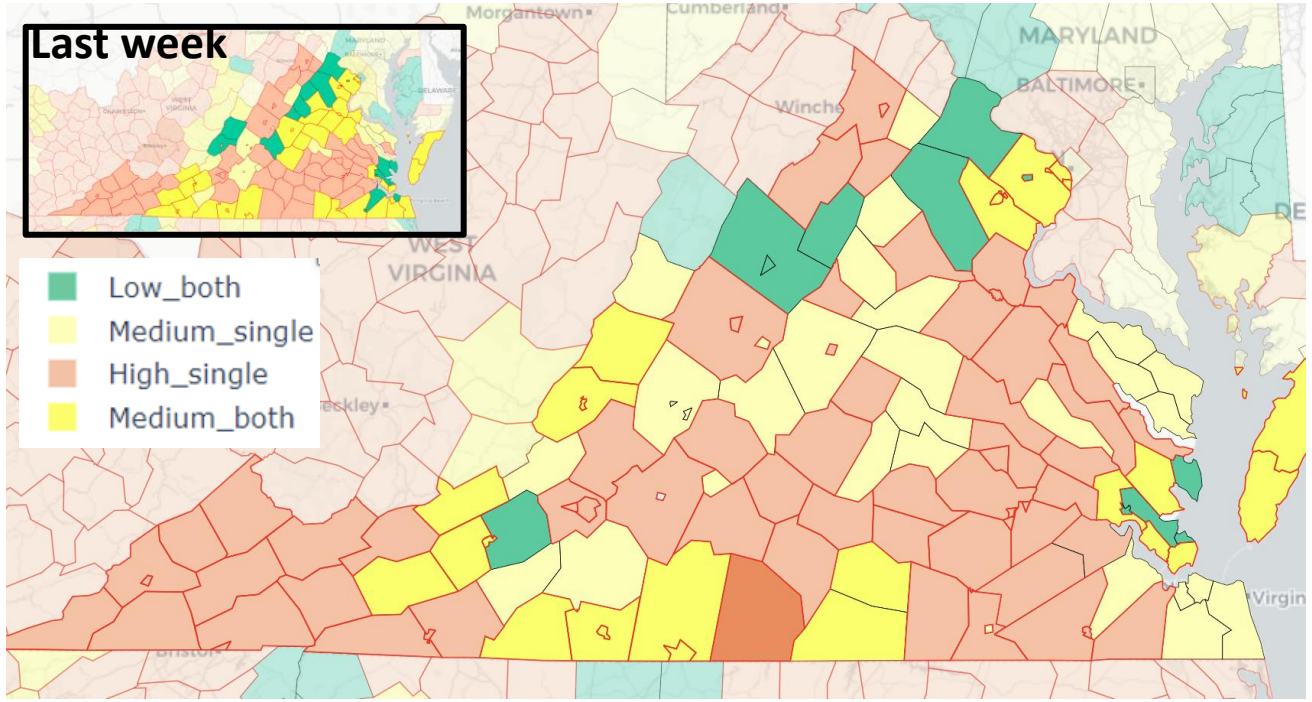
Data reporting at county level delayed by a week, thus these data are as of Aug 2nd

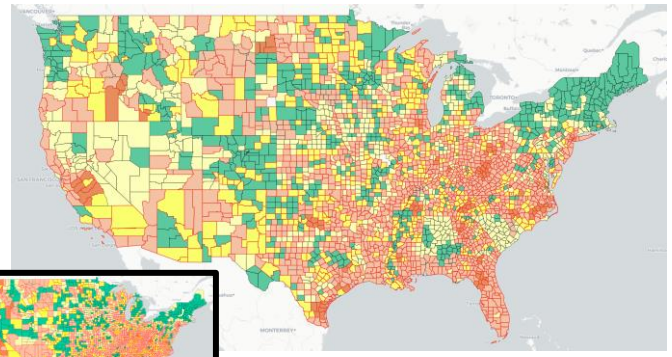
Curve shows smoothed hospitalization rate (per 100K) by district

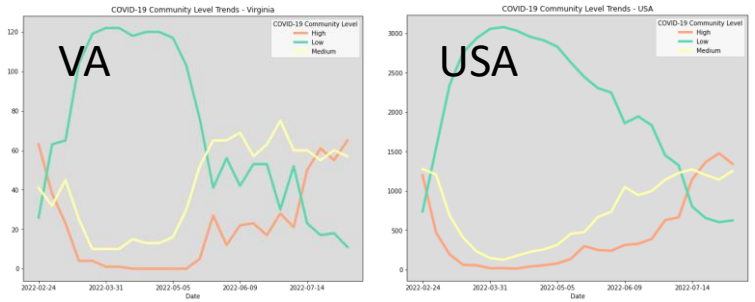
Hosp rate curve colored by Re number



CDC's COVID-19 Community Levels







Red outline indicates county had 200 or more cases per 100k in last week

Pale color indicates either beds or occupancy set the level for this county

Dark color indicates both beds and occupancy set the level for this county

COVID-19 Community Levels – Use the Highest Level that Applies to Your Community

New COVID-19 Cases Per 100,000 people in the past 7 days	Indicators	Low	Medium	High
Fewer than 200	New COVID-19 admissions per 100,000 population (7-day total)	<10.0	10.0-19.9	≥20.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	<10.0%	10.0-14.9%	≥15.0%
200 or more	New COVID-19 admissions per 100,000 population (7-day total)	NA	<10.0	≥10.0
	Percent of staffed inpatient beds occupied by COVID-19 patients (7-day average)	NA	<10.0%	≥10.0%

The COVID-19 community level is determined by the higher of the new admissions and inpatient beds metrics, based on the current level of new cases per 100,000 population in the past 7 days

UNIVERSITY of VIRGINIA

BIOCOMPLEXITY INSTITUTE

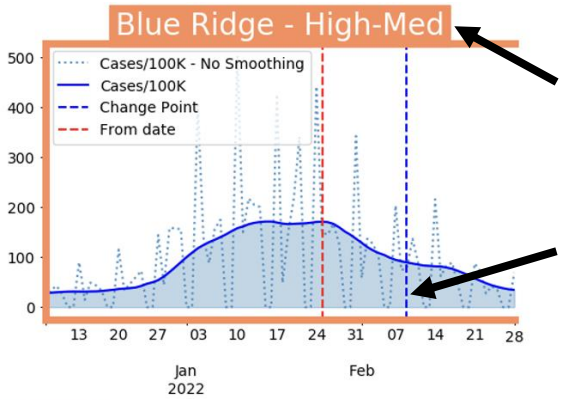
Data from: CDC Data Tracker Portal

District Trajectories with Community Levels

Community Level (Title Color)
- High
- High-Med
- Med-High
- Medium
- Med-Low
- Low-Med
- Low

Curve shows smoothed case rate (per 100K)
CDC's new Community Level aggregated to district level in label & chart box color
Case Rate curve colored by Trajectory

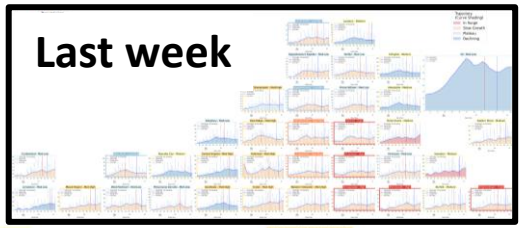
Trajectory (Curve Shading)
- In Surge
- Slow Growth
- Plateau
- Declining



District's Aggregate Community Level

Aggregate level a simple mean of all levels for counties in district

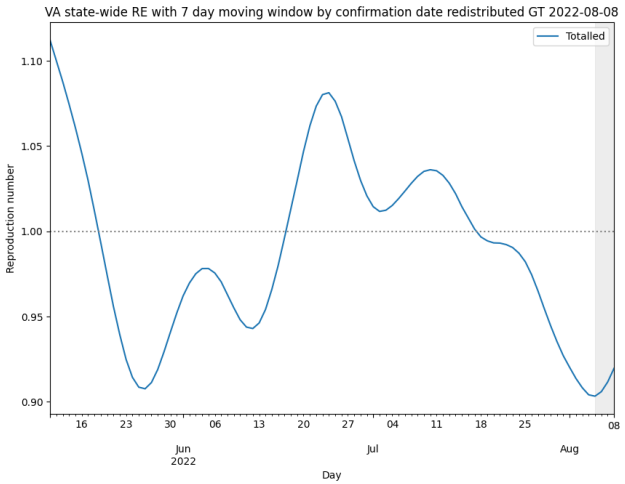
Case rate Trajectory

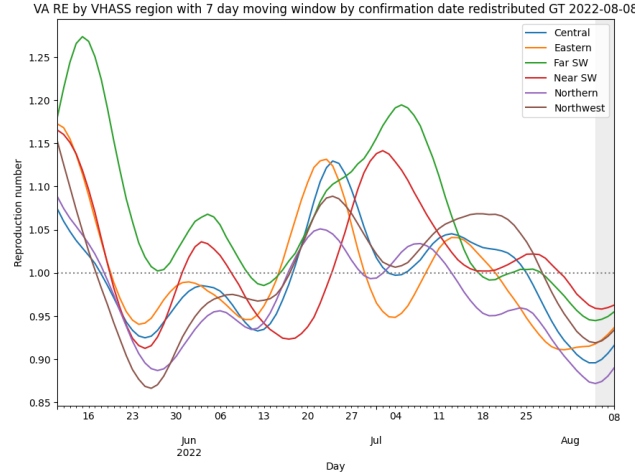


Estimating Daily Reproductive Number –
Redistributed gap

August 8th Estimates

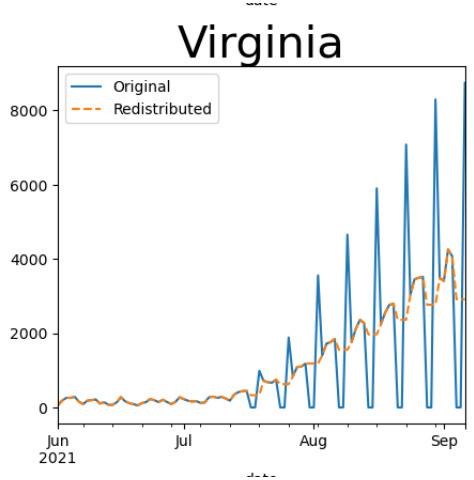
Region	Date Confirmed R_e	Date Confirmed Diff Last Week
State-wide	0.918	-0.037
Central	0.915	-0.060
Eastern	0.938	0.002
Far SW	0.956	0.015
Near SW	0.961	0.001
Northern	0.888	-0.069
Northwest	0.934	-0.039





Skipping Weekend Reports & holidays biases estimates

Redistributed "big" report day to fill in gaps, and then estimate R from "smoothed" time series



Methodology

- Wallinga-Teunis method (EpiEstim[1]) for cases by **<u>confirmation date</u>**
- 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

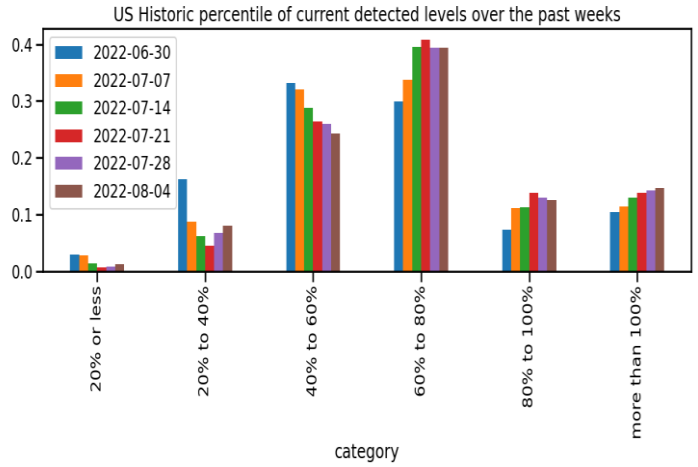
1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Wastewater Monitoring

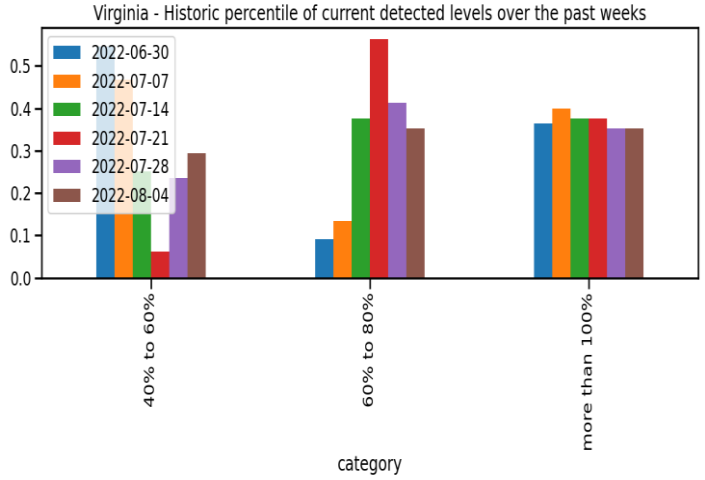
Wastewater provides a coarse early warning of COVID-19 levels in communities

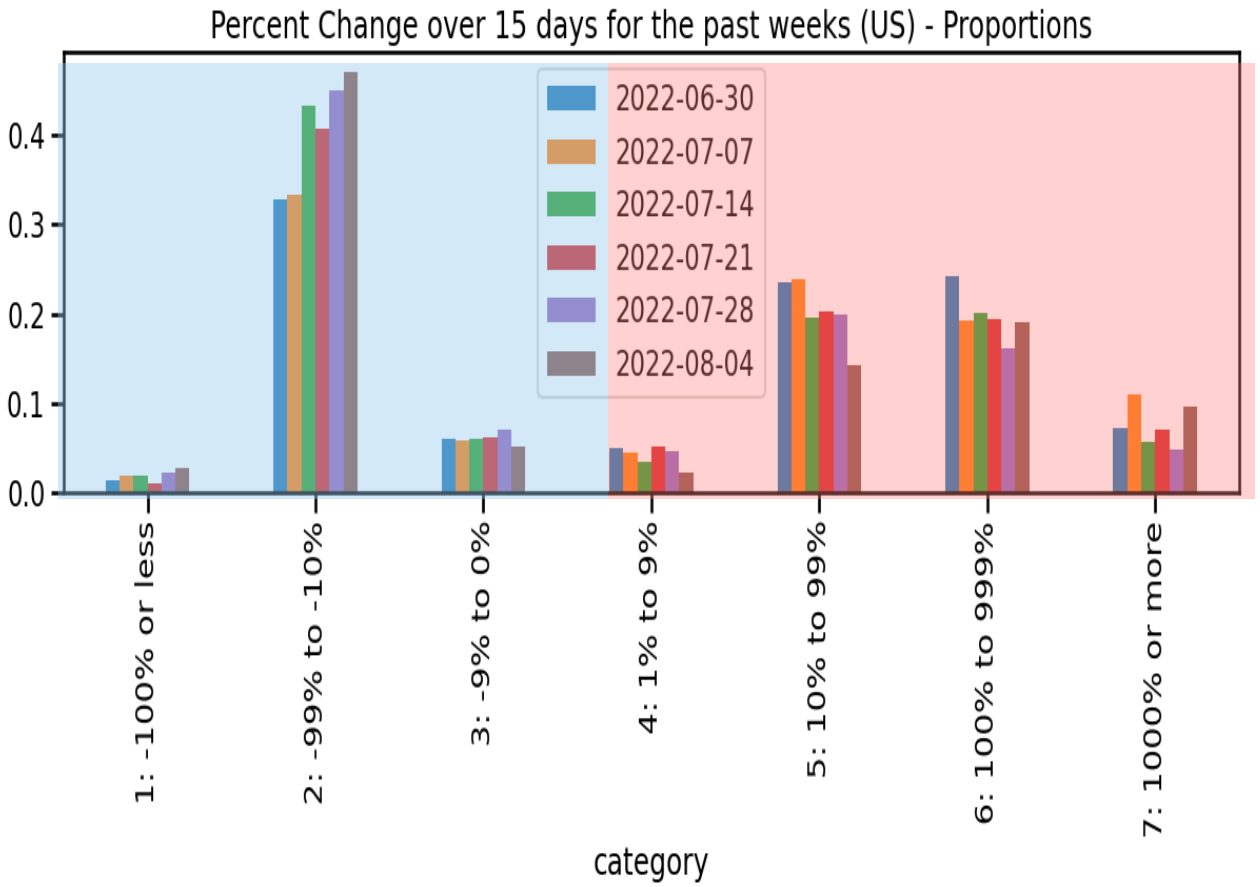
- Overall in the US, there is an increase in sites with increased levels of virus compared to 15 days ago
- Current virus levels are at or exceeding max of previous historical levels, has slowed, though more sites are entering upper quintiles

USA



VA



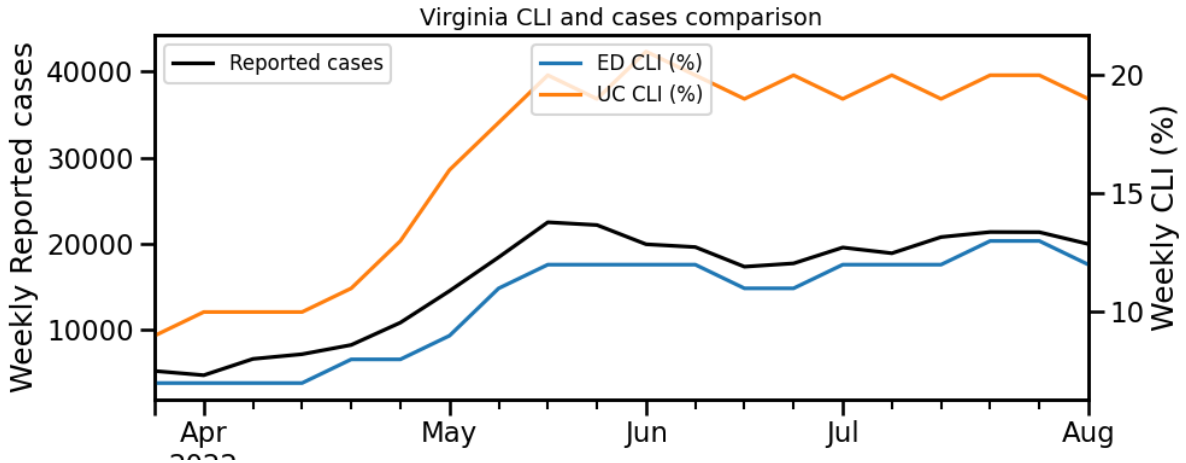


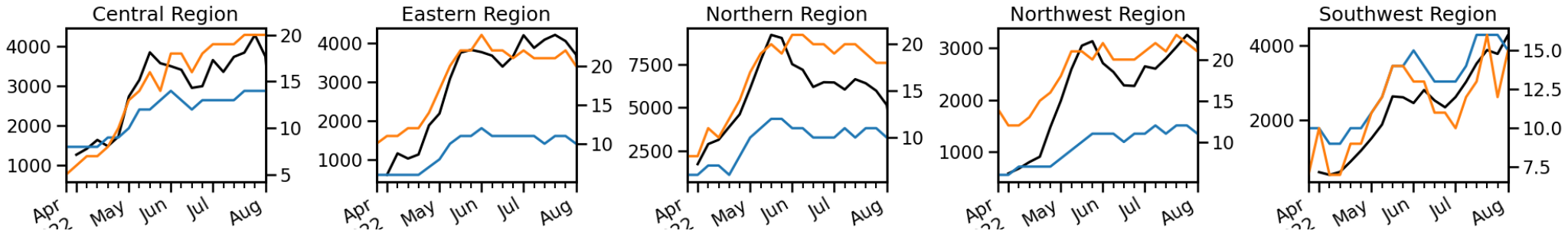
Data Source: [CDC Data Tracker]

COVID-like Illness Activity

COVID-like Illness (CLI) gives a measure of COVID transmission in the community

- Emergency Dept (ED) based CLI is more correlated with case reporting
- Urgent Care (UC) is a leading indicator but prone to some false positives
- **Current trends in UC CLI have plateaued for last 12 weeks state-wide with some regional signs of decline**

