COVID-19 Maryland Hospital Impact

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Disclaimer

- These are unpublished preliminary results of a fast moving epidemic with many uncertain parameters. All results are subject to change
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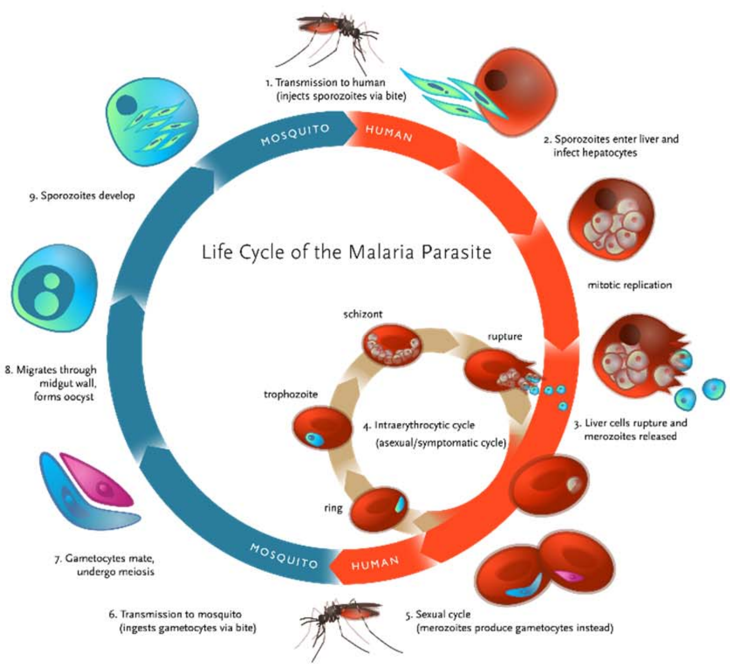
- Computational assistance provided by CCDC U.S. Army Research Laboratory and The National Center for Supercomputing Applications (NCSA)
- No other disclosures

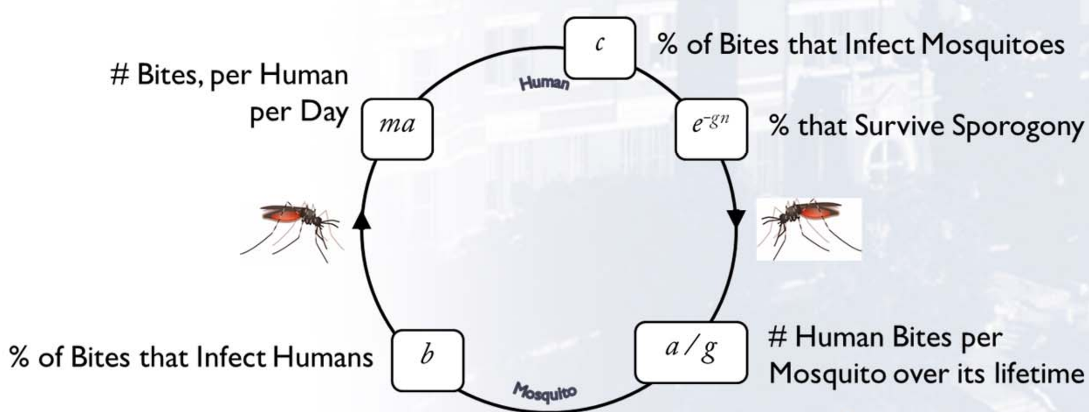
First Disease Model 1911

Malaria

$$S \underset{r}{\overset{h}{\longleftrightarrow}} I$$

Sir Ronald Ross





SIR Model

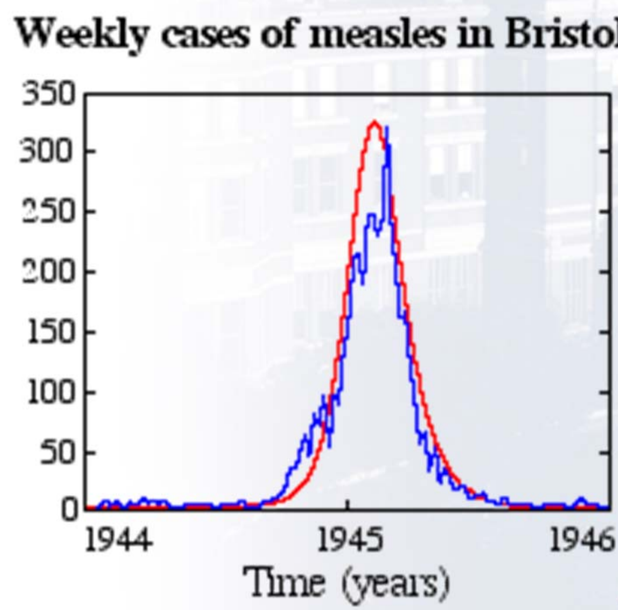
Susceptible $\xrightarrow{\text{Infection}}$ Infected $\xrightarrow{\text{Death/Recovery}}$ Removed

“Simple” model of infection assumes individuals are like molecules in a glass of water. Susceptible individuals become infected when the “bump into” already infected individuals

SIR Model

Susceptible $\xrightarrow{\text{Infection}}$ Infected $\xrightarrow{\text{Death/Recovery}}$ Removed

Measles is a nearly perfect example of an SIR modeled disease



https://plus.maths.org/content/mathematics-diseases

SIR Model

$$\frac{dS}{dt} = -\beta SI$$

$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

Progression of population can be described by a set of ordinary differential equations where:

β is the effective transmission rate

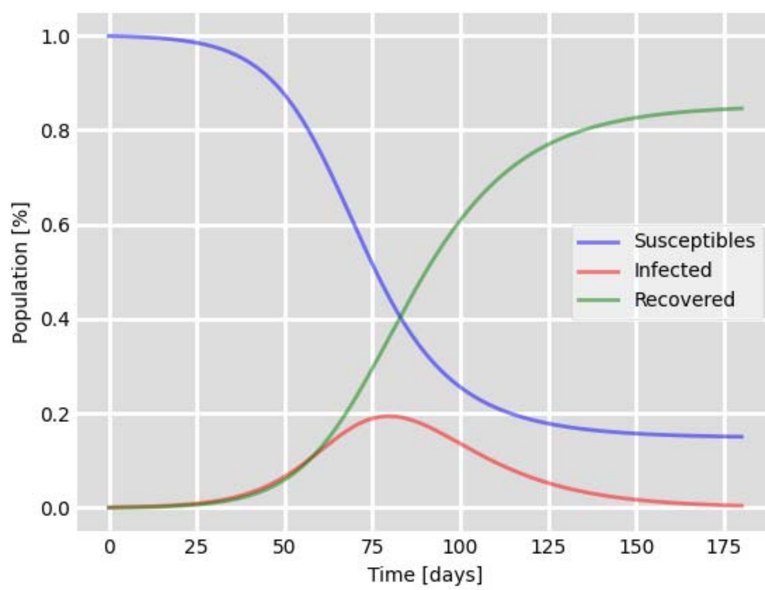
γ is the rate the individuals recover

SIR Model

$$\frac{dS}{dt} = -\beta SI$$

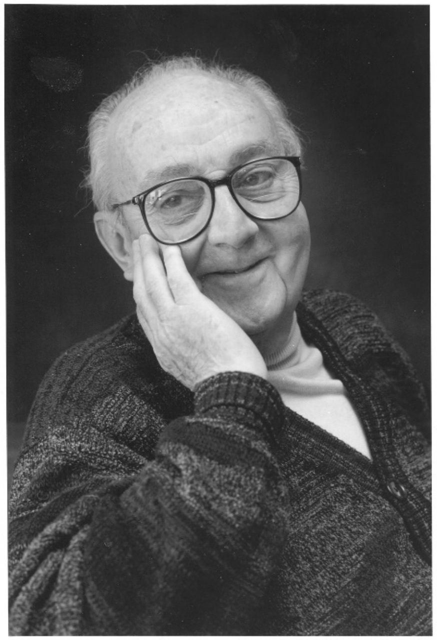
$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$



What are models good for?

"All models are wrong …
but some are useful"



George Box

Basic Reproductive Number (R_0)

$$\frac{dS}{dt} = -\beta SI$$

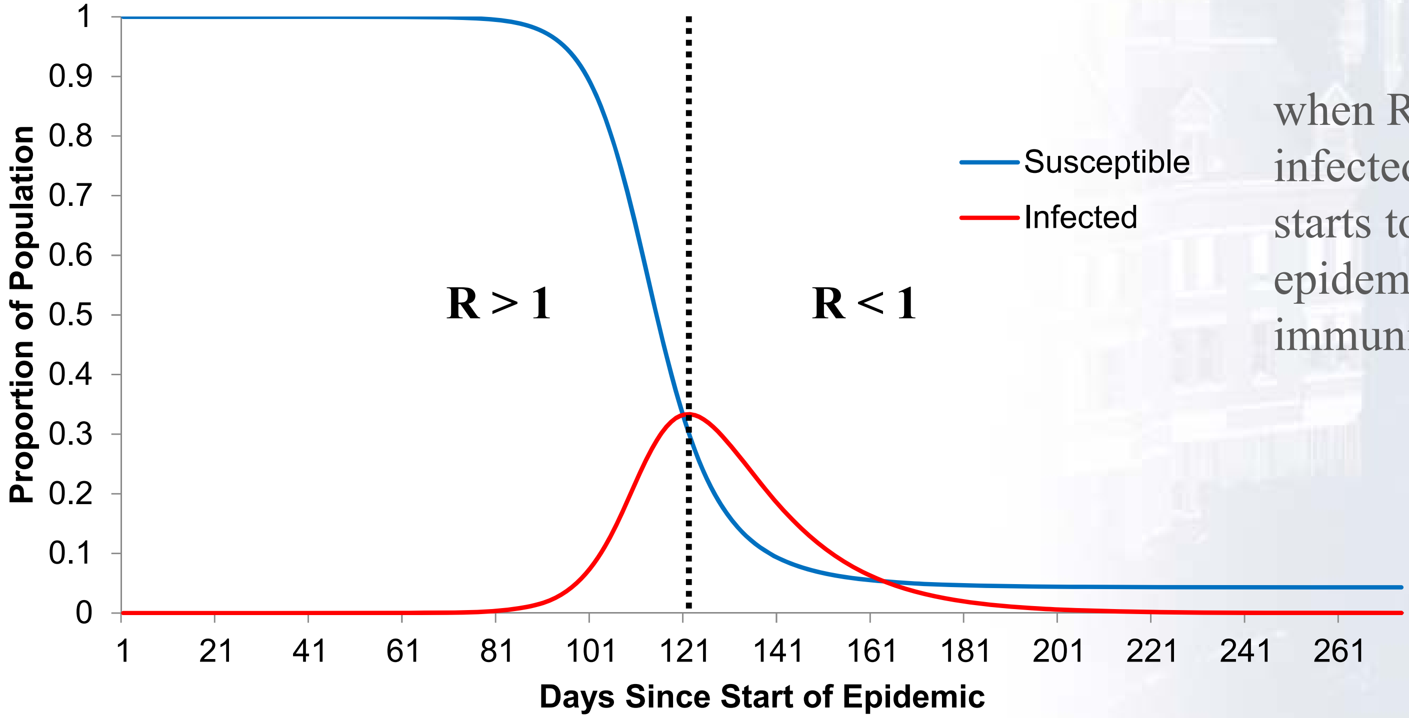
$$\frac{dI}{dt} = \beta SI - \gamma I$$

$$\frac{dR}{dt} = \gamma I$$

→ Can be rearranged to show that infections can only be increasing when → $\frac{\beta S_0}{\gamma} > 1$

Effective Reproductive Number (R)

Since the infection depletes the pool of susceptibles, the effective reproductive number drops in line with the proportion of susceptibles in the population (S), i.e. $R = R_0 S$



when R<1, the number of infected cases starts to fall and the epidemic dies out (i.e., herd immunity)