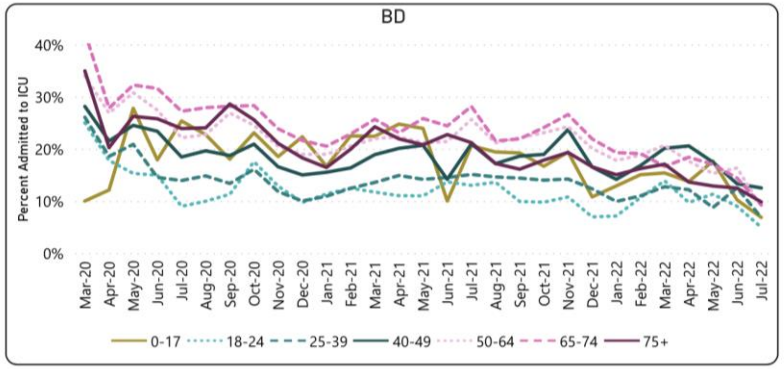


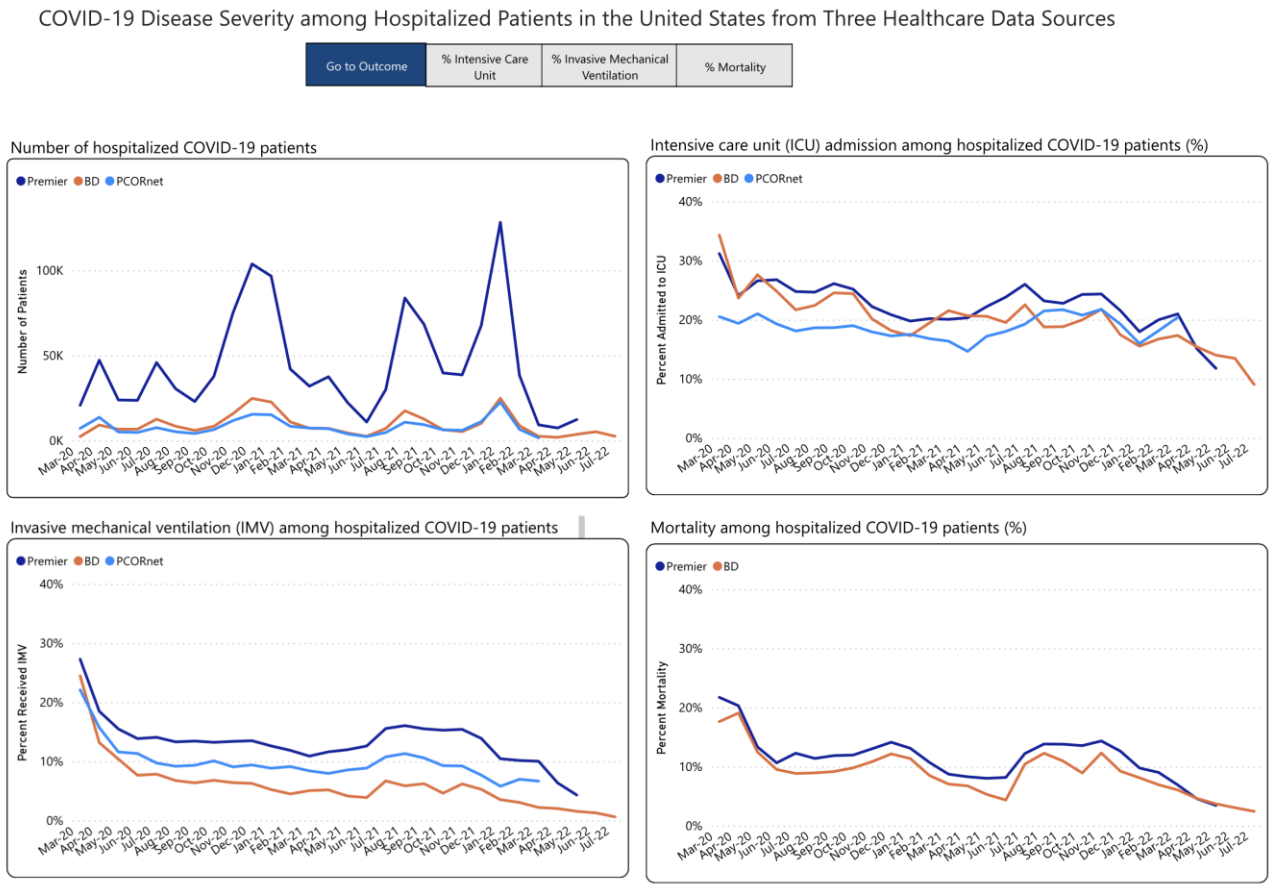


Hospitalizations and Severe Outcomes

Proportion of most severe outcomes decreasing among those who are hospitalized

- ICU has declined from ~20% of hospitalized to nearly 10% since the first wave of Omicron
- Similar levels of decline experience for mechanical ventilation and death
- Also seen across all age-groups





SARS-CoV2 Variants of Concern

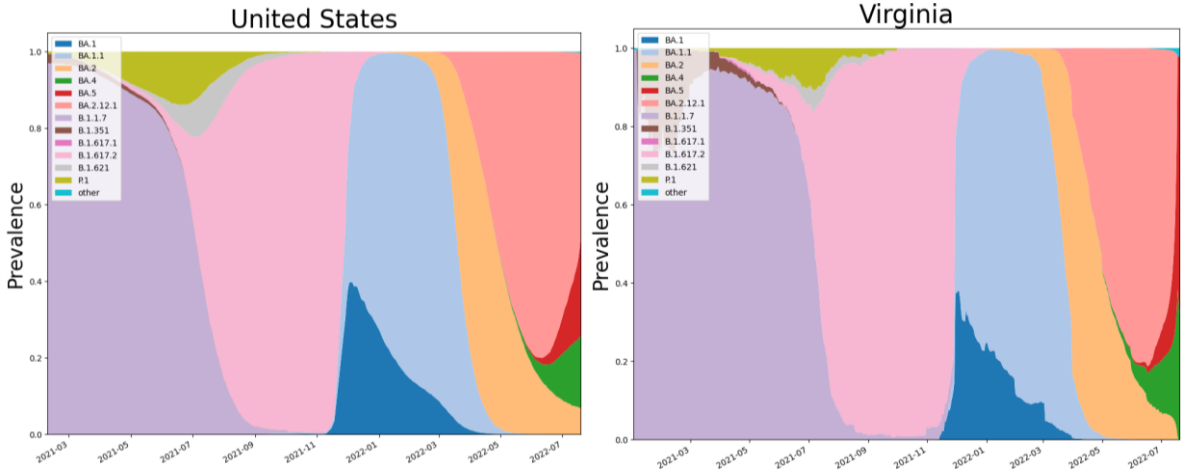
Emerging new variants will alter the future trajectories of pandemic and have implications for future control

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

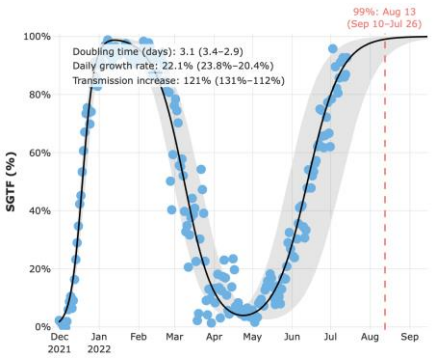
Omicron Updates

- BA.2.12.1 remains at ~12% after several weeks of declining proportions
- BA.4 has stagnated at 15-19% for past 5 weeks
- BA.5 continues to grow rapidly, nowcasted at 72% (up from 53% last week)
- BA.4 and BA.5 have same mutation as BA.1 that produces S-gene target failure, so can be tracked in more real time with SGTF from some PCR tests, will continue to monitor for signs of BA.2.x which lacks the mutation, thus should decline if these sub-variants return (e.g. BA.2.75 which has been growing in Europe)

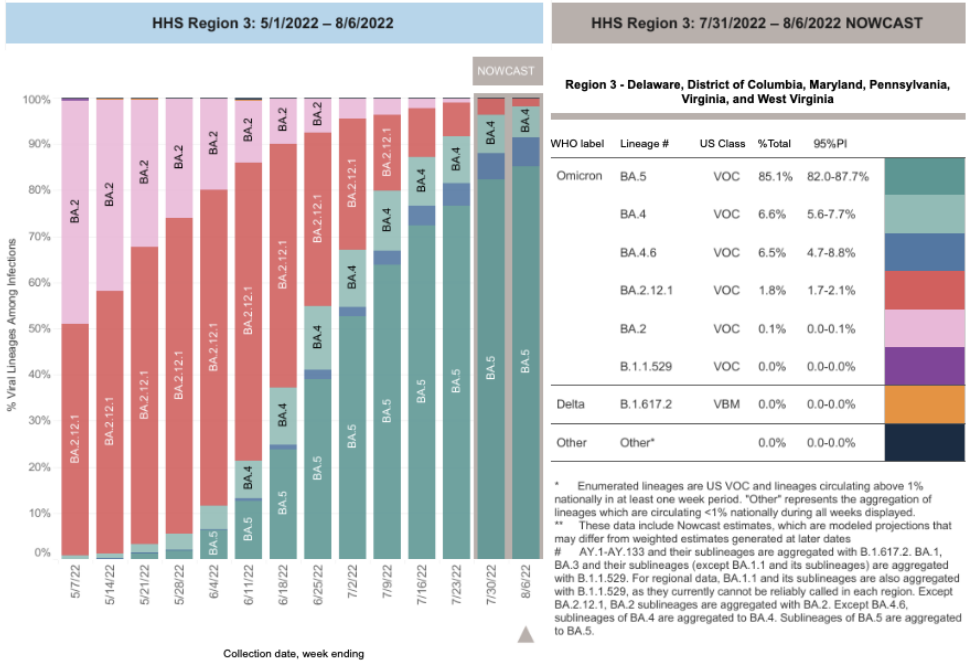
GISAID outbreak.info



SGTF in San Diego



Estimated to be over 95%



Region 3 - Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia

WHO label	Lineage #	US Class	%Total	95%PI
Omicron	BA.5	VOC	85.1%	82.0-87.7%
	BA.4	VOC	6.6%	5.6-7.7%
	BA.4.6	VOC	6.5%	4.7-8.8%
	BA.2.12.1	VOC	1.8%	1.7-2.1%
	BA.2	VOC	0.1%	0.0-0.1%
	B.1.1.529	VOC	0.0%	0.0-0.0%
Delta	B.1.617.2	VBM	0.0%	0.0-0.0%
Other	Other*		0.0%	0.0-0.0%

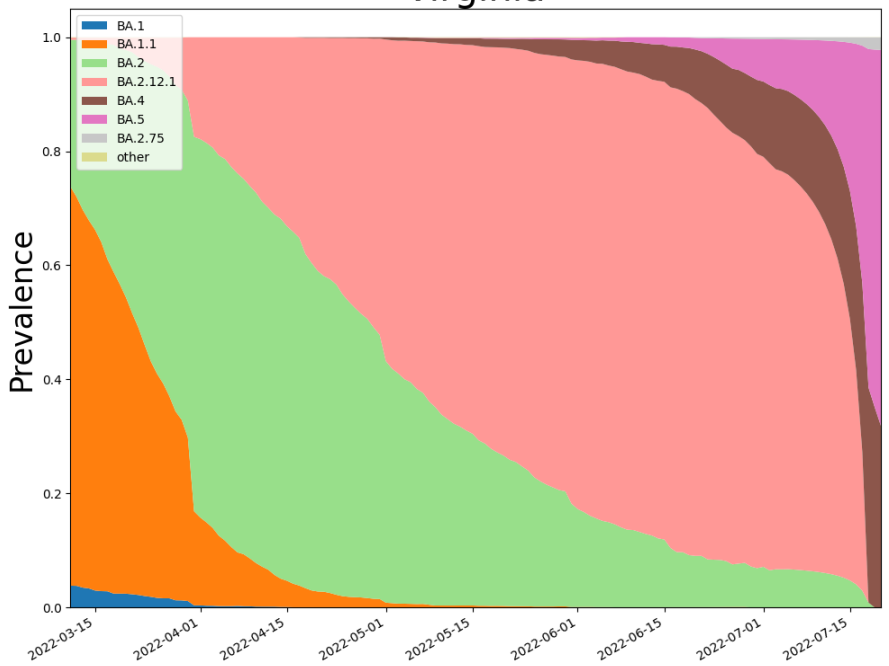
* Enumerated lineages are US VOC and lineages circulating above 1% nationally in at least one week period. "Other" represents the aggregation of lineages which are circulating <1% nationally during all weeks displayed.
** These data include Nowcast estimates, which are modeled projections that may differ from weighted estimates generated at later dates
# AY.1-AY.133 and their sublineages are aggregated with B.1.617.2. BA.1, BA.3 and their sublineages (except BA.1.1 and its sublineages) are aggregated with B.1.1.529. For regional data, BA.1.1 and its sublineages are also aggregated with B.1.1.529, as they currently cannot be reliably called in each region. Except BA.2.12.1, BA.2 sublineages are aggregated with BA.2. Except BA.4.6, sublineages of BA.4 are aggregated to BA.4. Sublineages of BA.5 are aggregated to BA.5.

CDC Variant Tracking

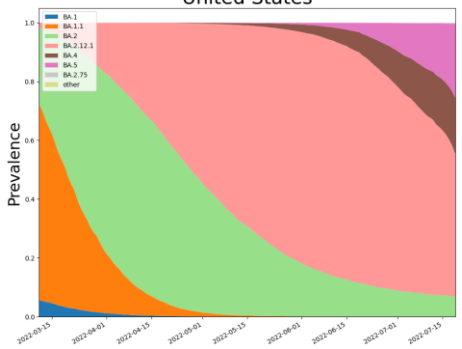
SARS-CoV2 Omicron and Sub-Variants

As detected in whole Genomes in public repositories

Virginia

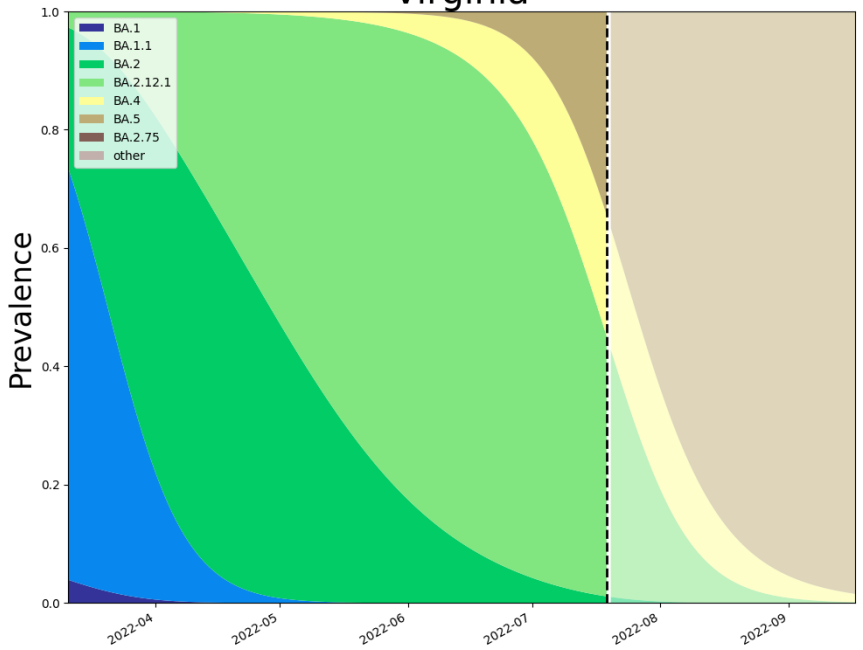


United States

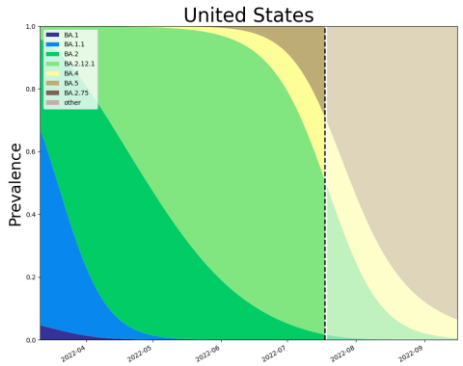


VoC Polynomial Fit Projections

Virginia



United States



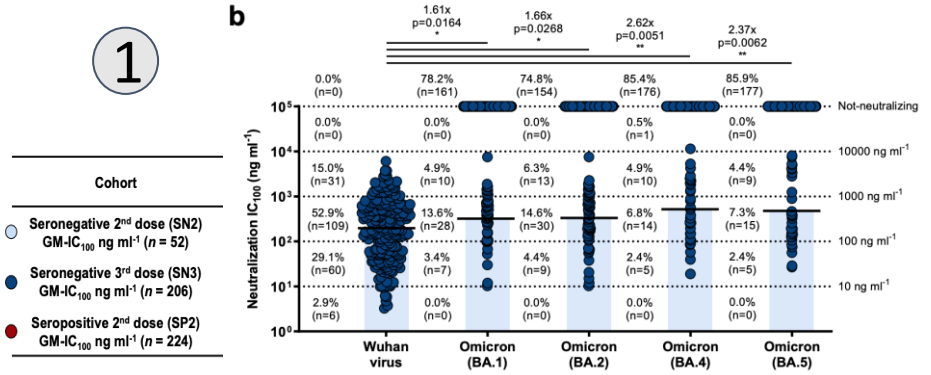
Note: Data lags force projections to start in past. Everything from dotted line forward is a projection.

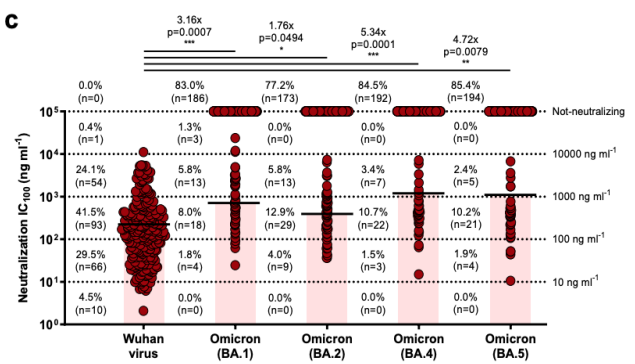
GISAID outbreak.info

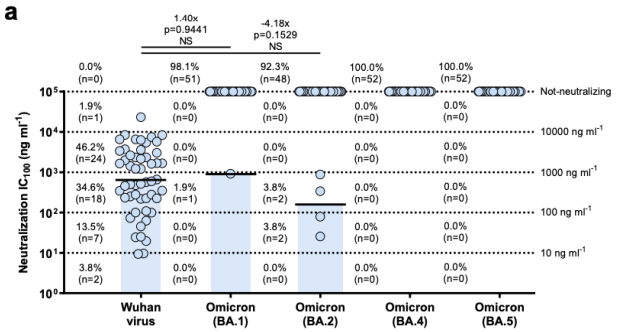
Pandemic Pubs

1. mRNA vaccination and hybrid immunity elicit different immunity targets on the spike protein
2. While correcting for seasonal fluctuations and non-infectious health aspects of the pandemic on symptom dynamics, new study finds that about one in every eight patients are affected by persistent symptoms after COVID-19
3. Study suggests BA.2.75 is highly resistant to the BA.5-induced immunity and has high histopathology scores similar to BA.5

1

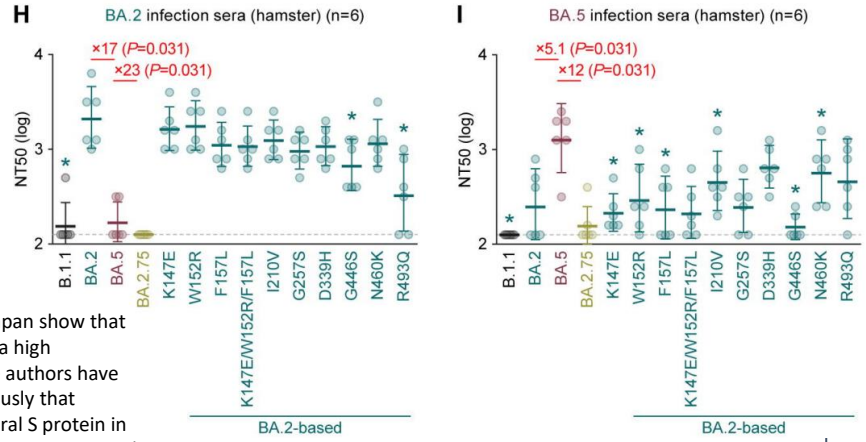




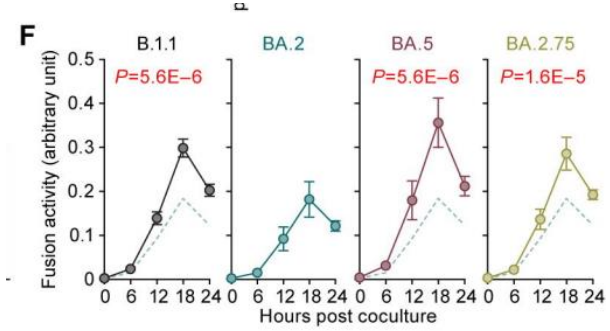


Researchers in Italy tested the neutralizing activity against omicron BA.4 and BA.5 of a panel of 482 human monoclonal antibodies that had been isolated from people who received two or three mRNA vaccine doses or from people that had been vaccinated after infection. None of the antibodies isolated after two vaccine doses neutralized omicron BA.4 and BA.5, while these variants were neutralized by approximately 15% of antibodies obtained from people that received three doses or had been vaccinated after infection. Remarkably, the antibodies isolated after three vaccine doses targeted mainly the receptor binding domain (RBD) Class 1/2 epitope region and were encoded by the IGHV1-69 and IGHV3-66 B cell germlines, while the antibodies isolated after infection recognized mostly the RBD Class 3 epitope region and the NTD, and were encoded by the IGHV2-5;IGHJ4-1 and IGHV1-24;IGHJ4-1 germlines. https://www.biorxiv.org/content/10.1101/2022.08.04.502828v1

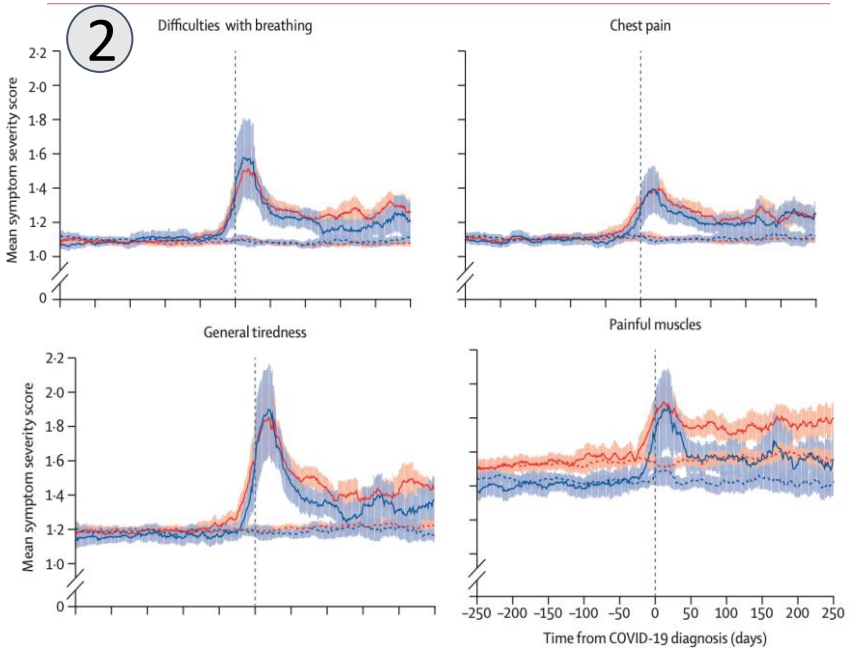
3



Researchers in Japan show that BA.2.75 displays a high fusogenicity. The authors have suggested previously that fusogenicity of viral S protein in in vitro cell cultures is associated with viral pathogenicity in vivo. In the Indian states analyzed, where both BA.5 and BA.2.75 are dominant, such as Telangana and Tamil Nadu (for BA. 5-dominant states) and Odisha, Haryana, Rajasthan, and Maharashtra (for BA.2.75-dominant states), the Re value of BA.2.75 was greater than that of BA.5 https://www.biorxiv.org/content/10.1101/2022.08.07.503115v1