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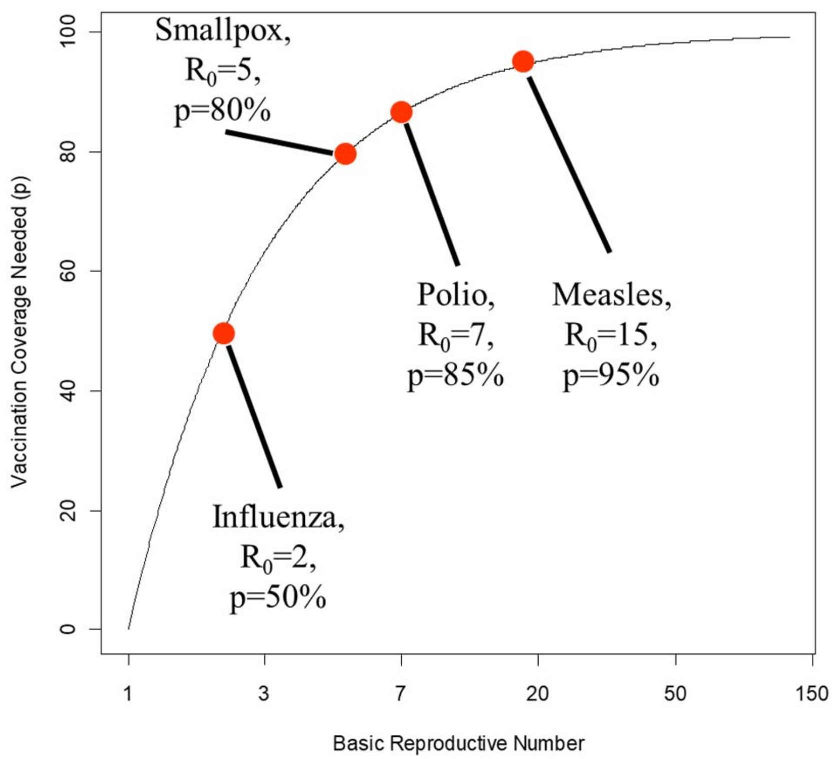
Why does R0 matter?

Drives dynamics and can aid in understanding concepts, such as how many people need to be vaccinated to stop transmission …



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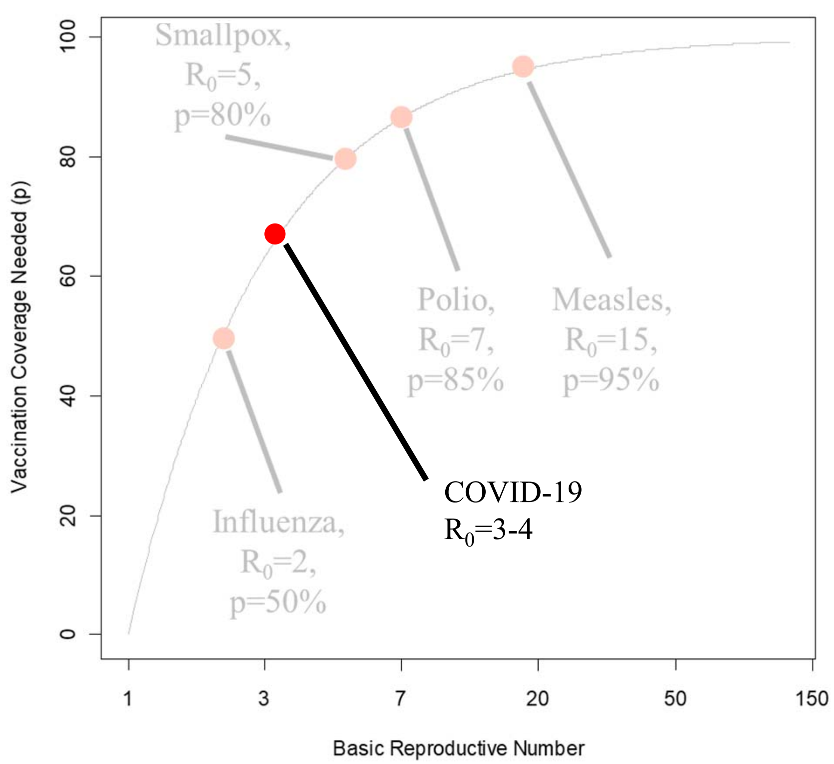
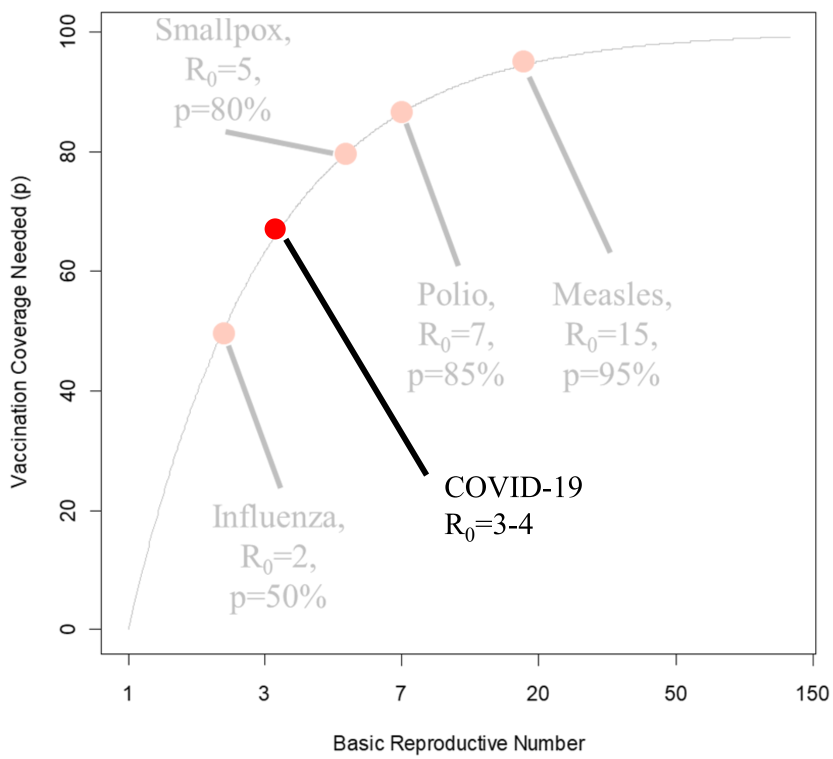
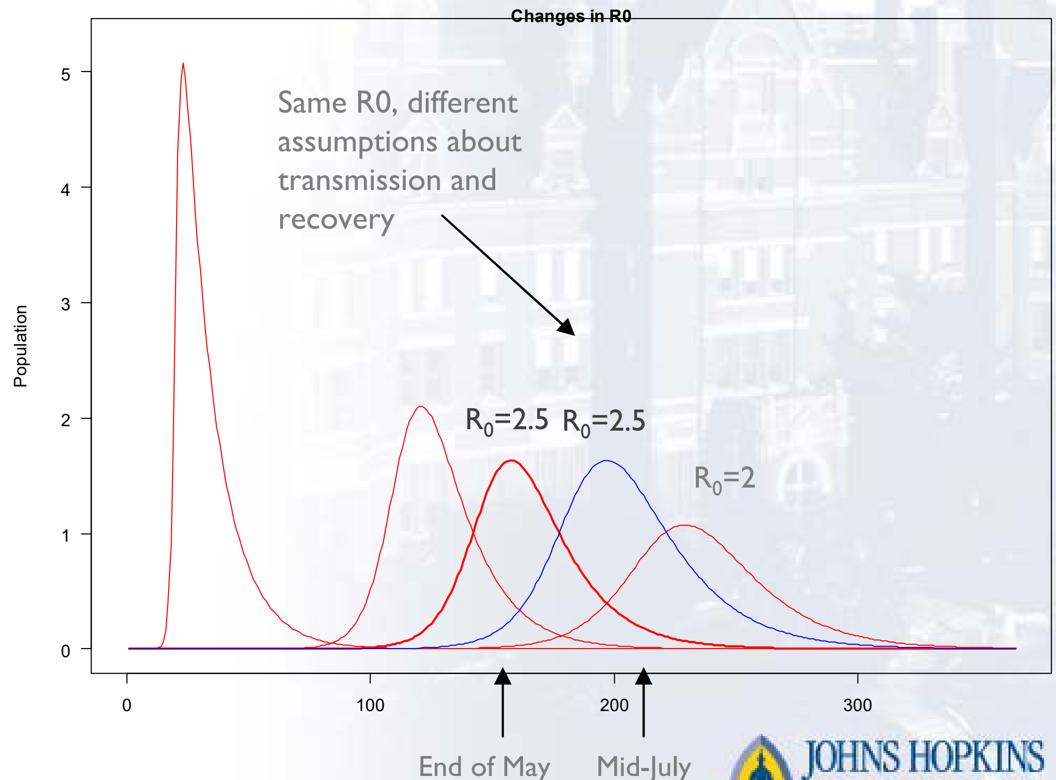