2

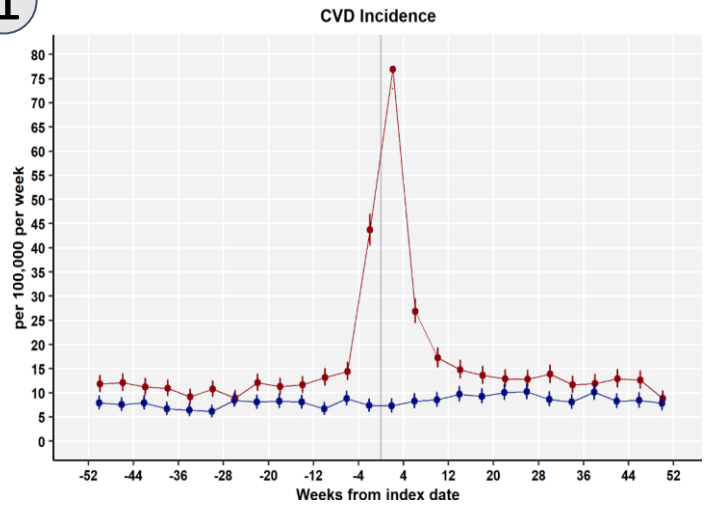


A study from the Netherlands is perhaps the first to report the nature and prevalence of post-COVID-19 condition, while correcting for individual symptoms present before COVID-19 and the symptom dynamics in the population without SARS-CoV-2 infection during the pandemic. The prospective, population-based, observational cohort study examining the health and health-related behaviours of people living in the north of the Netherlands. 76,422 participants (mean age 53, 60.8% female) completed a total of 883,973 questionnaires between March 31, 2020, and Aug 2, 2021. Of these, 4231 (5·5%) participants had COVID-19 and were matched to 8462 controls. Persistent symptoms in COVID-19-positive participants at 90–150 days after COVID-19 compared with before COVID-19 and compared with matched controls included chest pain, difficulties with breathing, pain when breathing, painful muscles, ageusia or anosmia, tingling extremities, lump in throat and more. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(22)01214-4/fulltext

Pandemic Pubs (last week)

1. Acute COVID-19 was associated with net increased cardiovascular disease incidence (5.82, 4.82 to 7.03)
2. More than ninety percent in the Geneva population have developed anti-SARS-CoV-2 antibodies through vaccination and/or infection, but less than half have antibodies with neutralizing activity against BA.5 subvariant
3. Study among Rhode Island residents suggest that among people who have recovered from COVID-19, subsequent completion of the primary vaccination series reduced the risk of reinfection by approximately half
4. Booster vaccination with mRNA-1273 COVID-19 vaccine was more effective than BNT162b2 in preventing infection and COVID-19 hospitalisation during the first 12 weeks after vaccination, during a period of Delta followed by Omicron variant dominance

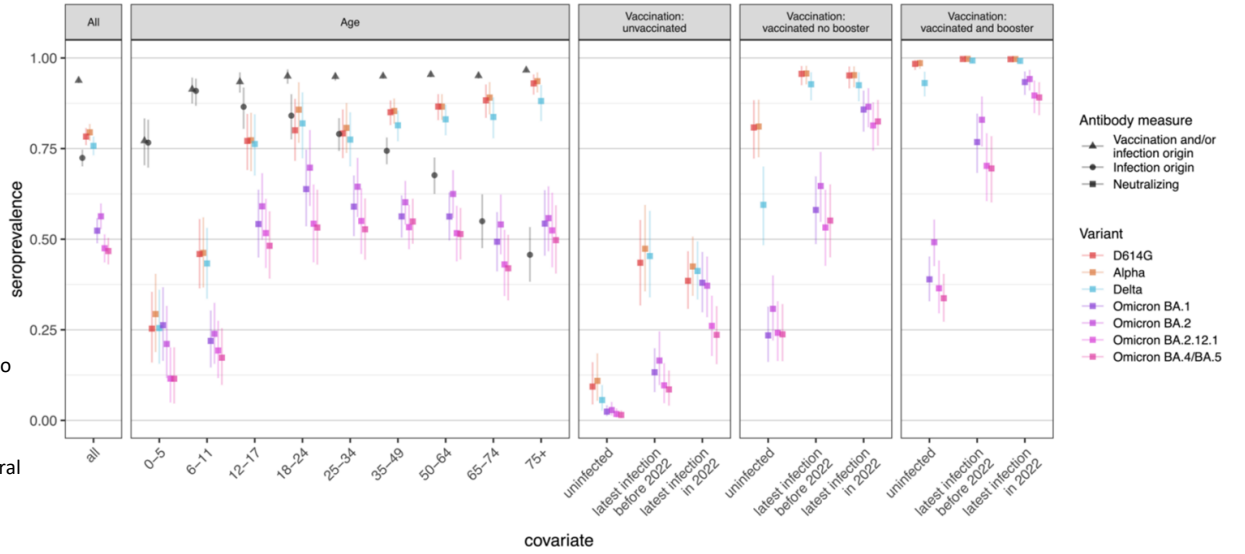
1



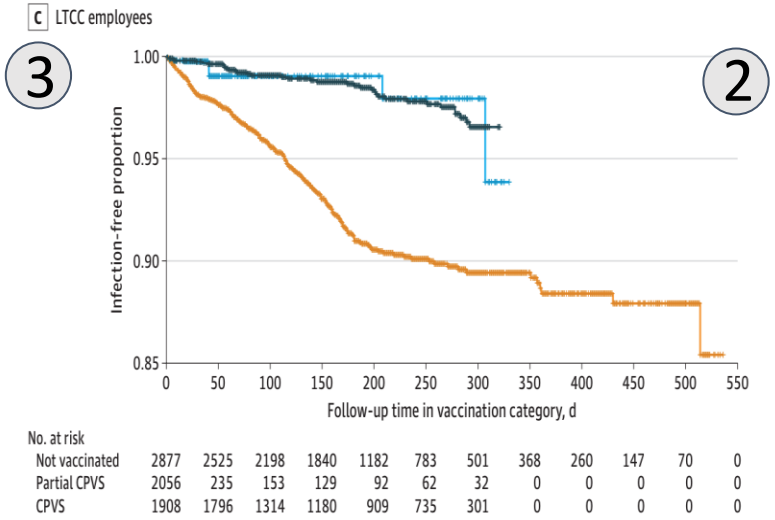
Researchers at Kings College London cohort study from 2020 to 2021 analysing electronic records for 1,356 United Kingdom family practices with a population of 13.4 million. Participants were 428,650 COVID-19 patients without DM or CVD who were individually matched with 428,650 control patients on age, sex, and family practice and followed up to January 2022.study of that found that CVD was increased early after COVID-19 mainly from pulmonary embolism, atrial arrhythmias, and venous thromboses. DM incidence remained elevated for at least 12 weeks following COVID-19 before declining. People without preexisting CVD or DM who suffer from COVID-19 do not appear to have a long-term increase in incidence of these conditions.
https://journals.plos.org/plosmedicine/article/authors?id=10.1371/journal.pmed.1004052

2

Researchers in Geneva conducted a population-based serosurvey between April 29th and June 9th, 2022, recruiting children and adults of all ages from age-stratified random samples of the Geneva general population. Among the 2521 individuals included in the analysis (55.2% women; 21.4% aged <18 years and 14.2% aged ≥65 years), overall seroprevalence of antibodies was 93.8%. Estimates of neutralizing antibodies based on a representative subsample of 1160 participants ranged from 79.5% against the Alpha variant to 46.7% against the Omicron BA.4/BA.5 subvariants. Despite having high seroprevalence of infection-induced antibodies (76.7% for ages 0-5 years, 90.5% for ages 6-11 years), children aged <12 years had substantially lower neutralizing activity than older participants, particularly against Omicron subvariants. Higher levels of neutralization activity against pre-Omicron variants were associated with vaccination, higher levels of neutralization activity against Omicron subvariants were associated with booster vaccination alongside recent infection.
https://www.medrxiv.org/content/10.1101/2022.07.27.22278126v1

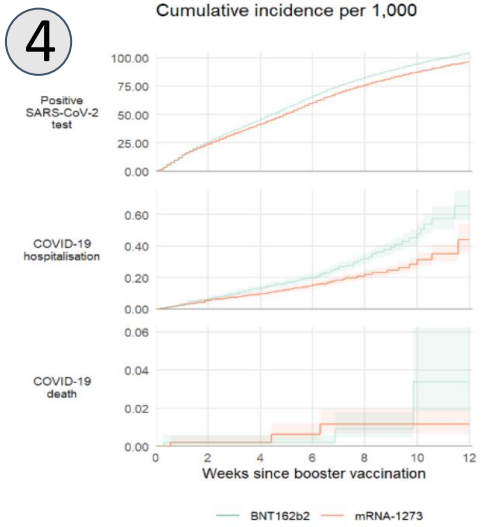


3



In this cohort study of more than 95 000 Rhode Island residents from March 2020 to December 2021, including residents and employees of long-term congregate care (LTCC) facilities, completion of the primary vaccination series after recovery from COVID-19 was associated with 49% protection from reinfection among LTCC residents, 47% protection among LTCC employees, and 62% protection in the general population during periods when wild type, Alpha, and Delta strains of SARS-CoV-2 were predominant.
https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2794702

4

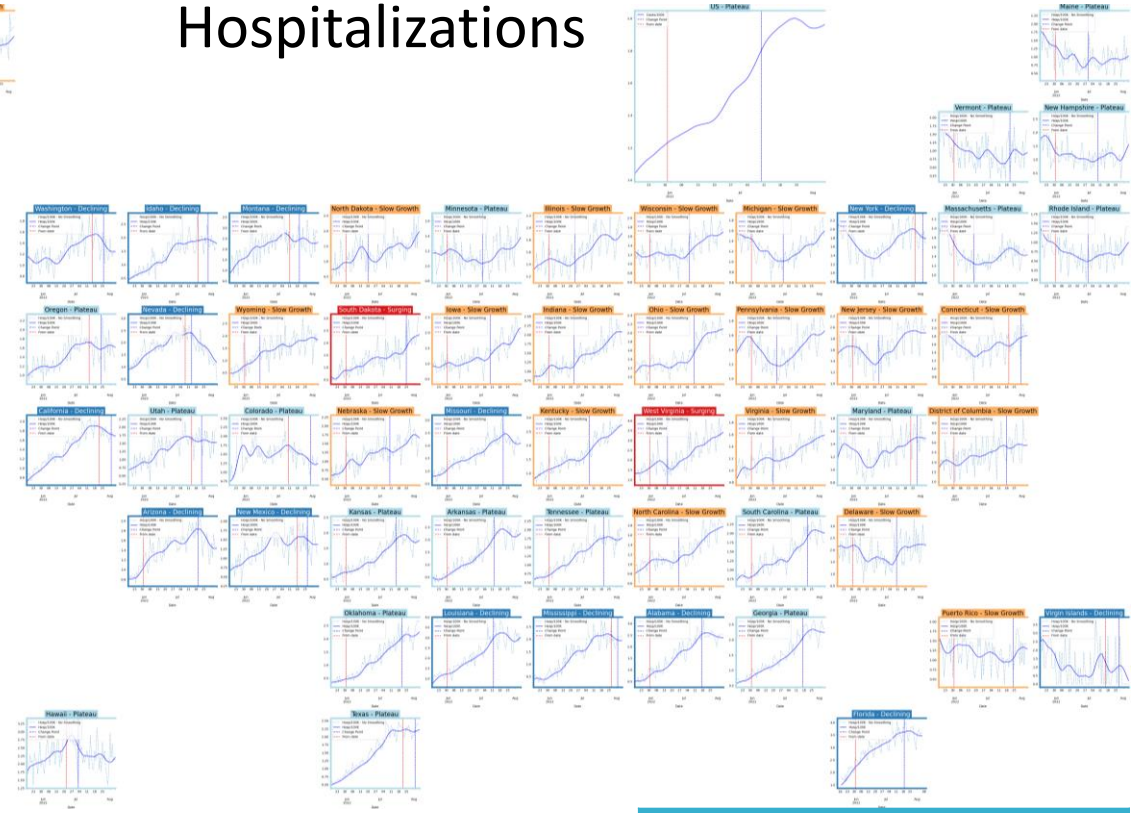


Oxford study: eligible if boosted between 29 October 2021 and 31 January 2022. 1,528,431 people were matched in each group, contributing a total 23,150,504 person-weeks of follow-up. The 12-week risks per 1,000 people of positive SARS-CoV-2 test were 103.2 (95%CI 102.4 to 104.0) for BNT162b2 and 96.0 (95.2 to 96.8) for mRNA-1273:
https://www.medrxiv.org/content/10.1101/2022.07.29.22278186v1

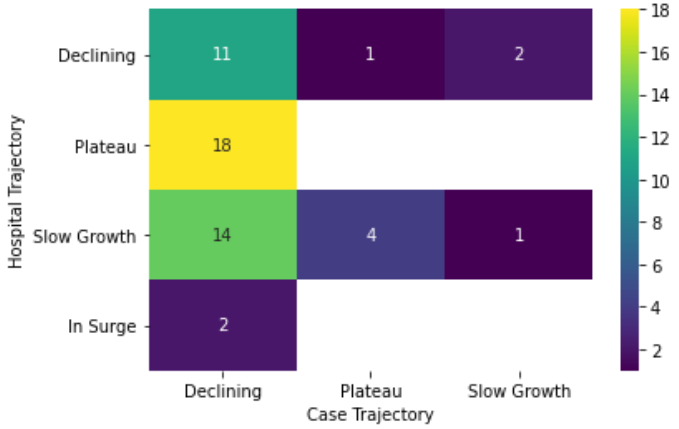
United States Case & Hospitalizations

Cases

Hospitalizations



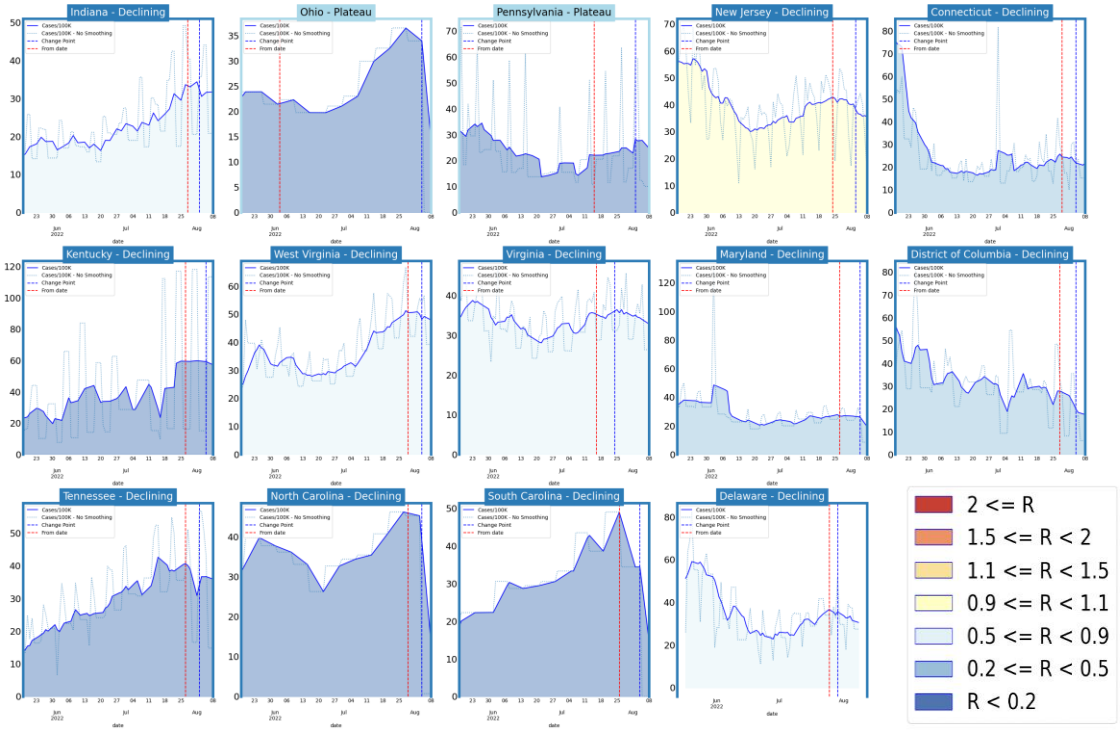
Status	# States
Declining	46 (38)
Plateau	5 (9)
Slow Growth	3 (3)
In Surge	0 (3)



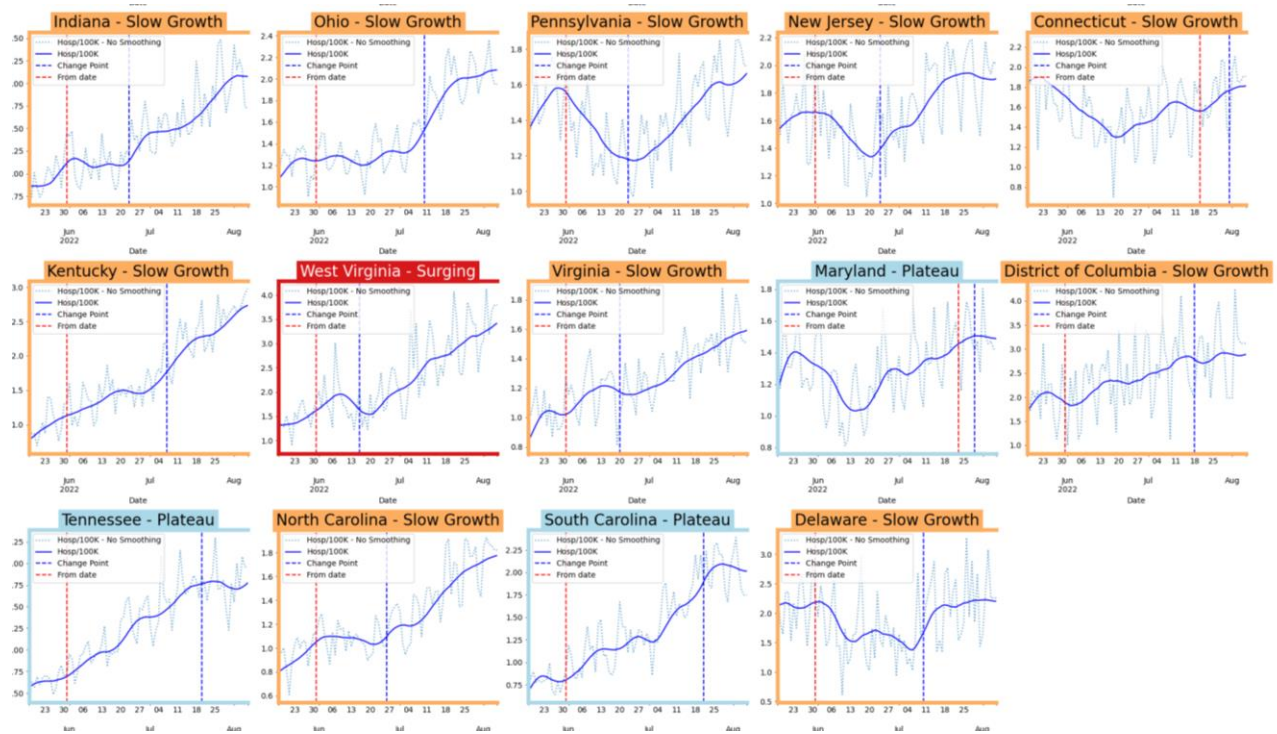
Status	# States
Declining	14 (6)
Plateau	18 (13)
Slow Growth	19 (25)
In Surge	2 (8)

Virginia and Her Neighbors

Cases



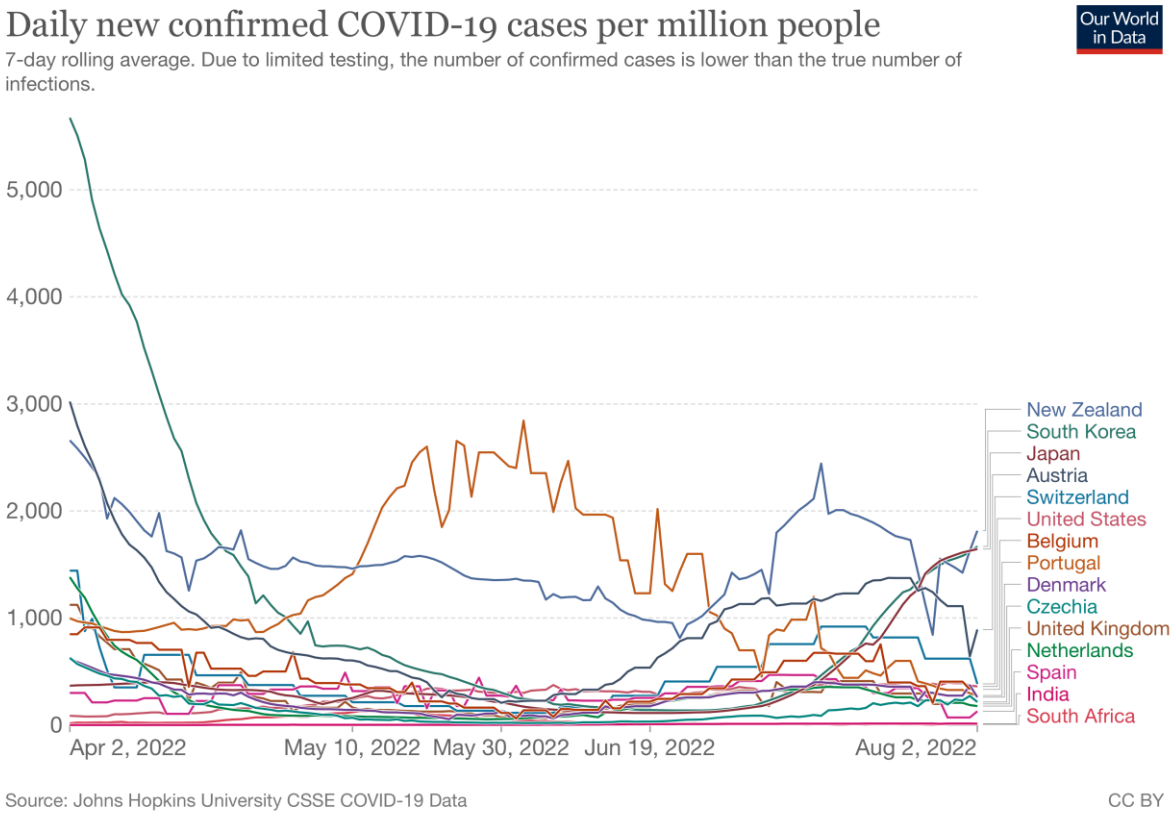
Hospitalizations



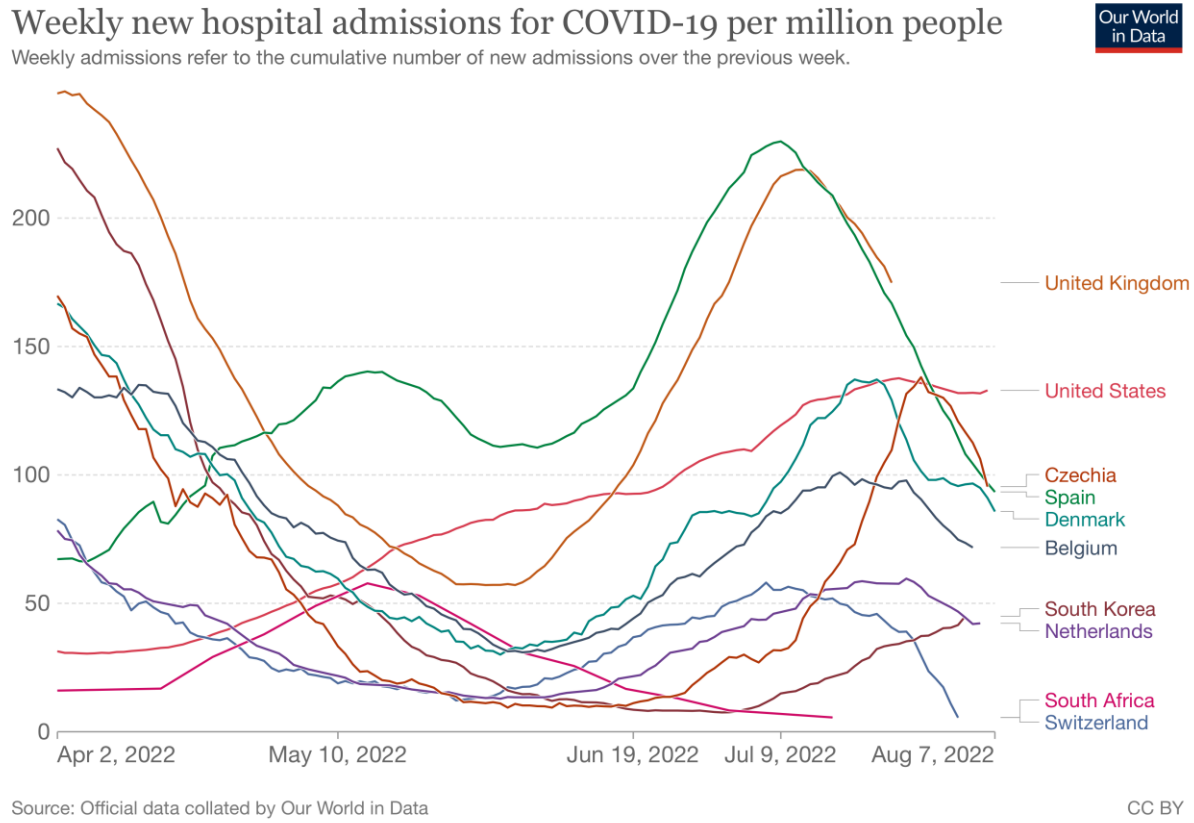
Around the World – New sub-variant impacted countries

Countries where BA.4, BA.5, and BA.2.75 have been or are increasing

Confirmed cases

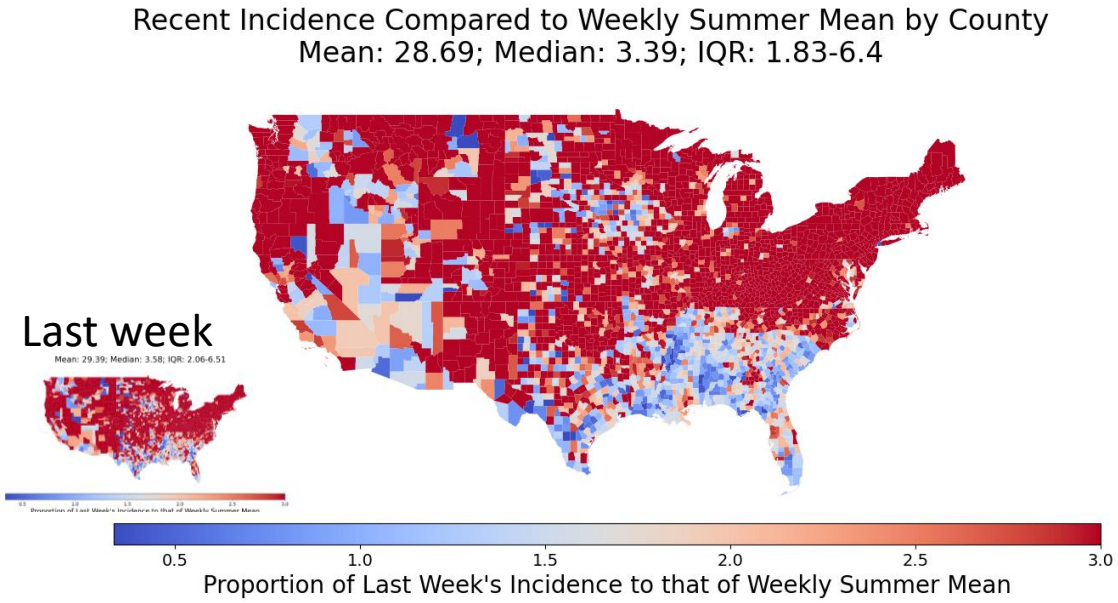


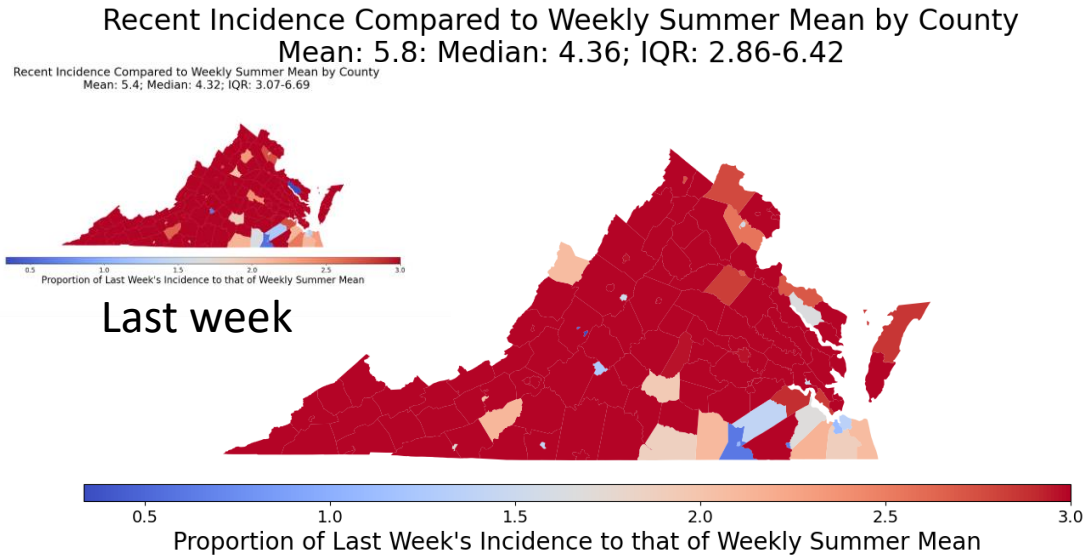
Hospitalizations



[Our World in Data]

County-level comparison to last Summer





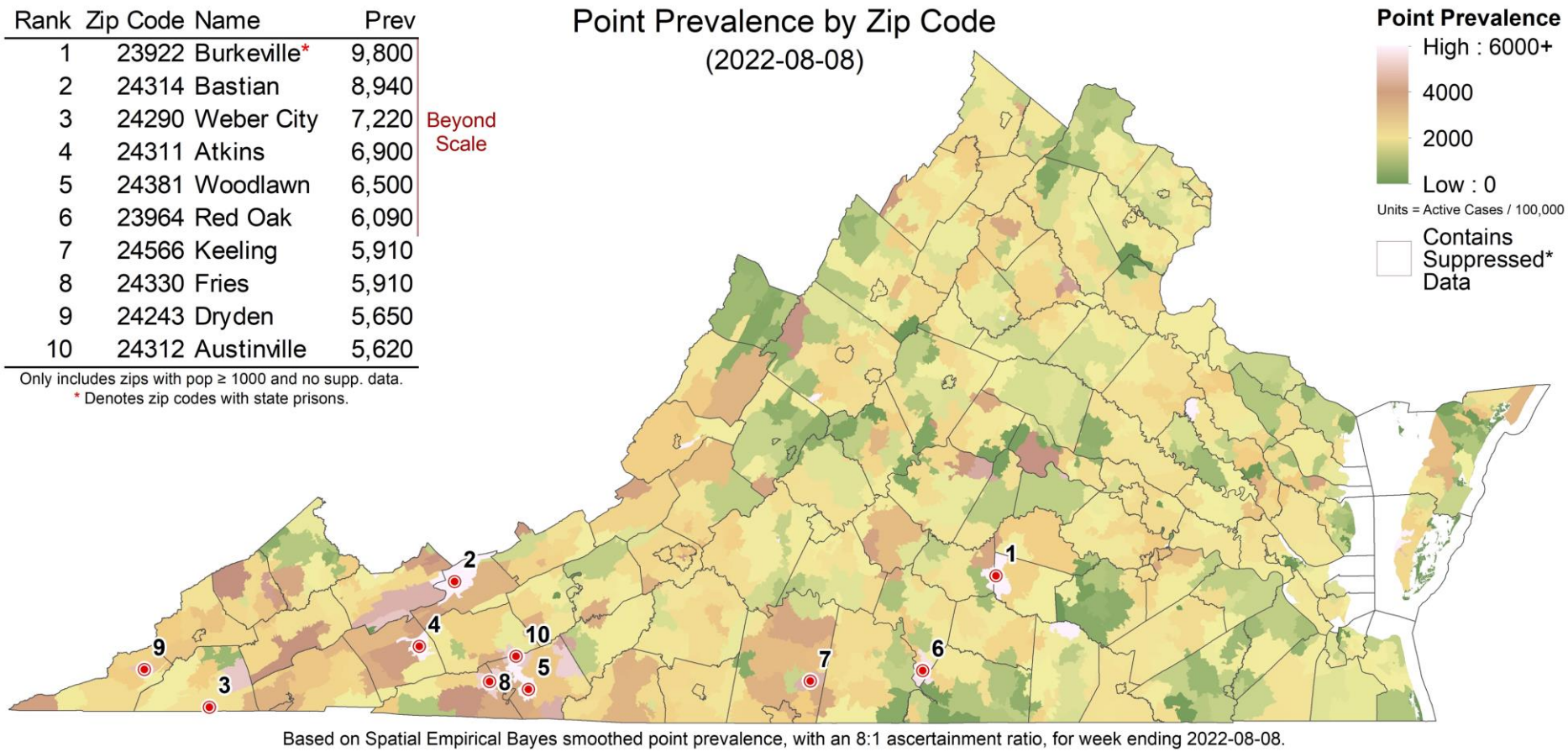
Zip code level weekly Case Rate (per 100K)

Case Rates in the last week by zip code

- Some counts are low and suppressed to protect anonymity, those are shown in white

Rank	Zip Code	Name	Prev	
1	23922	Burkeville*	9,800	
2	24314	Bastian	8,940	
3	24290	Weber City	7,220	Beyond Scale
4	24311	Atkins	6,900	
5	24381	Woodlawn	6,500	
6	23964	Red Oak	6,090	
7	24566	Keeling	5,910	
8	24330	Fries	5,910	
9	24243	Dryden	5,650	
10	24312	Austinville	5,620	

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



Based on Spatial Empirical Bayes smoothed point prevalence, with an 8:1 ascertainment ratio, for week ending 2022-08-08.

Risk of Exposure by Group Size and HCW prevalence

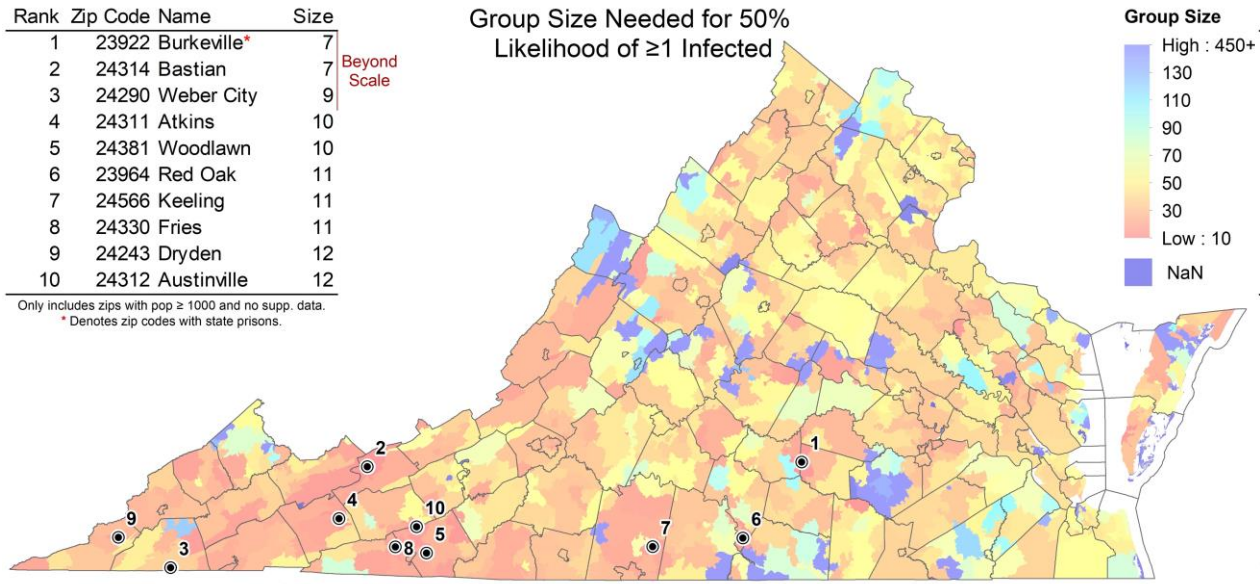
Case Prevalence in the last week by zip code used to calculate risk of encountering someone infected in a gathering of randomly selected people (group size 25)

- **Group Size**: Assumes **8 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 7 in Burkeville, there is a 50% chance someone will be infected)
- **HCW ratio**: Case rate among health care workers (HCW) in the last week using patient facing health care workers as the denominator / general population's case prevalence

Rank	Zip Code	Name	Size
1	23922	Burkeville*	7
2	24314	Bastian	7
3	24290	Weber City	9
4	24311	Atkins	10
5	24381	Woodlawn	10
6	23964	Red Oak	11
7	24566	Keeling	11
8	24330	Fries	11
9	24243	Dryden	12
10	24312	Austinville	12

Beyond Scale

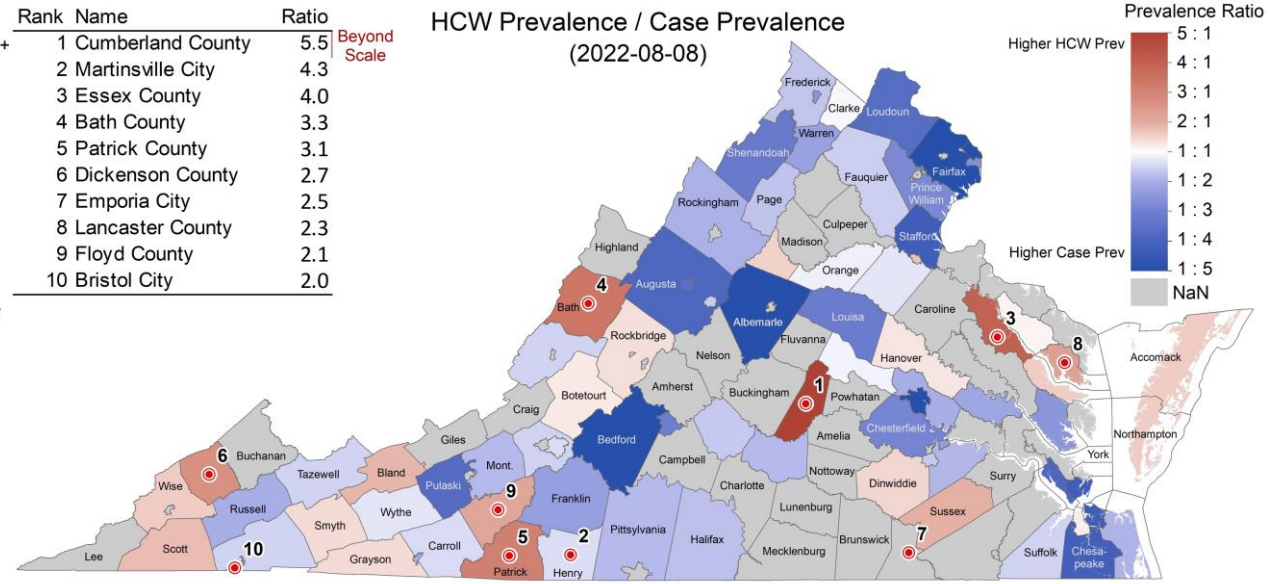
Only includes zips with pop ≥ 1000 and no supp. data.
* Denotes zip codes with state prisons.



Based on Spatial Empirical Bayes smoothed point prevalence, with an 8:1 ascertainment ratio, for week ending 2022-08-08.

Rank	Name	Ratio
1	Cumberland County	5.5
2	Martinsville City	4.3
3	Essex County	4.0
4	Bath County	3.3
5	Patrick County	3.1
6	Dickenson County	2.7
7	Emporia City	2.5
8	Lancaster County	2.3
9	Floyd County	2.1
10	Bristol City	2.0

Beyond Scale



Note: This assumes that the ascertainment rate of healthcare workers is double that of the public.

Current Hot-Spots

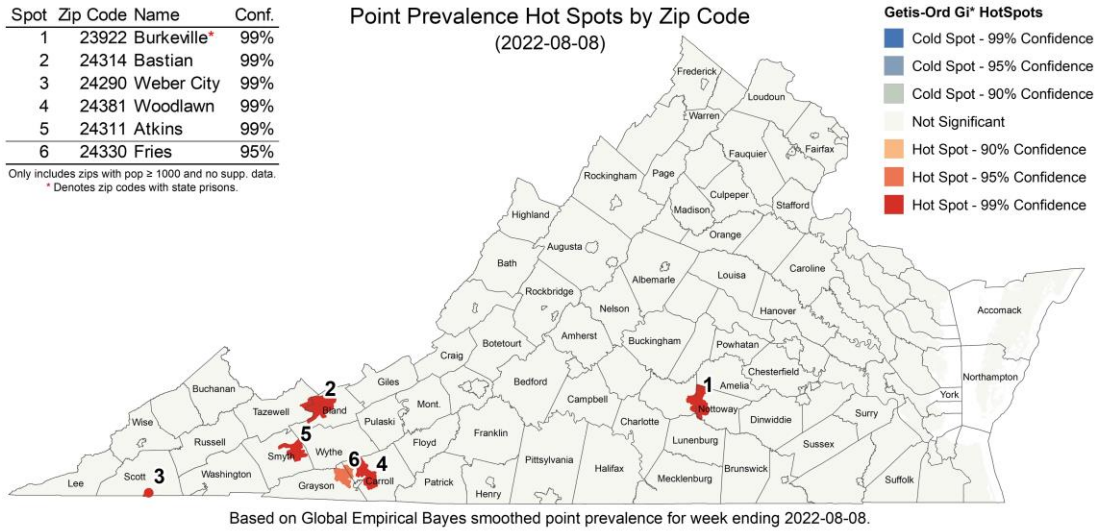
Case rates that are significantly different from neighboring areas or model projections

- **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

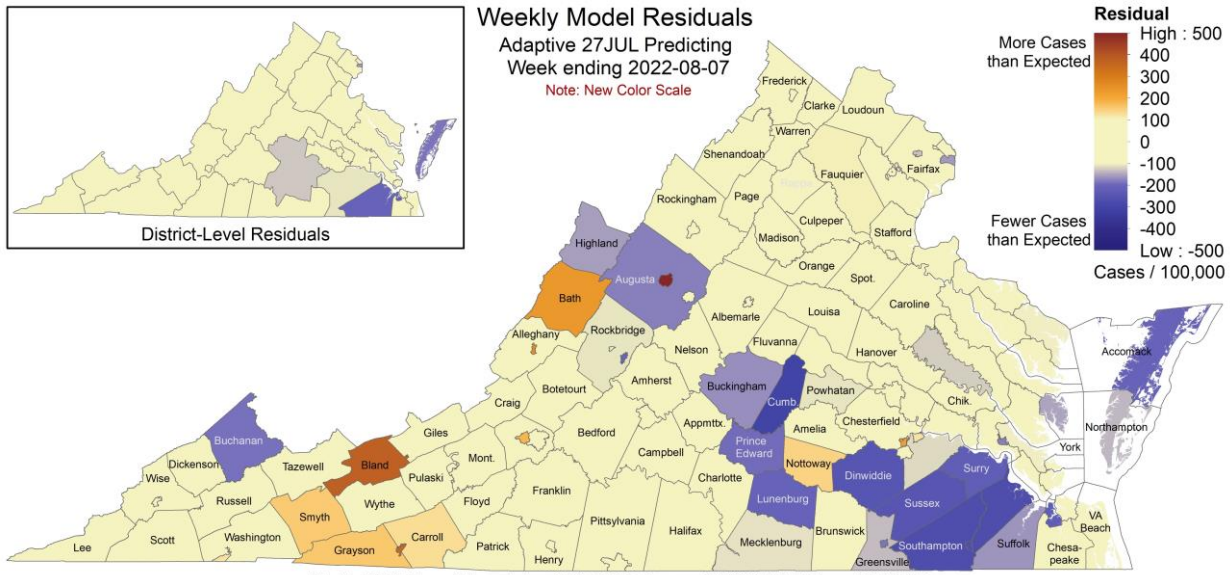
Spot	Zip Code	Name	Conf.
1	23922	Burkeville*	99%
2	24314	Bastian	99%
3	24290	Weber City	99%
4	24381	Woodlawn	99%
5	24311	Atkins	99%
6	24330	Fries	95%

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 2022-08-08.