Why does R0 matter?

Drives dynamics and can aid in understanding concepts, such as how many people need to be vaccinated to stop transmission … but the same R_0 can produce different dynamics depending on transmission/recovery

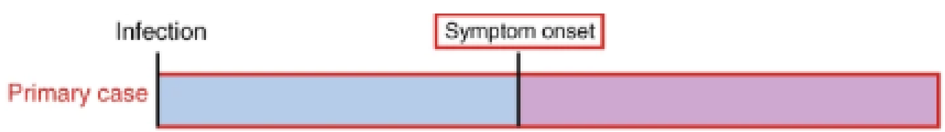


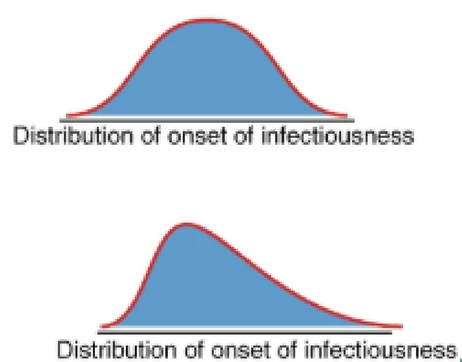


R0 and SARS-CoV-2

- Heterogeneity in transmission

Infected individuals have an incubation period and then a period of infectiousness





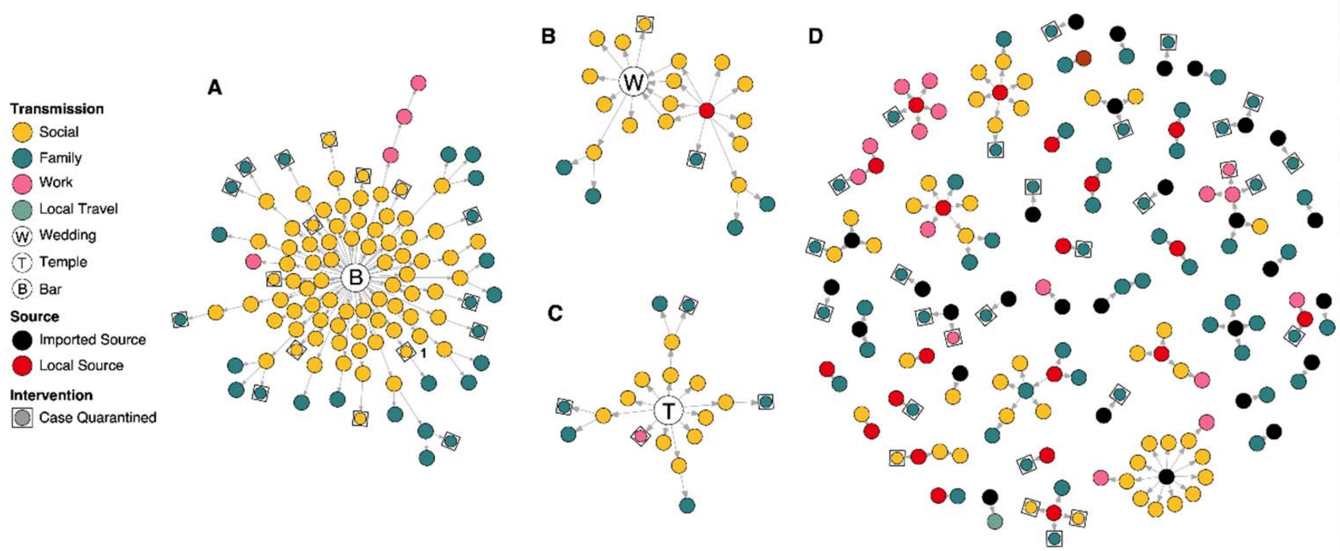
SARS

Influenza

Uncertainty remains about SARS-CoV-2 infectiousness pattern

R0 and SARS-CoV-2

- Heterogeneity in transmission
- Superspreader events
- How to model?