Clustered Temporal Hotspots from BA.4_BA.5

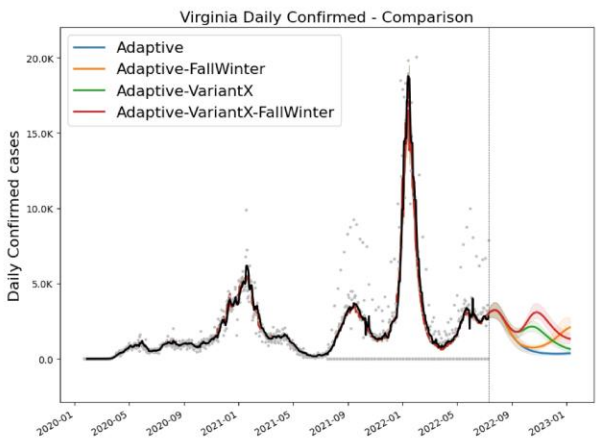


Health District Level Moran's I = -0.010749, Z-Score = 0.319263, P-Value = 0.749527
No Residual Autocorrelation Detected

Scenario Trajectory Tracking

Which scenario from a month ago did projection for each county track closest?

- One month out separates the projections more and reveals larger overall patterns
- Overall state level models were on target, with Eastern part of the state moving with the lower growth Adaptive, and the Southwest following the more growth oriented VariantX trajectory

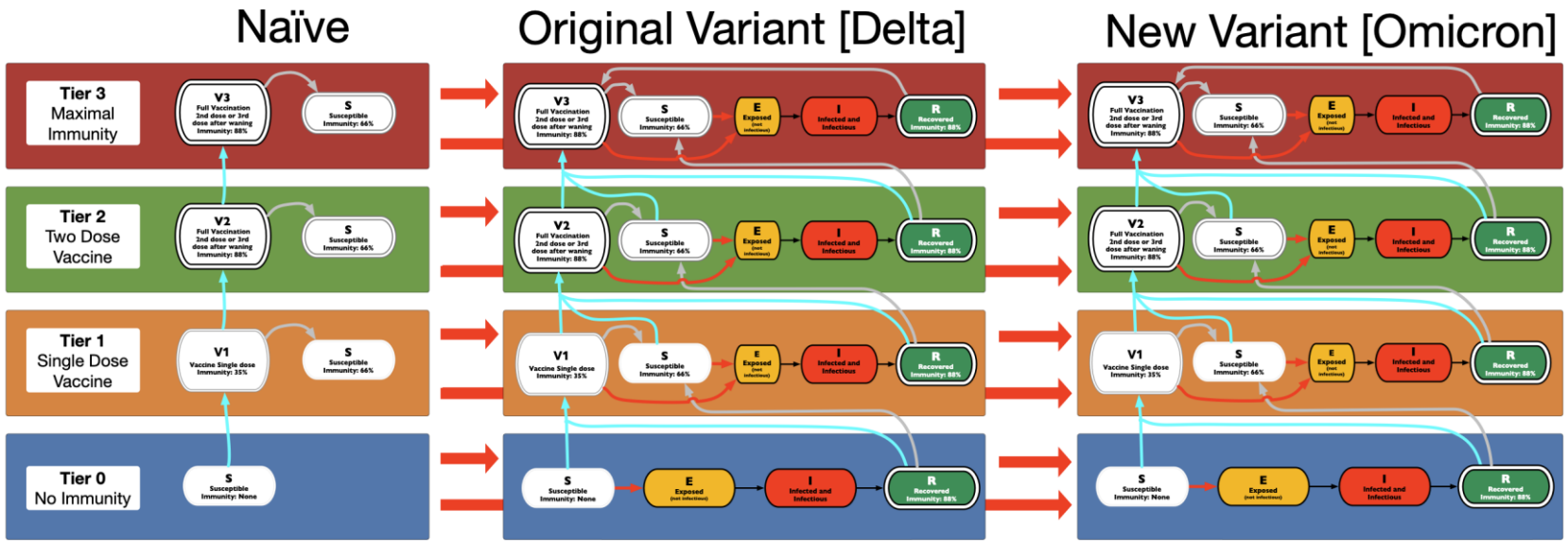


Model Update – Adaptive Fitting

Model Structure Extended for more sub-variants

Omicron sub-variants escape immunity induced by previous sub-variants

- Multiple strain support allows representation of differential protection based on immunological history (BA.1, BA.2, BA.2.12.1, BA.4/5, and future variants (VariantX))
- Each sub-variant has differing levels of immune escape to previous sub-variants, the prevalences are based on observations for fitting purposes, and projections use estimated future prevalences
- Adaptive fitting approach continues to use simulation to generate the full distribution of immune states across the population



Adaptive Fitting Approach

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

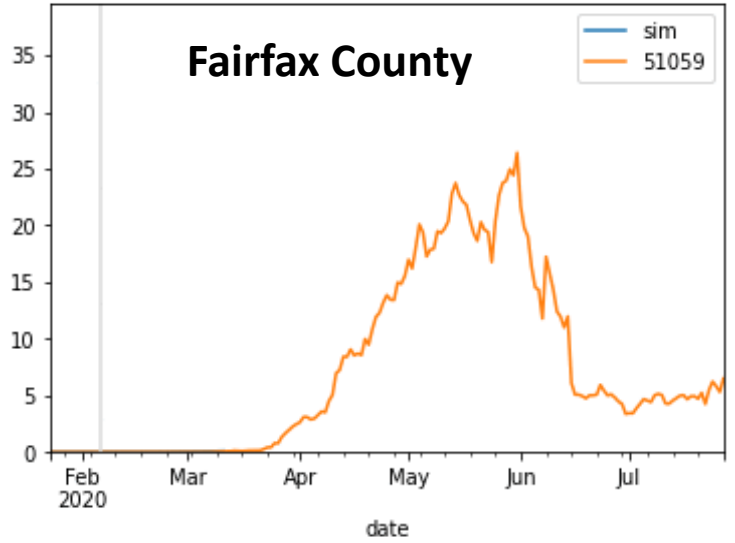
- Allows history to be precisely captured, and used to guide bounds on projections

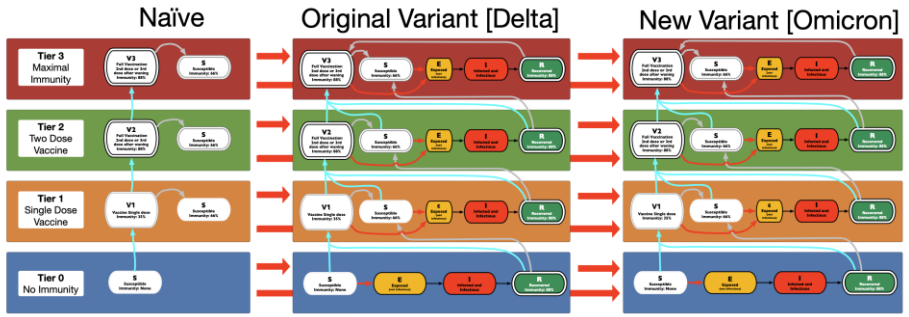
Model: An alternative use of the same meta-population model, PatchSim with multiple tiers of immunity

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Allows for waning of immunity and for partial immunity against different outcomes (eg lower protection for infection than death)

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions, we use 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:

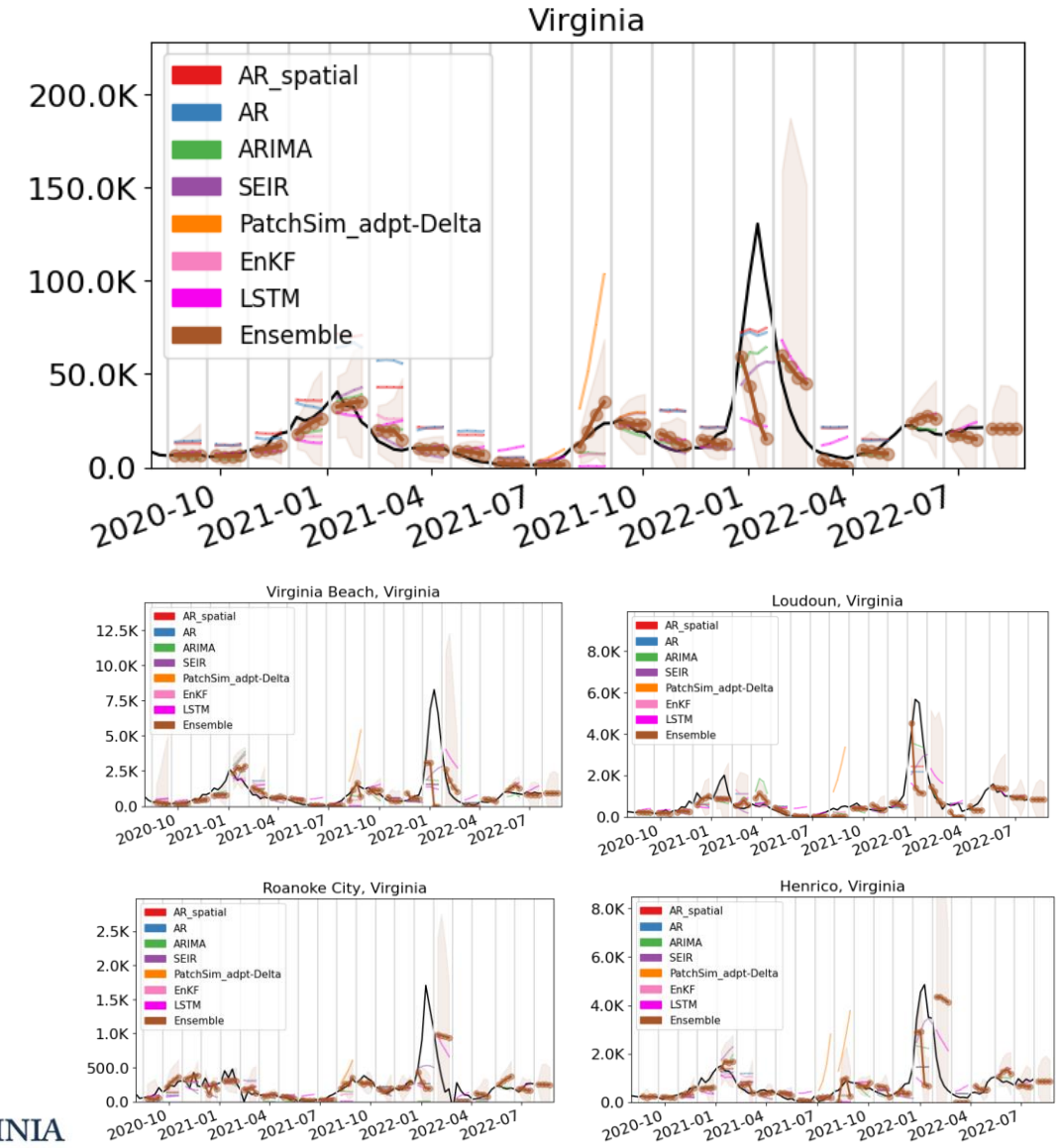
- Autoregressive (AR, ARIMA)
- Neural networks (LSTM)
- Kalman filtering (EnKF)

<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.



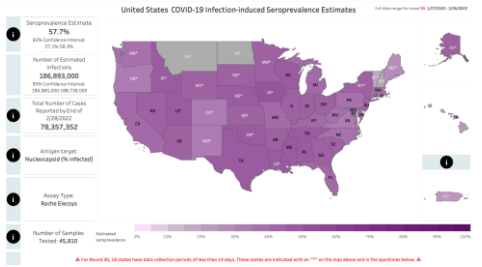
Seroprevalence updates to model design

Several seroprevalence studies have stopped

- CDC Nationwide Commercial Laboratory Seroprevalence Survey, is no longer reporting updates; Pre-Omicron this data estimated ascertainment ratio of ~4-6x

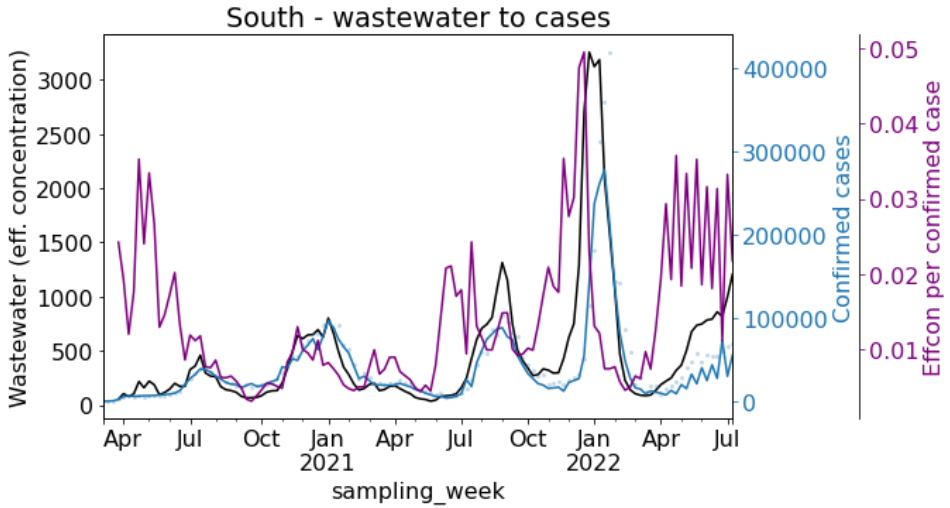
Testing Behavior has changed, fewer cases are reported

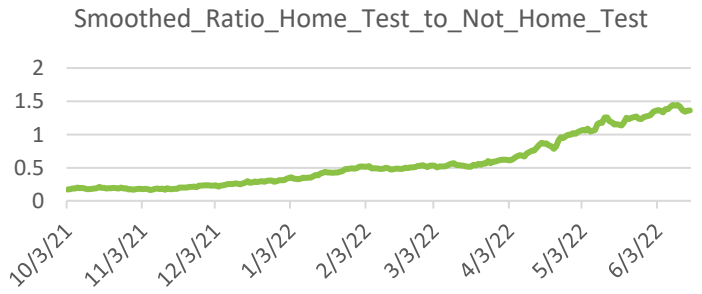
- Home testing, reduced symptoms due to breakthrough / reinfection, and elimination of public health leave
- Outbreaks Near Me from Boston Children's Hospital and Momentive collects reports of home testing
- Wastewater data is consistent with case ascertainment being significantly lower than during the Omicron BA.1 wave
- Accounting for home testing, changes case ascertainment to be 2 times more than Pre-Omicron resulting in a current rate of 16 infections to one case



Virginia
Feb 22nd: 45% [42% - 48%];
Jan 22nd: 34% [31%-39%]

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

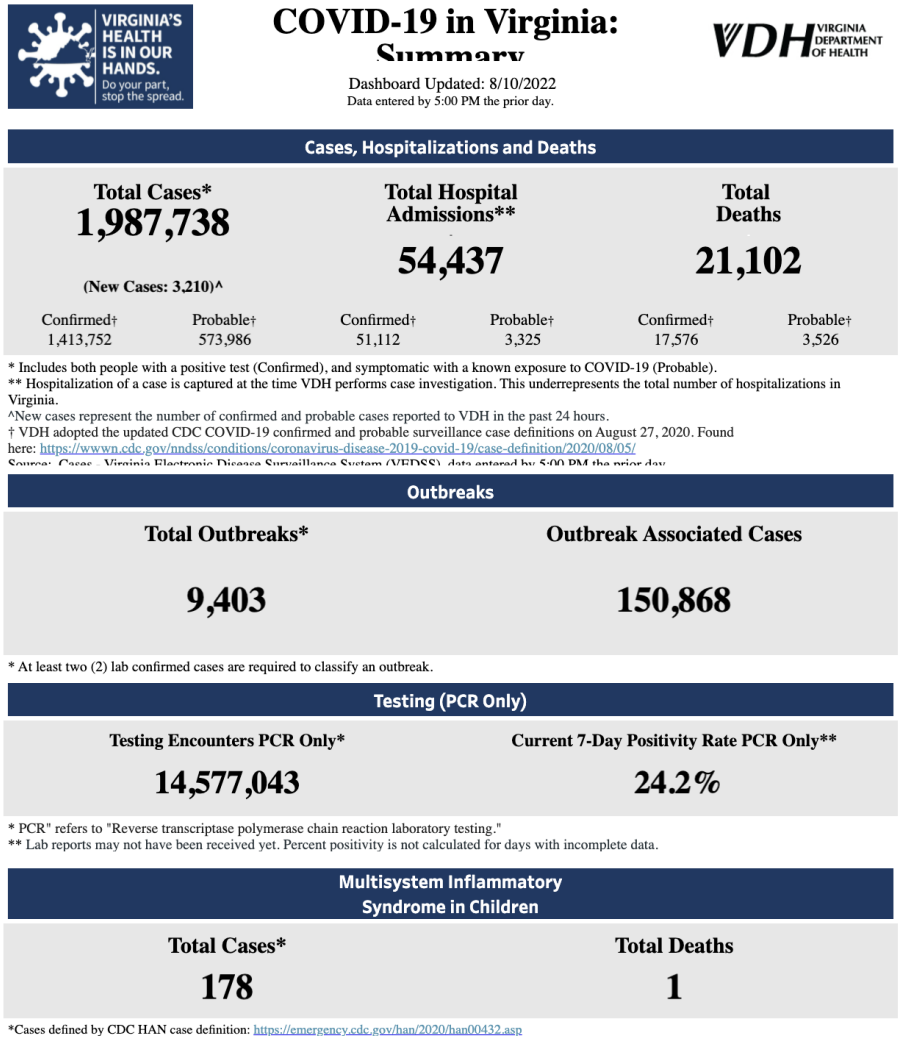




OutbreaksNearMe

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
- **Outcomes**: Data driven by shift and ratio that has least error in last month of observations
  - Hospitalizations: 3 days from confirmation, 6.8% of cases hospitalized
  - Deaths: 11 days from confirmation, 1.45% of cases die



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

COVID-19 in Virginia: Summary

VDH VIRGINIA DEPARTMENT OF HEALTH

Dashboard Updated: 8/10/2022
Data entered by 5:00 PM the prior day.