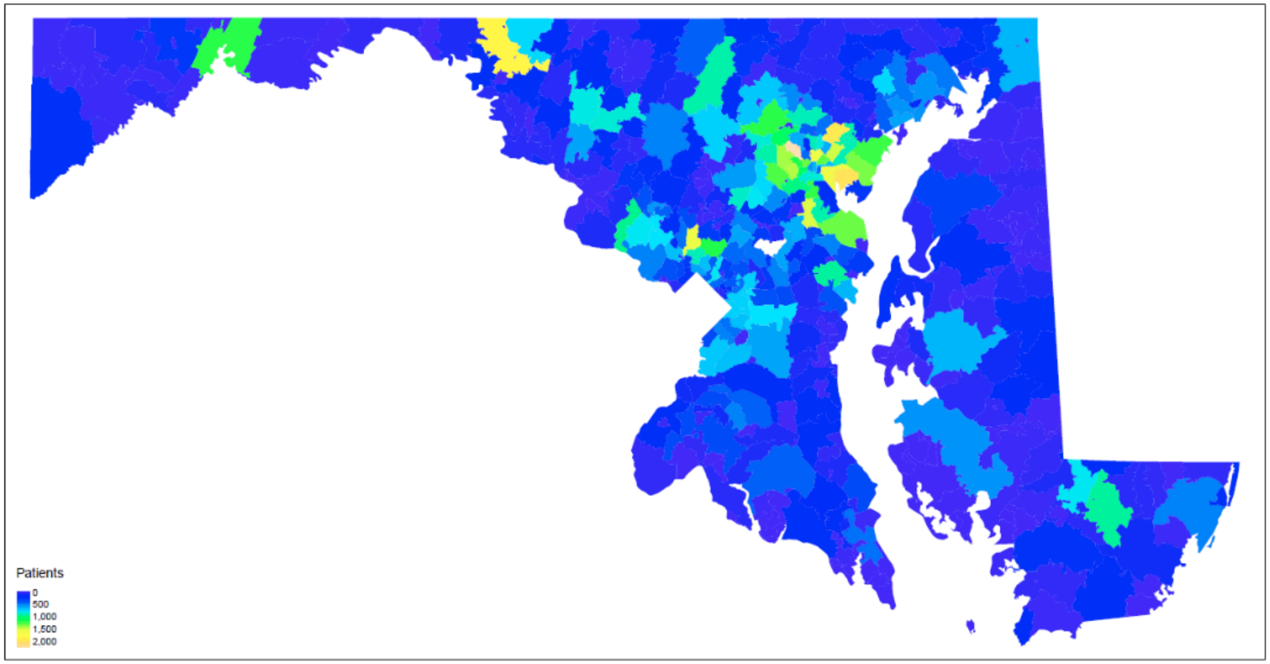


20% of cases were responsible for 80% of local transmission

Traced spread of SARS-CoV-2 cases in Hong Kong: DOI: 10.21203/rs.3.rs-29548/v1

Model Structure

- Individual Agent Model of Maryland
  - All Maryland zip codes
  - Includes surrounding zip codes with patients that visit MD hospitals
- Individuals are assumed to live in households and are spread across the state based on zip code level Census data
  - total population is ~9 million in 500+ zip codes



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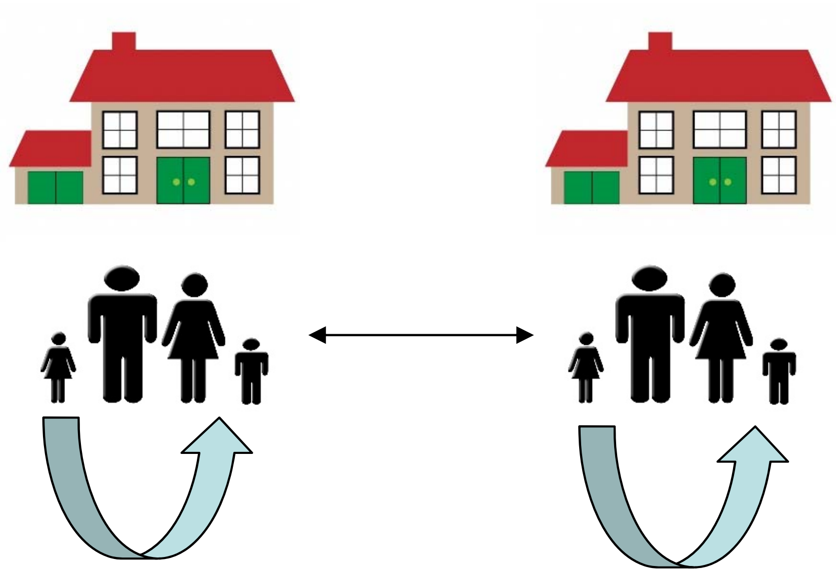
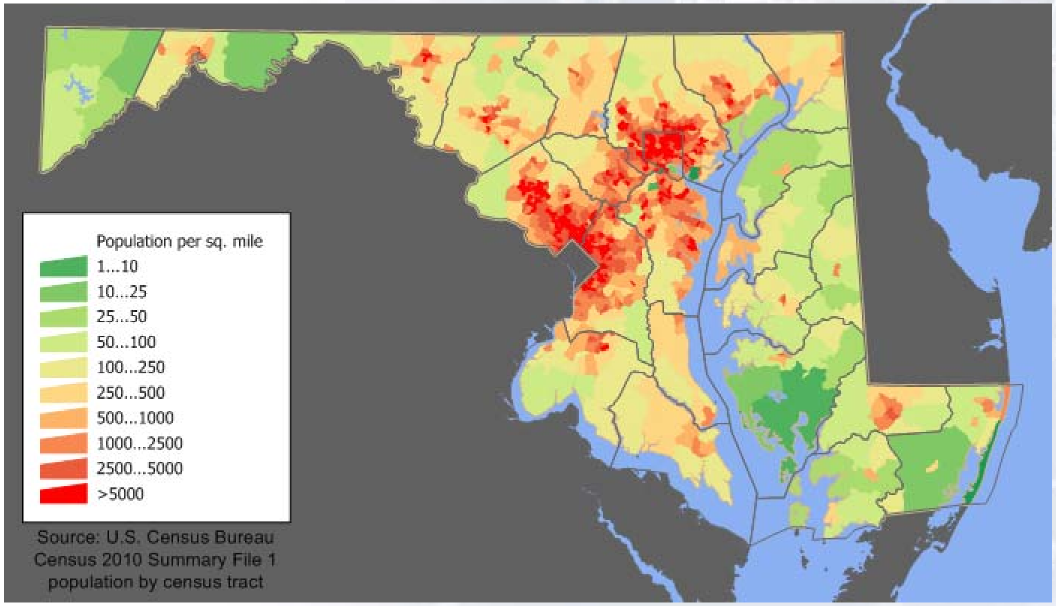
Model Assumptions