Cases, Hospitalizations and Deaths

Total Cases*	Total Hospital Admissions**	Total Deaths
1,987,738	54,437	21,102
(New Cases: 3,210)^		

Confirmed†	Probable†	Confirmed†	Probable†	Confirmed†	Probable†
1,413,752	573,986	51,112	3,325	17,576	3,526

* 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/
Source: Cases - Virginia Electronic Disease Surveillance System (VEDSS), data entered by 5:00 PM the prior day

Outbreaks

Total Outbreaks*	Outbreak Associated Cases
9,403	150,868

* 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**
14,577,043	24.2%

* 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
178	1

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

Accessed 10:00am Aug 10, 2022
https://www.vdh.virginia.gov/coronavirus/

Scenarios – Transmission Conditions

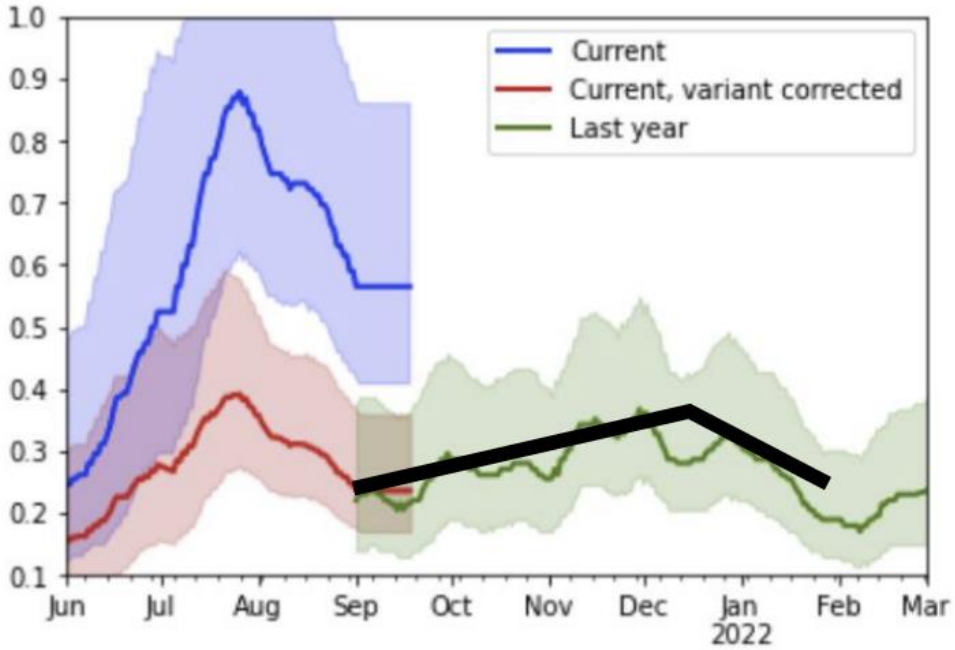
- Variety of factors continue to drive transmission rates
  - Seasonal impact of weather patterns, travel and gatherings, fatigue and premature relaxation of infection control practices
- **Waning Immunity**: Omicron waning with a mean of 4 months
- **Projection Condition Ingredients**:
  - **Adaptive:** Control remains as is currently experienced into the future with NO influence from other conditions (eg seasonal, variants, etc.)
  - **Seasonal (Fall-Winter boosting):** Controls remain the same, however, seasonal forcing similar to past Fall-Winter waves is added on from Sept-Feb
  - **Vaccine Booster Campaign (Booster):** Reformulated booster available this fall provides improved immunity against Omicron sub-variants
  - **New Variants (VariantX)**: As of yet not identified novel sub-variant with similar immune escape but no transmission advantage emerges 4 months after the last significant sub-variant and grows at a similar rate

Scenarios – FallWinter

September – February saw strong waves of transmission for both years

- Based on analyses of the past 2 seasons we generate a “coarse baseline transmission boost”
  - In 2021 the distribution of fitted model transmissibility was nearly identical between these periods when corrected for Delta’s increased transmissibility
- **FallWinter** captures these “transmission drivers” from the past and use them as if they were to occur again this season

Fitting:
Black line represents the coarsely fitted base transmissibility



* “Last year” is transplanted into 2021-22

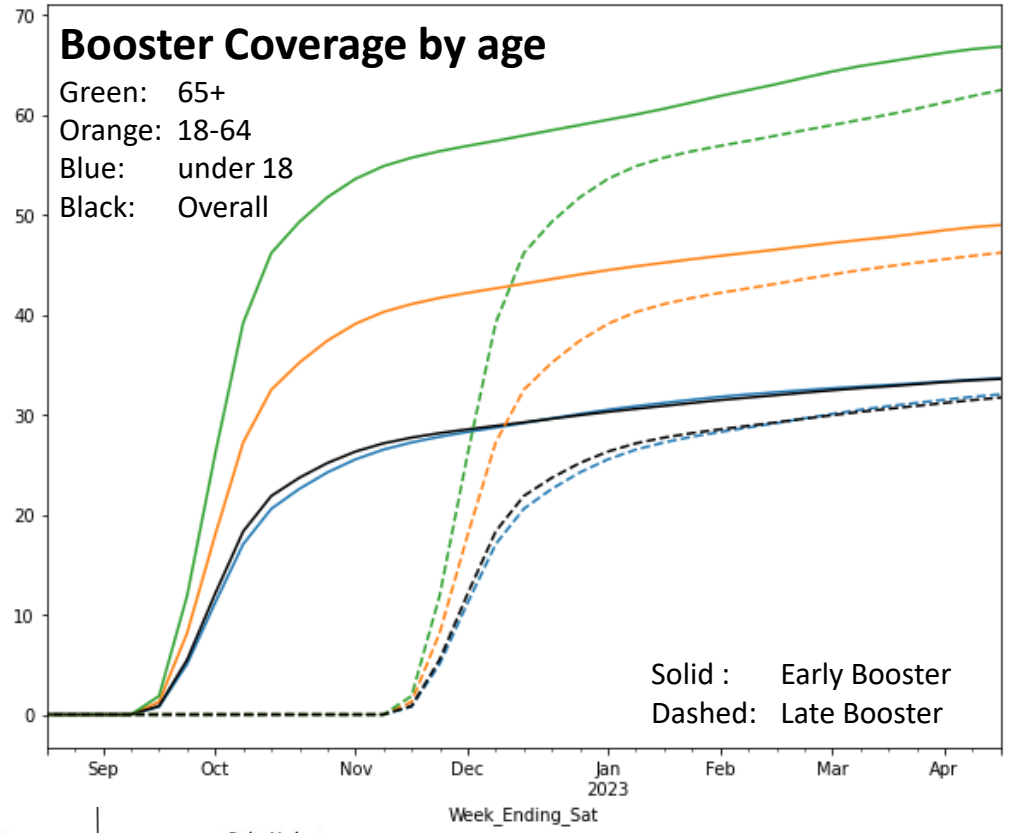
Scenarios – Early vs. Late Booster Campaign

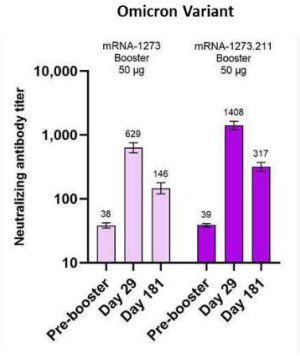
Reformulated Boosters will be available this Fall

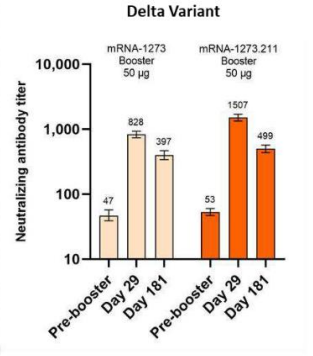
- Vax efficacy against BA.4/5 and all previous variants is 80% against symptomatic illness
- Total coverage is 90% of total for seasonal influenza vaccinations (varies by age)
- Pace of vaccination follows that of seasonal influenza, scenarios vary in timing only
- Variant X has same immune escape to these vaccines as against BA.5 (40%)

Early Booster: Mid-September start

Late Booster: Mid-November start







Moderna's bivalent vaccine approach shows promising neutralization profile

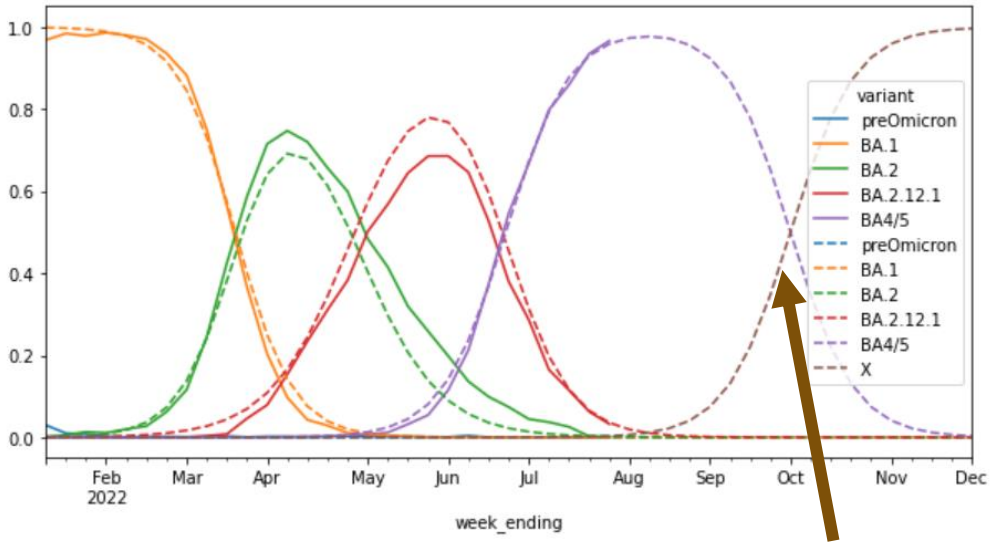
Moderna released data on a bivalent booster vaccine which contains mRNAs for both the original and Beta spike protein. The mRNA-1273.211 booster (50 and 100-µg) elicited higher neutralizing antibody responses against the ancestral SARS-CoV-2 and the Beta variant than that after the second mRNA-1273 dose. It also elicited a 2.15 fold increase against Omicron compared to the original.
https://assets.researchsquare.com/files/rs-1555201/v1_covered.pdf?c=1650045900

Scenarios – Variant X

Omicron sub-variants seem to be emerging and then dominating with some regularity

- ECDC currently monitoring BA.2 + L452X and BA.2.75 as VOI and BA.3 as a VUM;
- Limited growth of BA.2.75 observed in US, BA.4.6 being tracked by CDC as well
- Hypothetical future sub-variant, VariantX, may continue the pattern. Assumes similar growth and level of immune escape against previous sub-variants as BA.4/5 (same transmissibility and 40% immune escape against BA.4/5, higher for other sub-variants)

Sub-Variants with Fitted Prevalences and Hypothetical Future waves



Variants of Interest

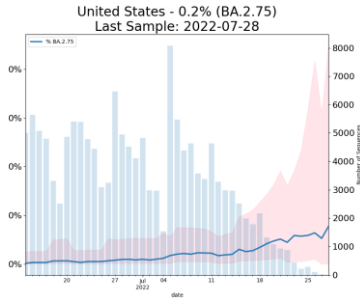
WHO label	Lineage + additional mutations	Country first detected (community)	Spike mutations of interest	Year and month first detected	Impact on transmissibility	Impact on immunity	Impact on severity	Transmission in EU/EEA
Omicron	BA.2 + L452X (x)	n/a	L452X	n/a	No evidence	Increased (13)	No evidence	Detected (a)
Omicron	BA.2.75	India	(y)	May 2022	No evidence	No evidence	No evidence	Detected (a)

Variants under Monitoring

Omicron	BA.3	South Africa	(z)	November 2021	No evidence	No evidence	No evidence	Detected (a)

[ECDC Variants of Concern]

BA.2.75 detected in US (very limited samples)



Variant X prevalence mid-point set to Oct 1st

Projection Scenarios – Combined Conditions

Name	Txm	Variant	Description
Adaptive	C	SQ	Likely trajectory based on conditions remaining similar to the current experience, includes immune escape due to Omicron
Adaptive-FallWinter	FallWinter	SQ	Like Adaptive, with seasonal forcing of FallWinter added on
Adaptive-FallWinter-EarlyBooster	FallWinter	SQ	Like Adaptive-Fall Winter but with Early Booster (mid-Sept)
Adaptive-FallWinter-Late Booster	FallWinter	SQ	Like Adaptive-Fall Winter but with Late Booster (mid-Nov)
Adaptive-VariantX	C	X	Like Adaptive, with emergence of a speculative unknown variant 4 months after BA.4/5 with similar level of immune escape and equal transmissibility
Adaptive-VariantX-FallWinter	FallWinter	X	Like Adaptive-VariantX but with the seasonal force of FallWinter added on

Transmission: C = Current levels persist into the future
FallWinter = Transmission rates learned from Sept through February of past seasons are estimated and added as a seasonal boosting to baseline transmission rates

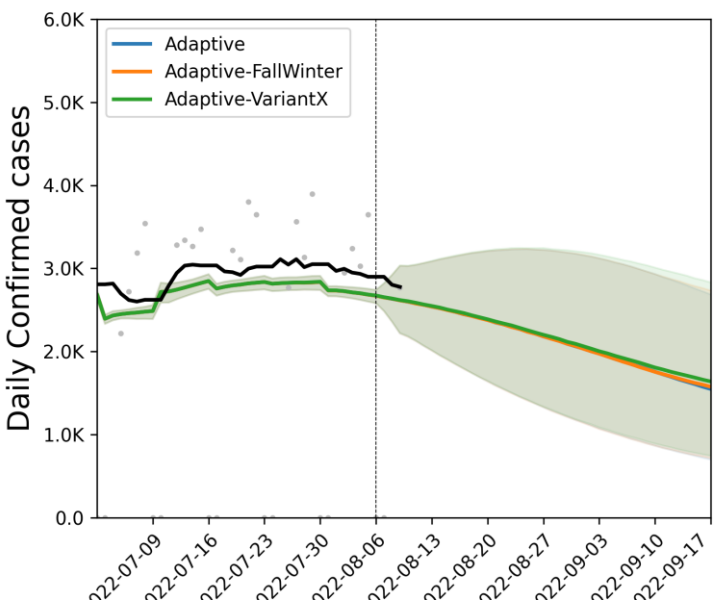
Variant: SQ = Status quo of current transmission driver from BA.5 remains the same (eg already significantly past dominance, thus no significant major driving of transmission anticipated)
X = Speculative novel sub-variant scenario, emerges 4 months after current varian, similar levels of escape

Model Results

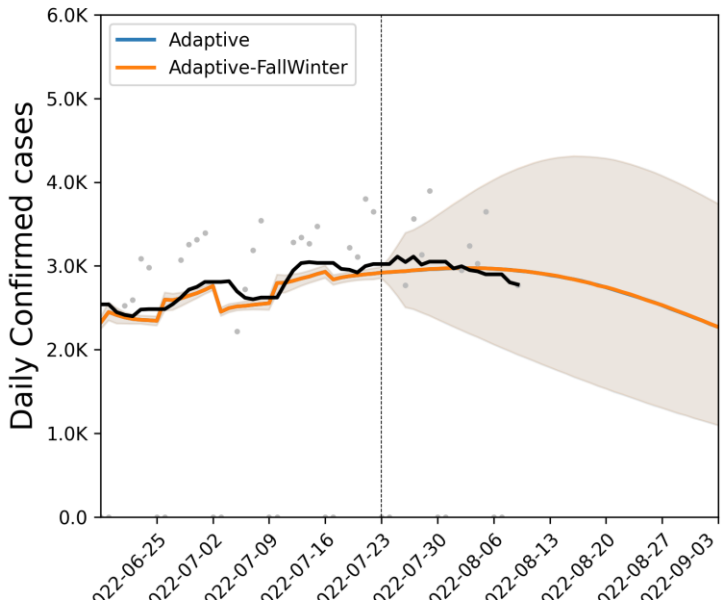
Previous projections comparison - Cases

- Previous projections have tracked observed cases well.
- Projection from 2 weeks ago anticipated a plateau giving way to gentle declines.
- Projection from beginning of July anticipated slow rise and then start of decline in early August as we are now experiencing

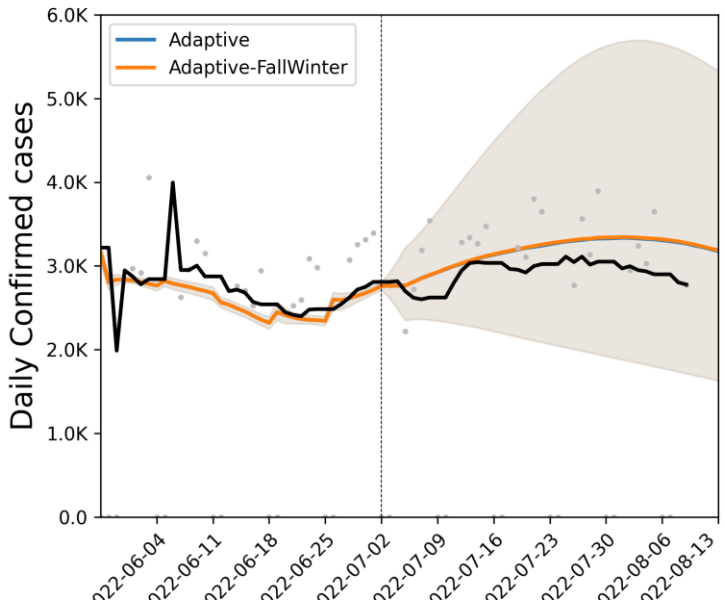
This week's projection



Projection from 2 weeks ago

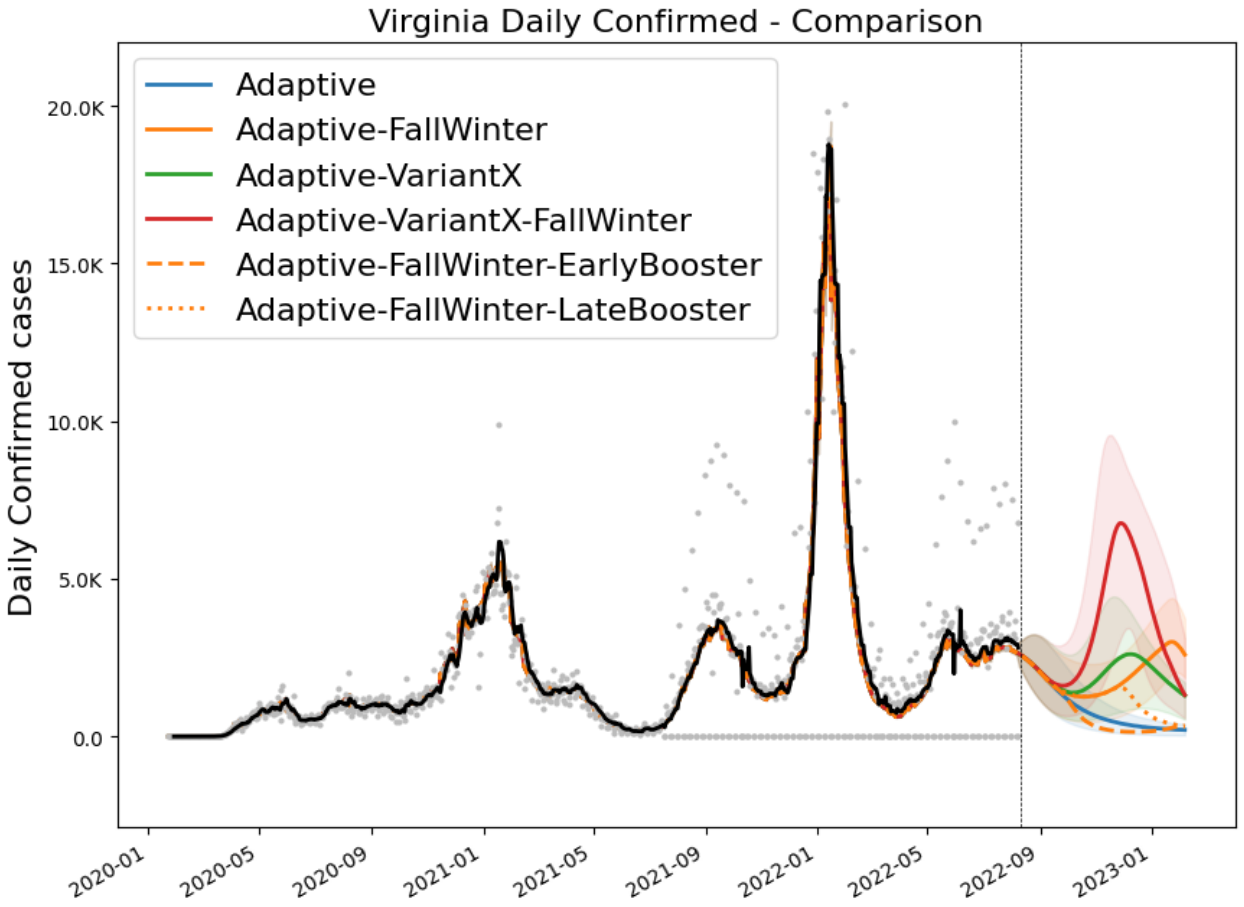


Projection from 4 weeks ago



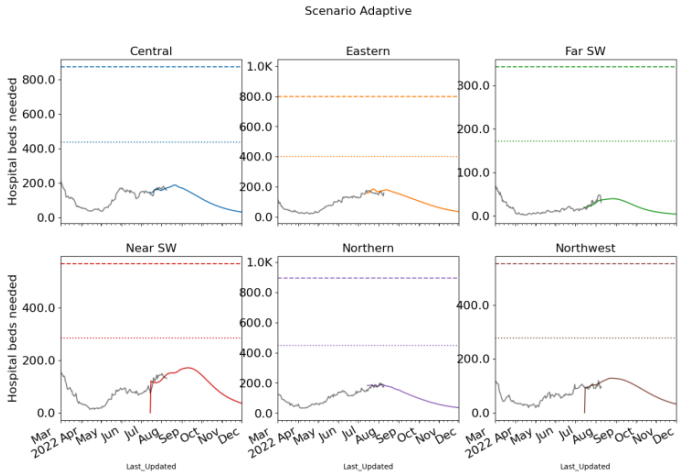
Outcome Projections

Confirmed cases

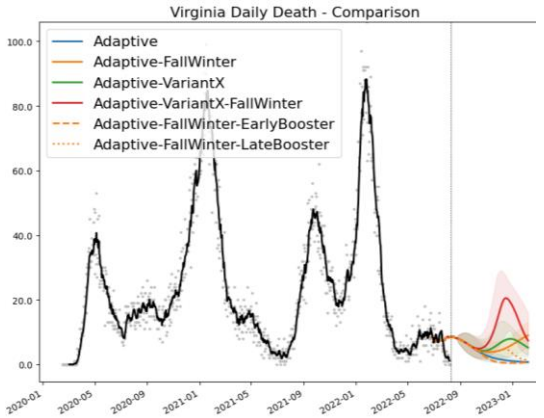


* without surveillance correction VariantBA2 peaked over 10K in July

Estimated Hospital Occupancy

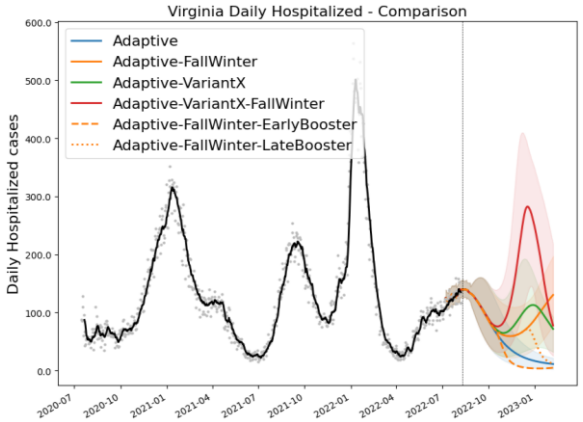


Daily Deaths



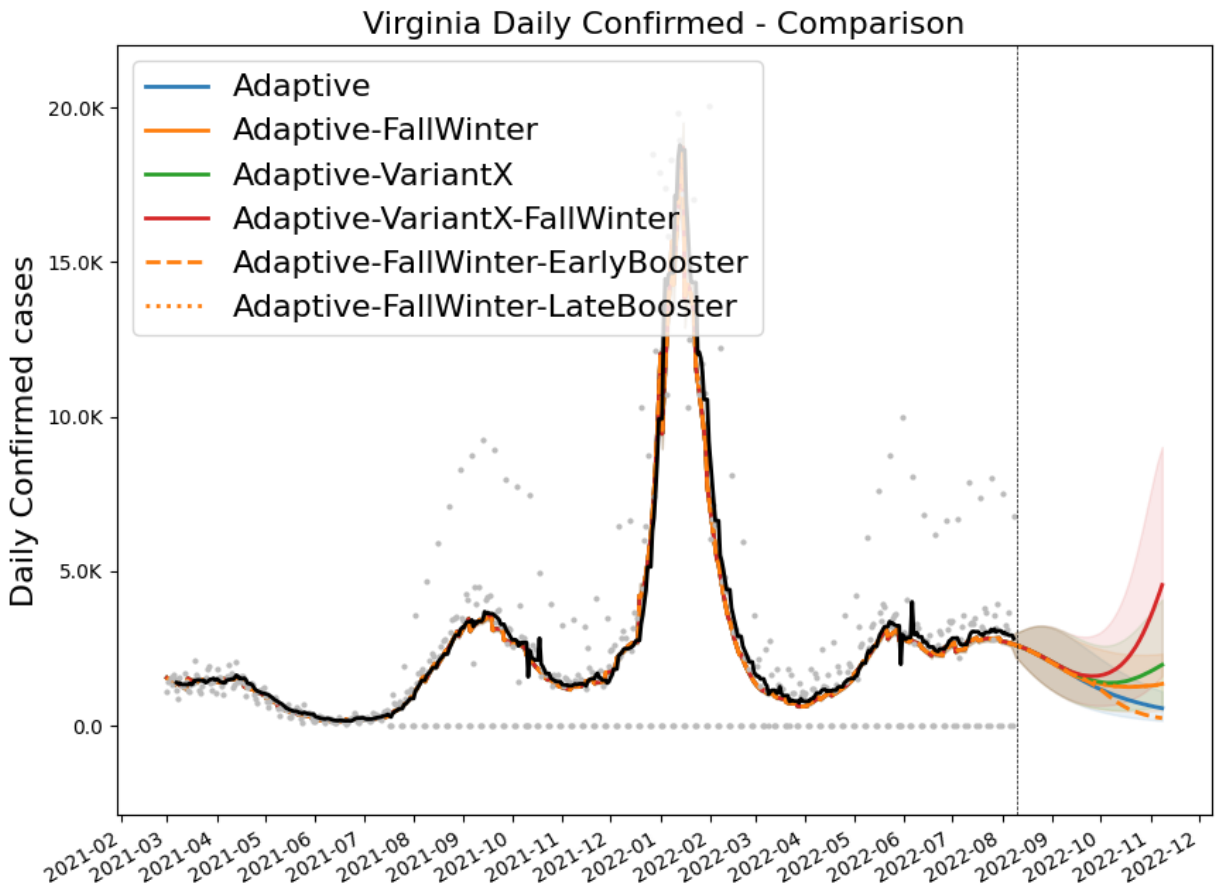
Death ground truth from VDH "Event Date" data, most recent dates are not complete

Daily Hospitalized



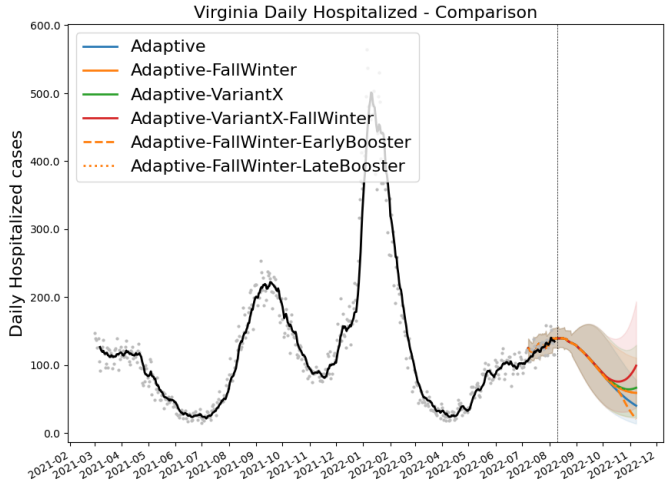
Outcome Projections – Closer Look

Confirmed cases

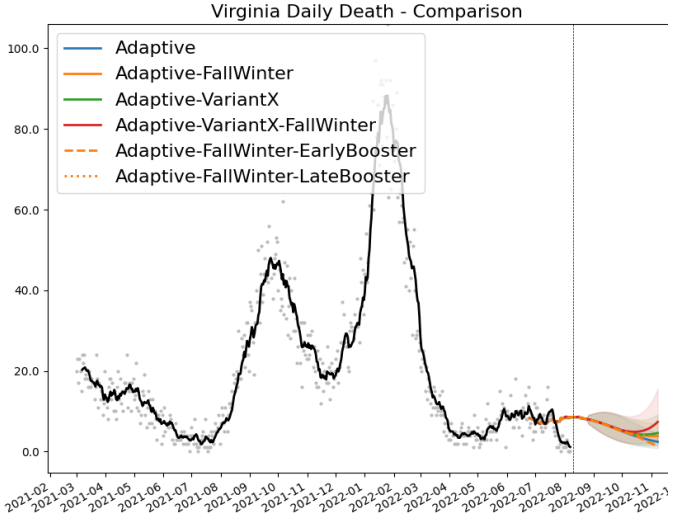


* without surveillance correction VariantBA2 peaked over 10K in July

Daily Hospitalized



Daily Deaths

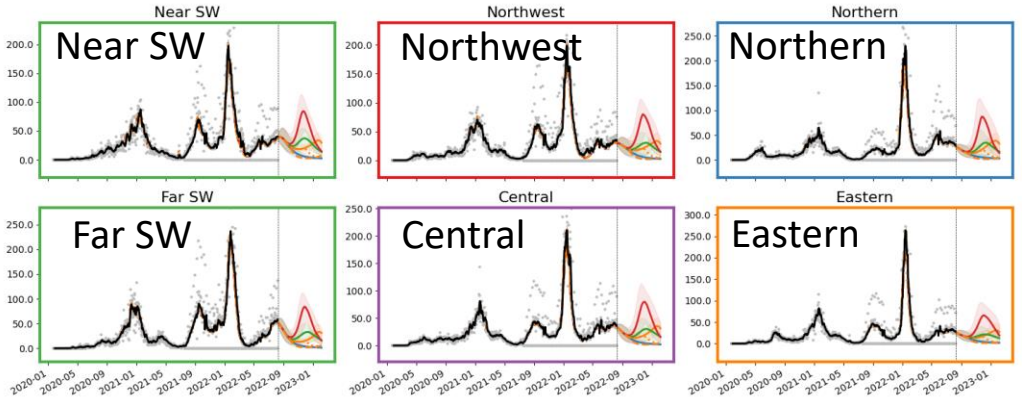


Death ground truth from VDH "Event Date" data, most recent dates are not complete

UNIVERSITY of VIRGINIA
BIOCOMPLEXITY INSTITUTE

Detailed Projections: All Scenarios

Projections by Region

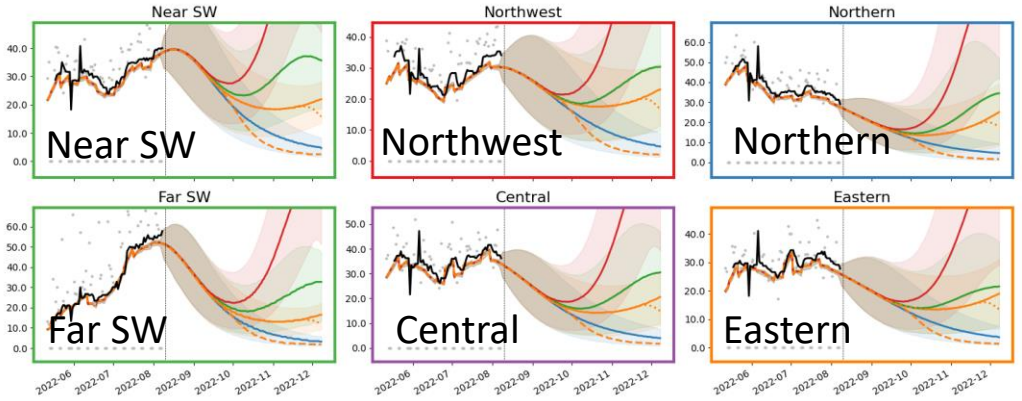


Projections by District

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

Detailed Projections: All Scenarios - Closer Look

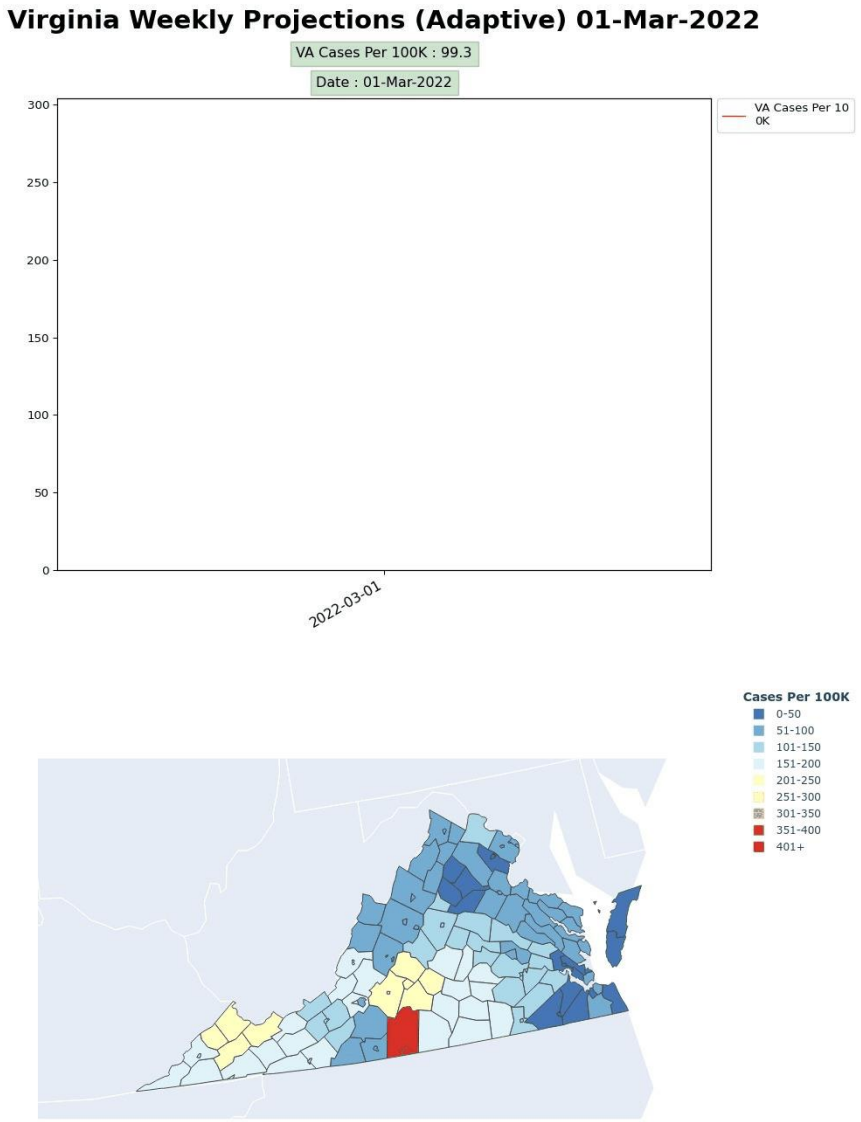
Projections by Region



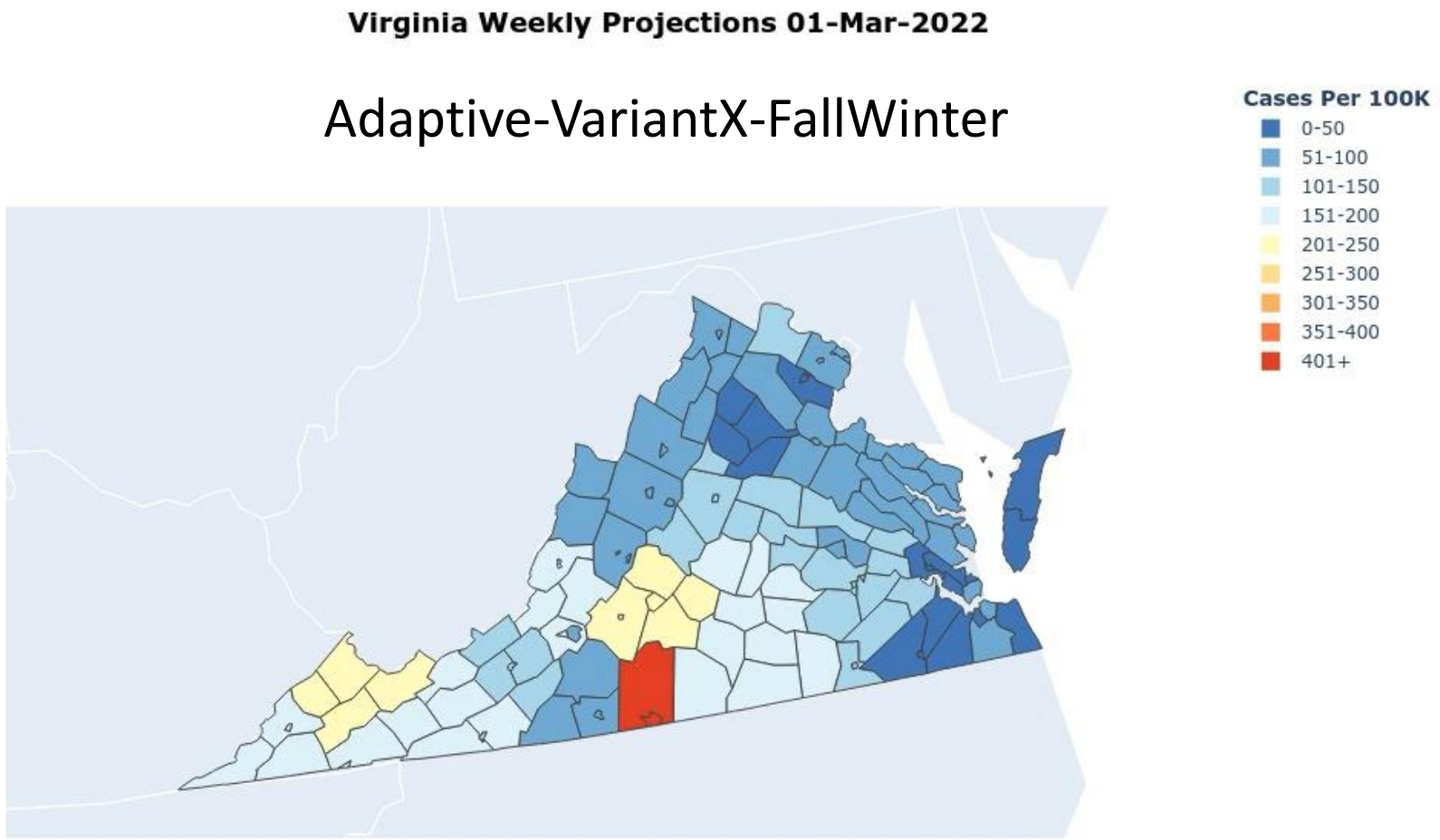
Projections by District

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

Detailed Projections: Map and EpiCurve



Detailed Projections: Animated

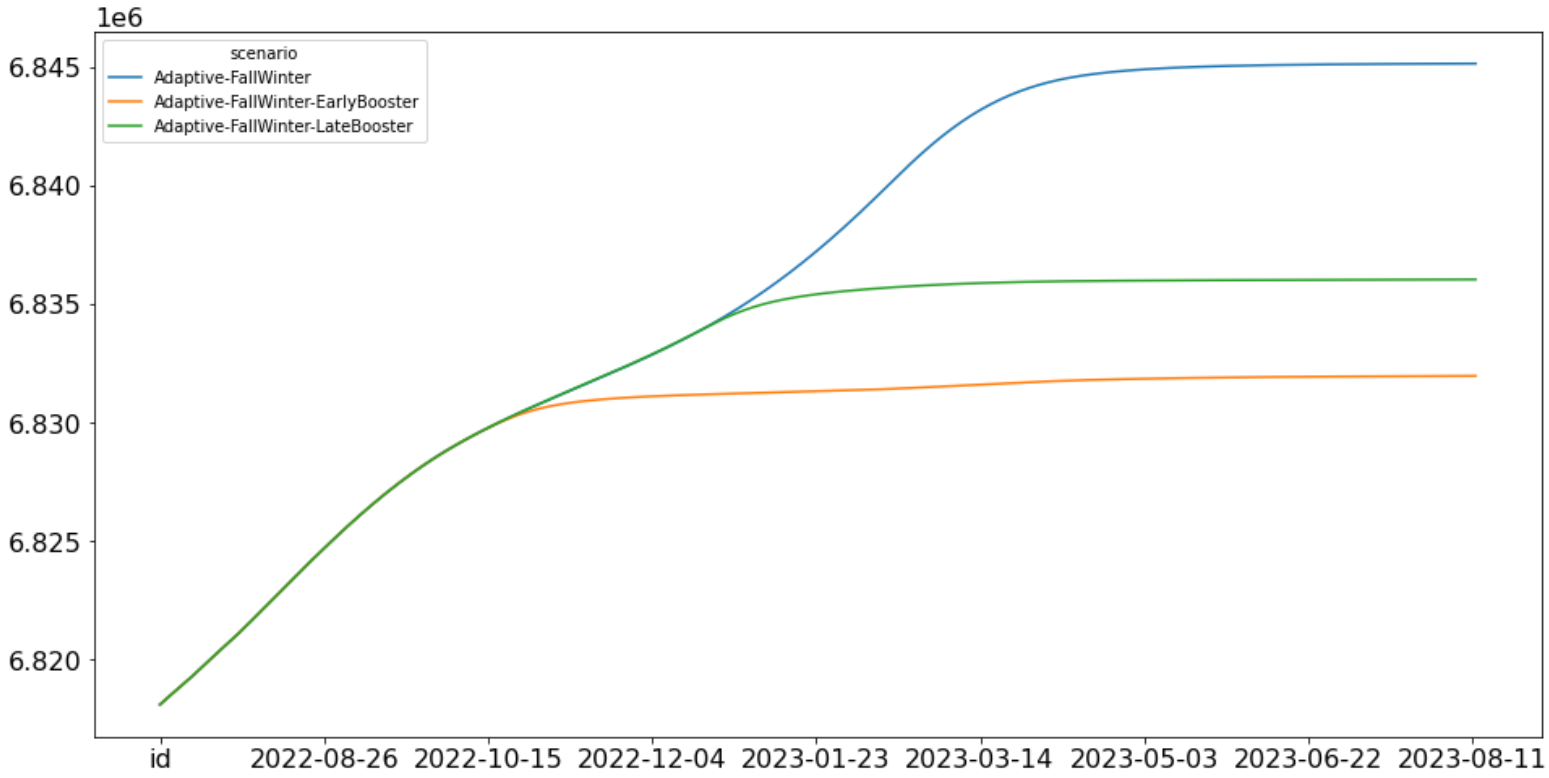


Weekly confirmed cases rate (per 100K)

Booster Campaign Timing has impact on future hospitalizations

Booster Campaign can significantly limit future hospitalizations and severe outcomes

- Reduction of 50-33% of future hospitalizations (~13K – 9K) through Spring 2023
- Early Booster campaign compared to Late Booster campaign could prevent as much as 4K hospitalizations

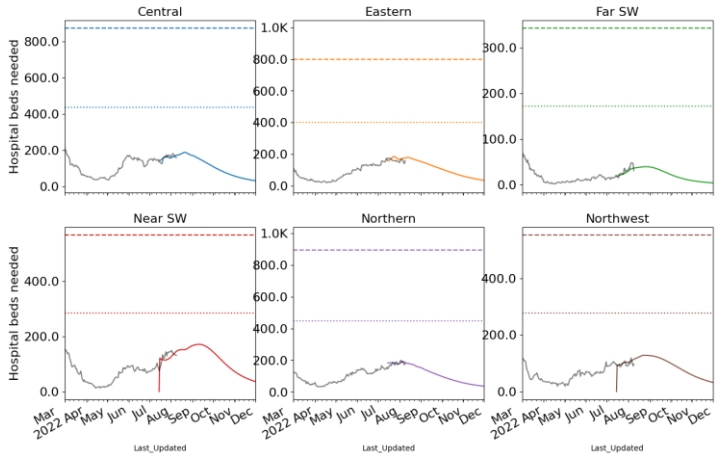


Hospital Demand and Bed Capacity by Region

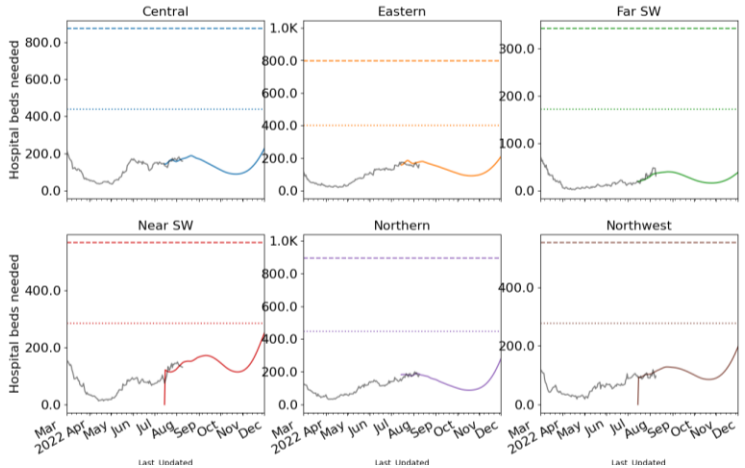
Capacities by Region

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

Adaptive



Adaptive – VariantX & Fall Winter



Length of Stay more variable with Omicron, occupancy projections may vary as a result, ad-hoc estimation performed per region