- Initial infections first arrived in Maryland in early to mid-February
- Continual seeding of infections is assumed to occur based on population size assuming largest zip codes more likely to get initial infections
- Contacts between non-household members are based on distance and population size of each zip code

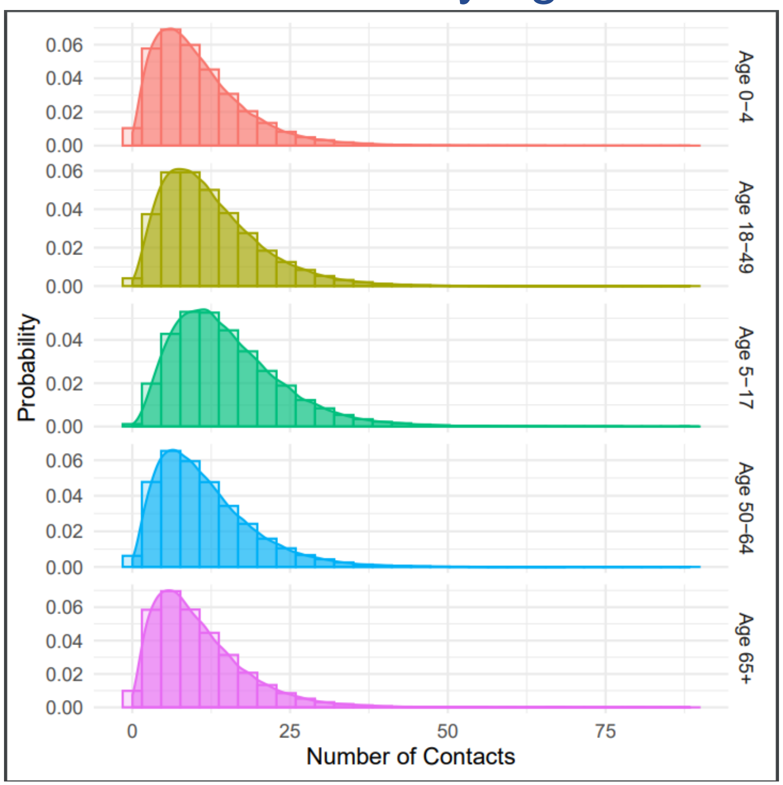




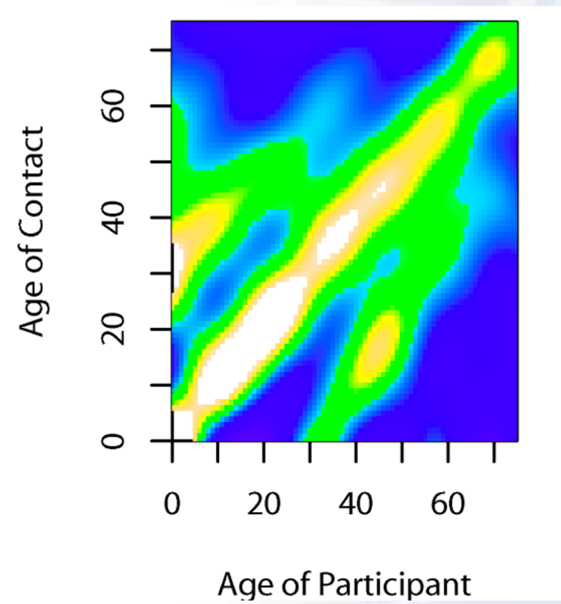
Model Assumptions

- Contact and Transmission depends on type of contact and with whom contact is made
  - Individuals have highly variable contact patterns by age
    - Gamma distributed with kids having higher rates of contact[1]
  - Age-related assortative contact patterns[1]