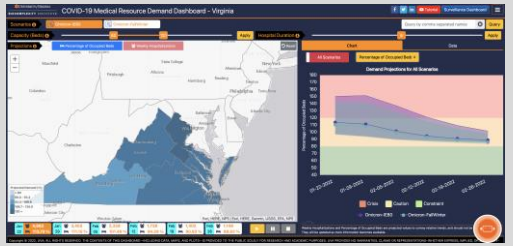
Estimated LOS shortened slightly to better fit observed data

Projections show continued declines and with expanded capacities and adjusted length of stay, no capacities exceeded

Length of Stay Estimates

Central	7
Eastern	6
Far SW	4
Near SW	9
Northern	4
Northwestern	9

Interactive Dashboard with regional projections



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 remain high though have continued their decline, hospitalizations have started to follow**
- VA weekly case rate down to 228/100K from 250/100K
  - US weekly case rate is relatively flat at 227/100K from 240/100K
  - VA hospital occupancy (rolling 7 day mean of 754 down from 776 a week ago) has continued to rise
- Projections anticipate continuation of these declines in cases as well as hospitalizations, but retain a potential for rebounds due to seasonal forces and/or novel sub-variants in the Fall
- Model updates:
  - Added preliminary scenarios for booster campaigns based on planned re-formulated boosters likely available this fall
  - Variant X introduction shifted back a month in the absence of any evidence of a new variant that is quickly gaining ground on BA.5

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:

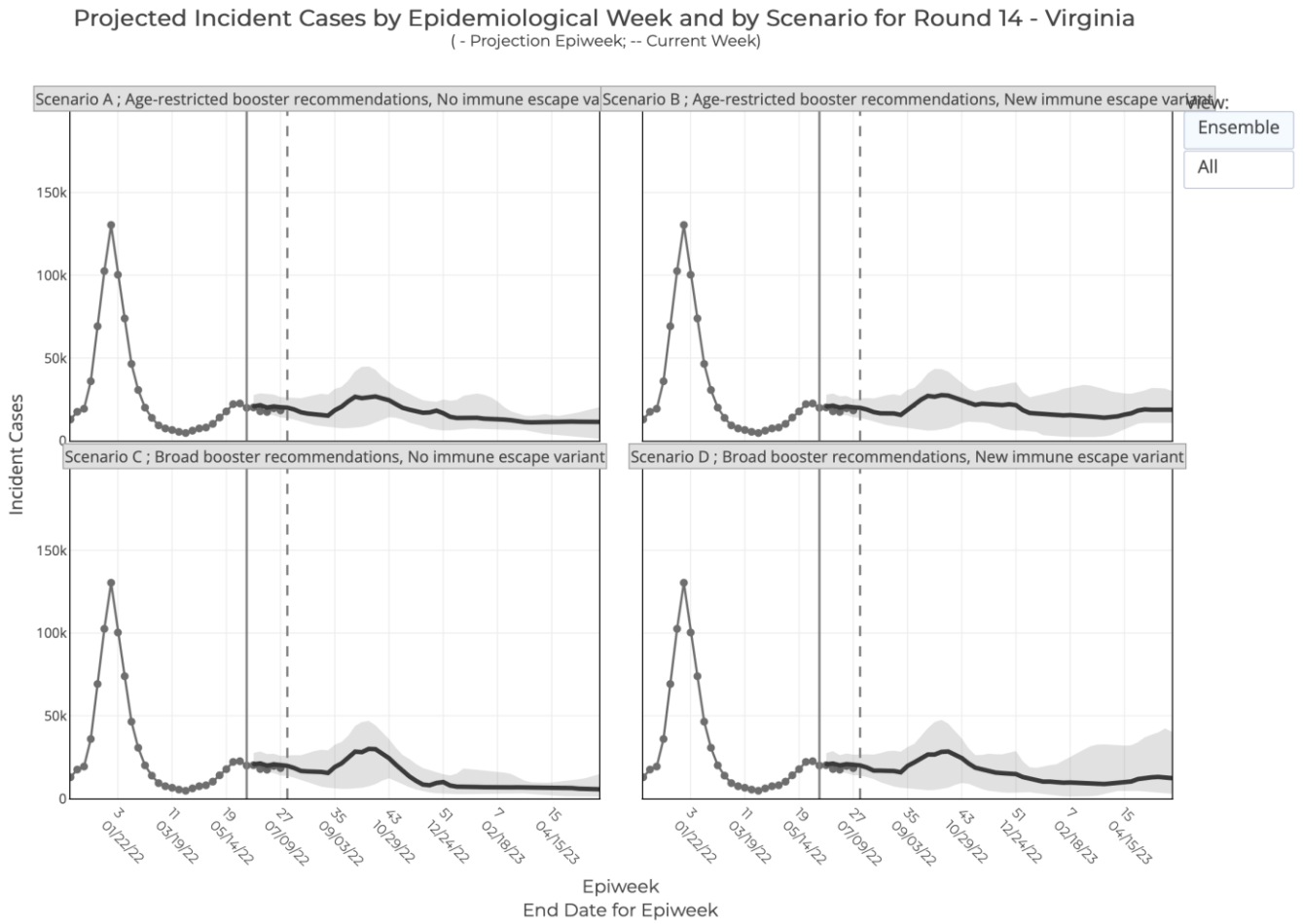
- **Scenario Modeling Hub:** Consortium of academic teams coordinated via MIDAS / CDC to that provides regular national projections based on timely scenarios
- **Genomic Surveillance:** Analyses of genomic sequencing data, VA surveillance data, and collaboration with VA DCLS to identify sample sizes needed to detect and track outbreaks driven by introduction of new variants etc.
- **Mobility Data driven Outreach locations:** Collaboration with VDH state and local, Stanford, and SafeGraph to leverage anonymized cell data to help identify sites most frequently visited by different demographic groups

COVID-19 Scenario Modeling Hub – Round 14

Collaboration of multiple academic teams to provide national and state-by-state level projections for 4 aligned scenarios

- Round 15 update underway
- Round 14 results released
  - Scenarios: Test benefits of reformulated fall boosters w/ and w/out a new variant

https://covid19scenariomodelinghub.org/viz.html



Round 14

Scenario defined as of 2022-05-17
Model Projecting from Epiweek 23 to Epiweek 23

- ☑ **Scenario A**
  Age-restricted booster recommendations
  No immune escape variant
  (A-2022-05-09)
- ☑ **Scenario B**
  Age-restricted booster recommendations
  New immune escape variant
  (B-2022-05-09)
- ☑ **Scenario C**
  Broad booster recommendations
  No immune escape variant
  (C-2022-05-09)
- ☑ **Scenario D**
  Broad booster recommendations
  New immune escape variant
  (D-2022-05-09)

Busiest Places: Mobility Data Can Assist

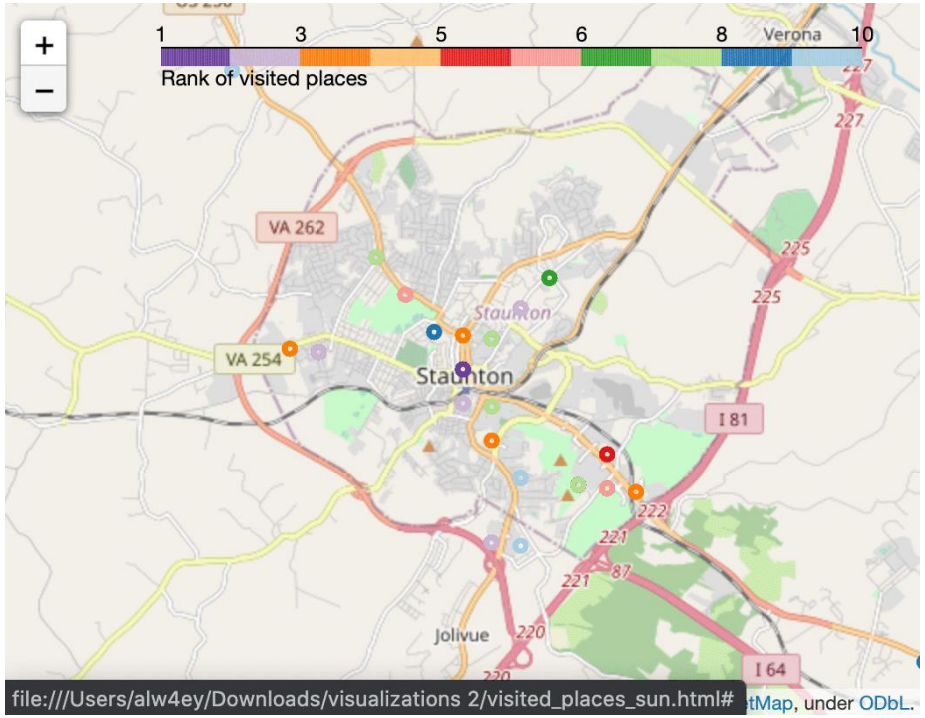
SafeGraph provides fine-grained mobility measures

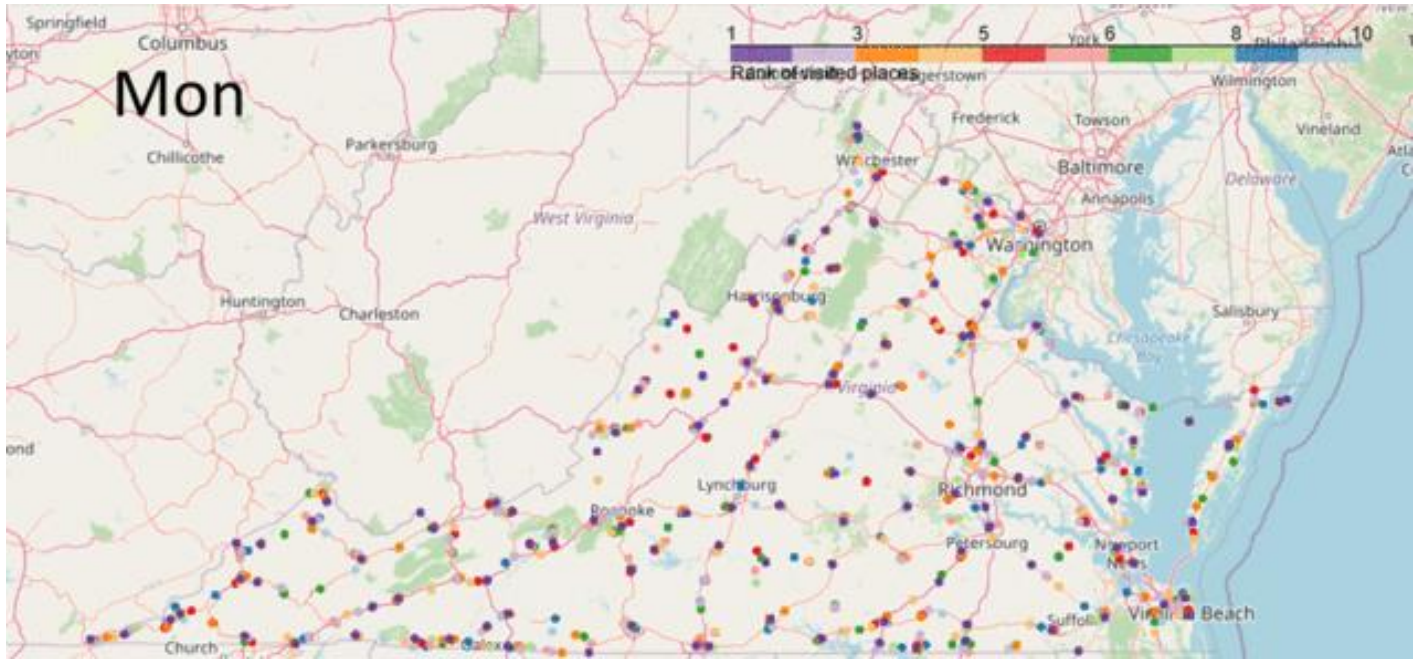
- SafeGraph: anonymized geolocation data aggregated from numerous cell phone apps
- One of the most fine-grained and high-coverage mobility data sources available: 6.4 million POIs in the US; 158,869 POIs in VA
- Has been utilized by hundreds of researchers, governments, and the CDC to aid COVID-19 efforts (Chang, Pierson, Koh, et al., *Nature* 2020; Chang et al, KDD 2021)
- Daily and hourly number of visits to points-of-interest (POIs), i.e., non-residential locations such as restaurants, bars, gas stations, malls, grocery stores, churches, etc.
- Weekly reports per POI of ***where visitors are coming from*** (at the census block group level)
- Still has limitations to be aware of (e.g., less representation among children and seniors)

SAFEGRAPH

Find the Busiest Locations

POIs are individual addresses, need some aggregation to busy areas

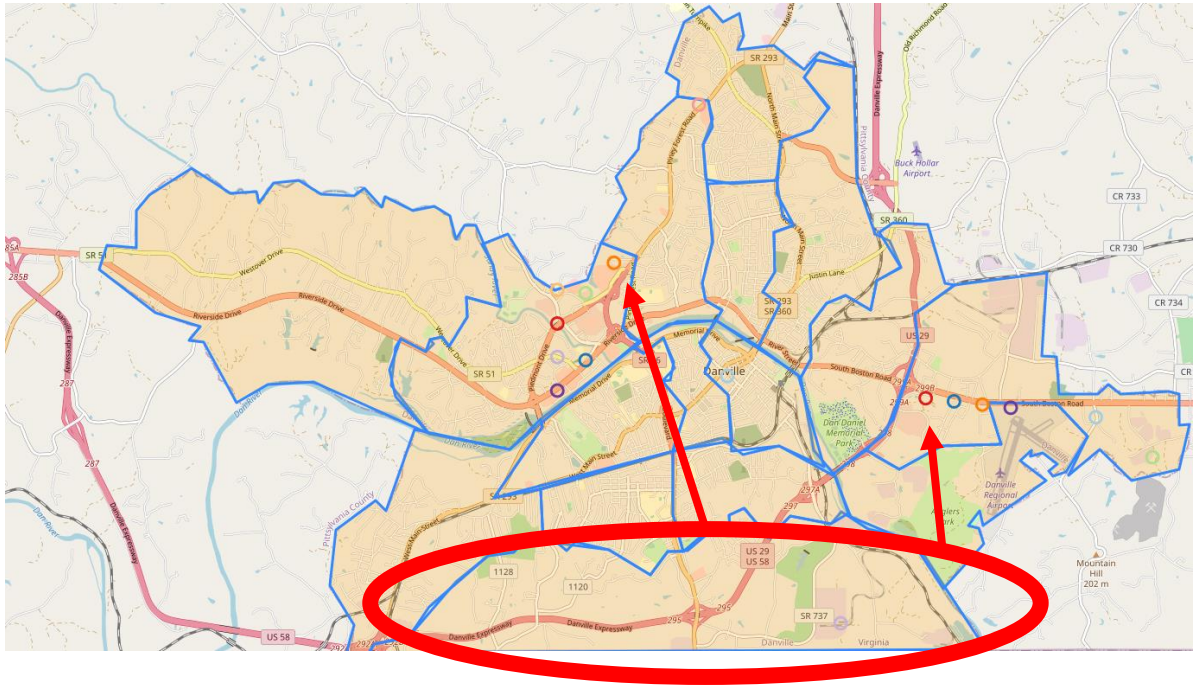




Busiest locations vary by day of week (and time of day)

Find locations visited by Population to Serve

Census Block Groups in Danville



1. Use census data to characterize the populations of the different census block groups
2. Identify most frequently visited POIs for each CBG
3. Cluster most visited POIs
4. Provide potential sites grouped by the demographic groups they likely serve

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

Example: List of locations in the Southside frequented by Black Virginians

Overview of the current roster of targeted populations

These are the current roster of targeted population groups that we are providing as part of the weekly delivery to VDH. (This roster is subject to change.)

- Whole population (eg, no target population filters are applied)
- Race Black
- Ethnicity Latinx
- Ages 20-40
- Ages 20-30
- Ages 30-40
- Unvaccinated populations
- Latinx or Black NEW

Data Elements in the CSV

HighlyVisitedAddress
This is the address of the POI in the L14 that sees the most visits. It is provided to make it easier to find the L14 on the map.

Rank & LocationWeight
The LocationWeight is estimated # of visits to POIs in the L14 from the target group. Rank indicates the order from most- to 25th most-visited

AreaMostVisitedPeriod
This is the 4-hour period in the week when the L14 sees its highest traffic. This is not target group-specifi

NEW

Population Group
For a targeted file like this one, these will all be the same value.

AreaMostVisitedDay
This is the day of the week when most visitors go to this S2 location. This is not target group-specific.

Lat and Lon
This is the latitude and longitude for the center of the L14.

VDH District

S2 Key (L14)

County

Locality	District	PopulationGroup	LocationID	Rank	LocationWeight	AreaMostVisitedDay	HighlyVisitedAddress	AreaMostVisitedPeriod	Lat	Lon
Accomack Cc	Eastern Shor	Latinx or Black	89ba2b55	1	4966.030095	Friday	25297 Lankford Hwy Rt 13 N, C	Friday 17:00-21:00	37.6978738	-75.716796
Accomack Cc	Eastern Shor	Latinx or Black	89ba2caf	2	3728.476605	Friday	26036 Lankford Hwy, Onley, VA	Friday 15:00-19:00	37.6881681	-75.722612
Accomack Cc	Eastern Shor	Latinx or Black	89ba2b57	3	3508.193676	Saturday	25274 Lankford Hwy, Onley, VA	Saturday 13:00-17:00	37.69859	-75.722612
Accomack Cc	Eastern Shor	Latinx or Black	89bbd4ad	4	2582.802769	Wednesday	25102 Lankford Hwy, Onley, VA	Sunday 11:00-15:00	37.7023677	-75.710981
Accomack Cc	Eastern Shor	Latinx or Black	89ba2b53	5	1844.868961	Sunday	25102 Lankford Hwy, Onley, VA	Friday 16:00-20:00	37.7030842	-75.716796
Albemarle Cc	Blue Ridge	Latinx or Black	89b38647	1	14088.0684	Thursday	1215 Lee St, University of Virg	Thursday 07:00-11:00	38.0327733	-78.500766
Albemarle Cc	Blue Ridge	Latinx or Black	89b477ff	2	6999.363545	Saturday	1980 Rio Hill Ctr, Charlottesvill	Saturday 12:00-16:00	38.087391	-78.472353
Albemarle Cc	Blue Ridge	Latinx or Black	89b38645	3	5824.383454	Wednesday	Cabell Hall 525 Mccormick Roa	Wednesday 11:00-15:00	38.033334	-78.506447
Albemarle Cc	Blue Ridge	Latinx or Black	89b3888d	4	5078.488029	Friday	540 Pantops Ctr, Pantops, VA,	Thursday 11:00-15:00	38.0334982	-78.455301
Albemarle Cc	Blue Ridge	Latinx or Black	89b387fd	5	4655.844131	Saturday	100 Twentyninth Place Ct, Cha	Saturday 11:00-15:00	38.077516	-78.478036

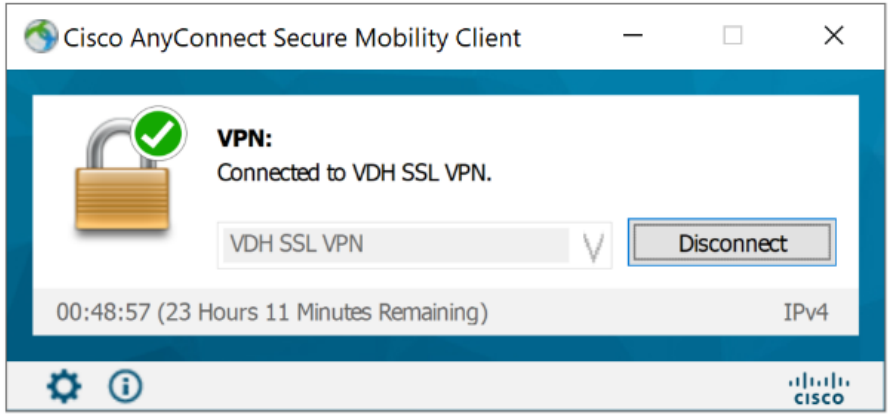
Mobility Data Updated Weekly

Box: https://virginia.box.com/s/03kq8el0kzd9w43wz2g3myozov76uizo

- Excel sheets and simple HTML maps packaged for use

VDH has a dashboard available upon request to allow interactive viewing

- https://arcgis.vdh.virginia.gov/portal/apps/opsdashboard/index.html#/8631cfc4f181460fafc7e1923f41d581
- Dashboard is restricted to VDH offices and those who VPN into the CoV Network



References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS Computational Biology* 15.9 (2019): e1007111.

Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. SIAM/ASA Journal on Uncertainty Quantification, 6(4):1685–1706, 2018.

Adiga, Aniruddha, Srinivasan Venkatramanan, Akhil Peddireddy, et al. "Evaluating the impact of international airline suspensions on COVID-19 direct importation risk." *medRxiv* (2020)

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

Virginia Department of Health. COVID-19 in Virginia. http://www.vdh.virginia.gov/coronavirus/

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?

Points of Contact

Bryan Lewis
brylew@virginia.edu

Srini Venkatramanan
srini@virginia.edu

Madhav Marathe
marathe@virginia.edu

Chris Barrett
ChrisBarrett@virginia.edu

Biocomplexity COVID-19 Response Team

Aniruddha Adiga, Abhijin Adiga, Hannah Baek, Chris Barrett, Golda Barrow, Richard Beckman, Parantapa Bhattacharya, Jiangzhuo Chen, Clark Cucinell, Patrick Corbett, Allan Dickerman, Stephen Eubank, Stefan Hoops, Ben Hurt, Ron Kenyon, Brian Klahn, Bryan Lewis, Dustin Machi, Chunhong Mao, Achla Marathe, Madhav Marathe, Henning Mortveit, Mark Orr, Joseph Outten, Akhil Peddireddy, Przemyslaw Porebski, Erin Raymond, Jose Bayoan Santiago Calderon, James Schlitt, Samarth Swarup, Alex Telionis, Srinivasan Venkatramanan, Anil Vullikanti, James Walke, Andrew Warren, Amanda Wilson, Dawen Xie