Contact Rates by Age



Age Assortative Contact

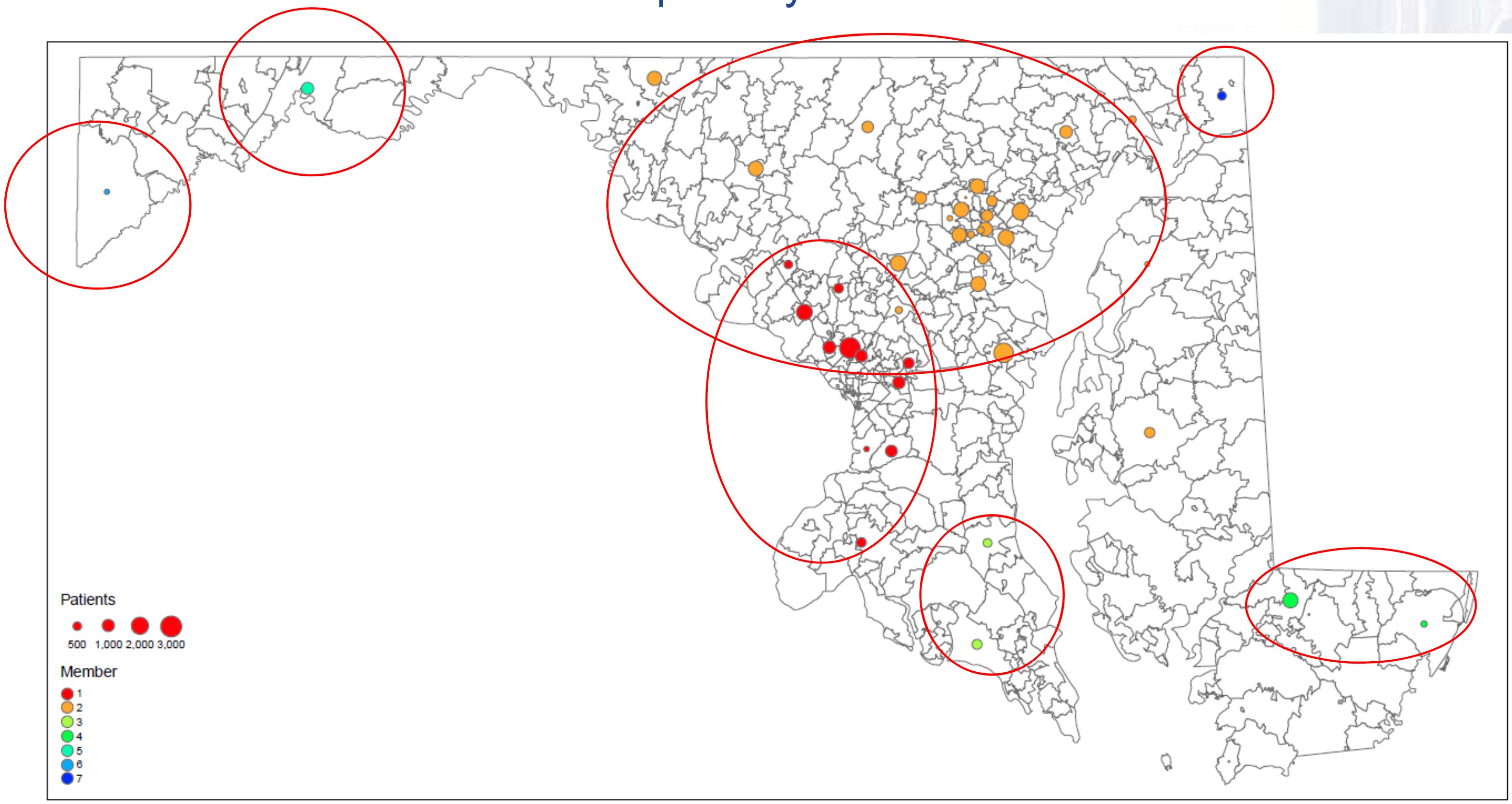


1. 10.1371/journal.pmed.0050074

Hospital Aggregations

Patients in general visit hospitals near them, particularly for emergency visits.
More hospitals in an area spread out case load

- We based likelihood of patients visiting a hospital based on average wintertime visits for respiratory viruses



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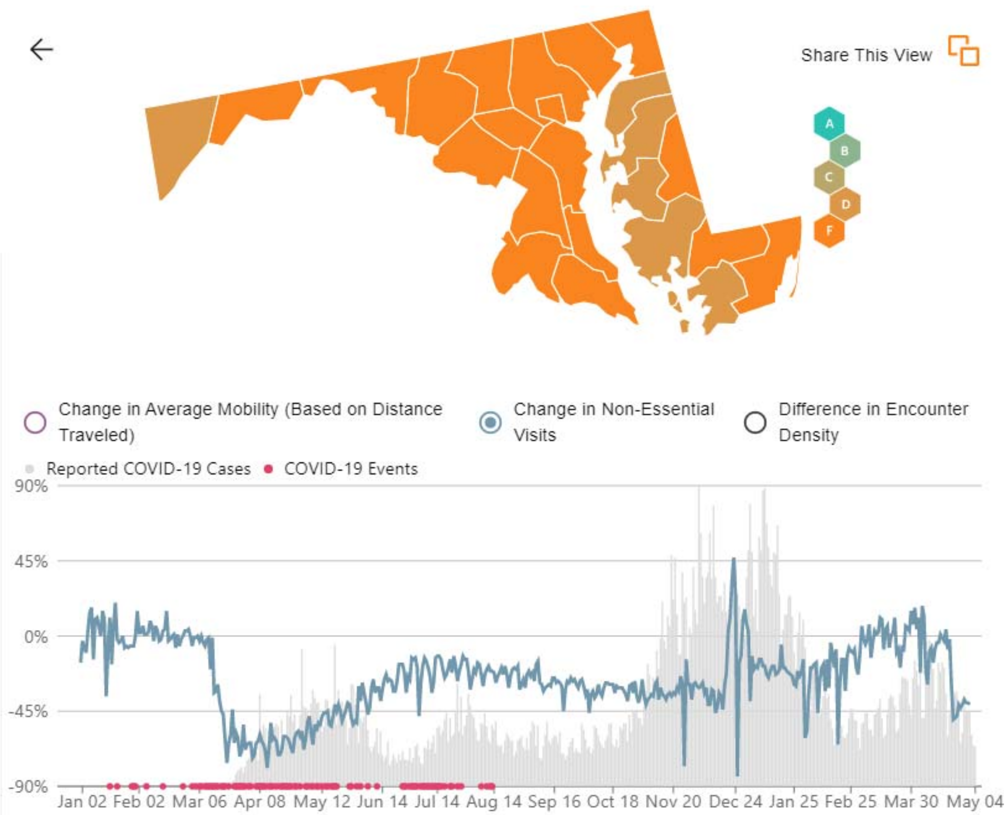
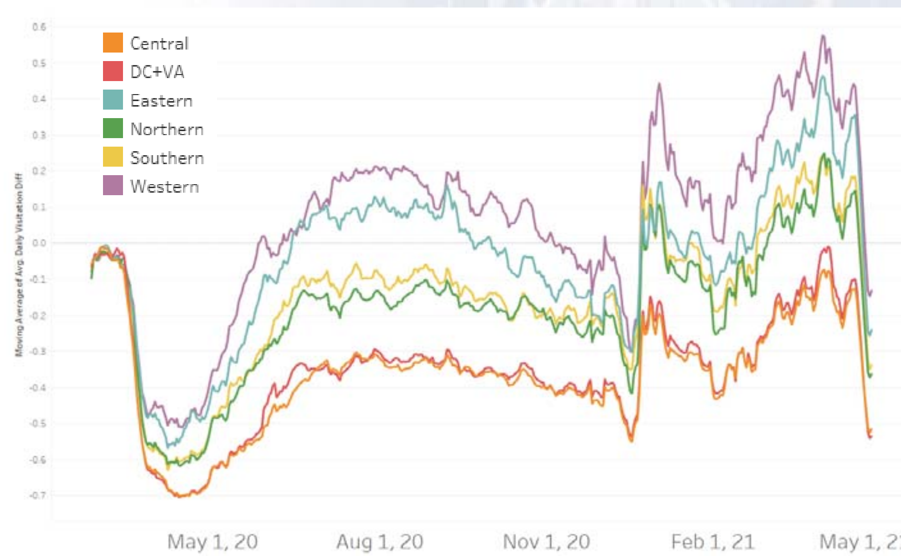
Patient Movement

Changes in movement based on mobile phone data



https://www.unacast.com/covid19/social-distancing-scoreboard?view=state&fips=24

Patterns have been different depending on the county



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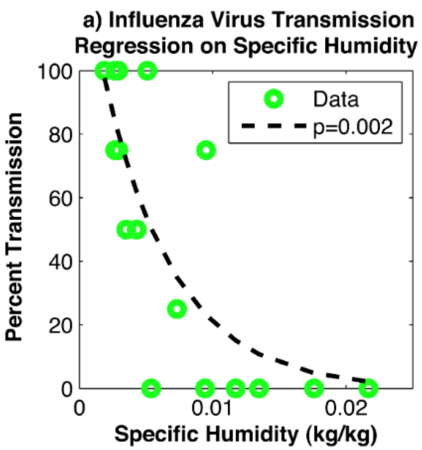
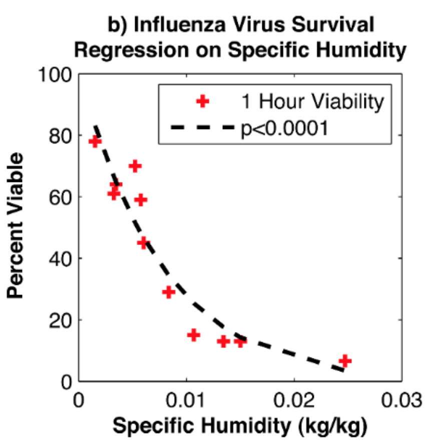
Humidity

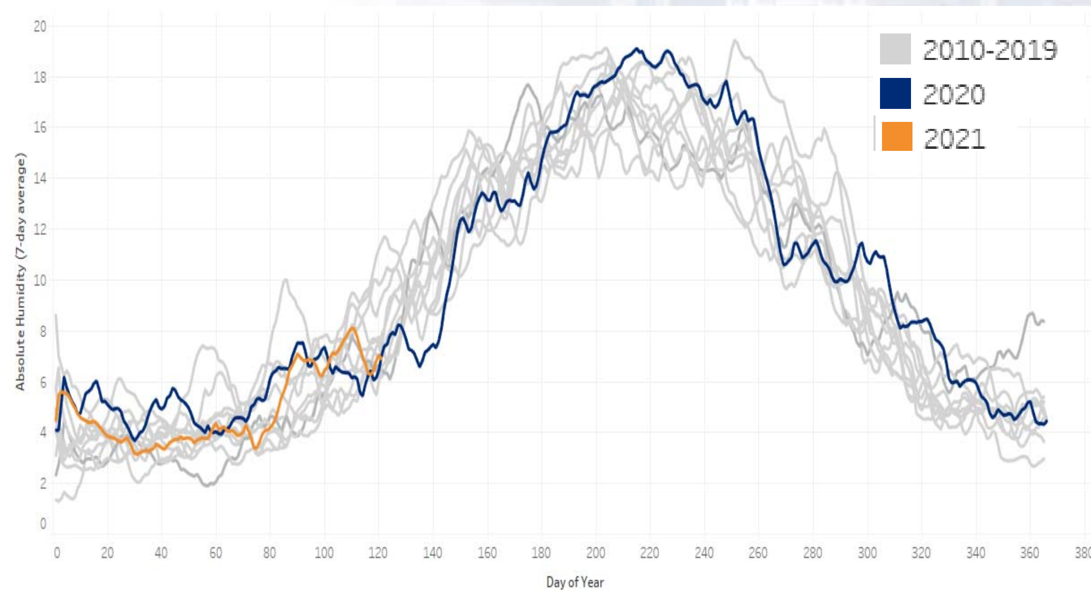


Data from Guinea Pigs, suggests that transmission increases as humidity falls



Viruses may also survive longer in lower humidity conditions

Humidity has been shown to be related to transmission and infectivity in influenza. Evidence for COVID-19 is still emerging, but all respiratory viruses decrease in the summer when humidity increases and increase again when humidity falls in the winter



Humidity data in 2020/1 similar to prior years

Absolute Humidity and the Seasonal Onset of Influenza in the Continental United States
Jeffrey Shaman , Virginia E. Pitzer, Cécile Viboud, Bryan T. Grenfell, Marc Lipsitch
https://doi.org/10.1371/journal.pbio.1000316

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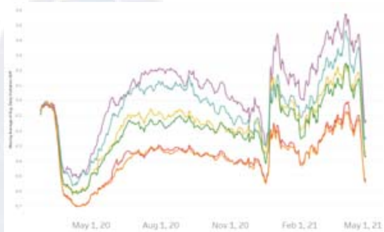
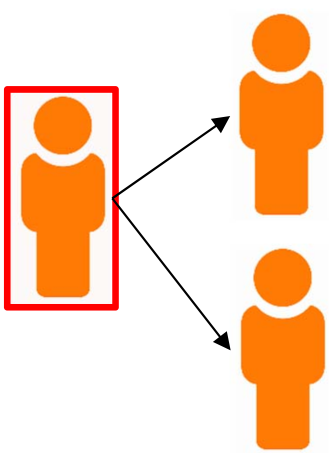
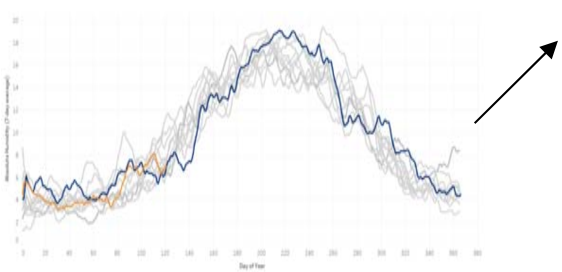
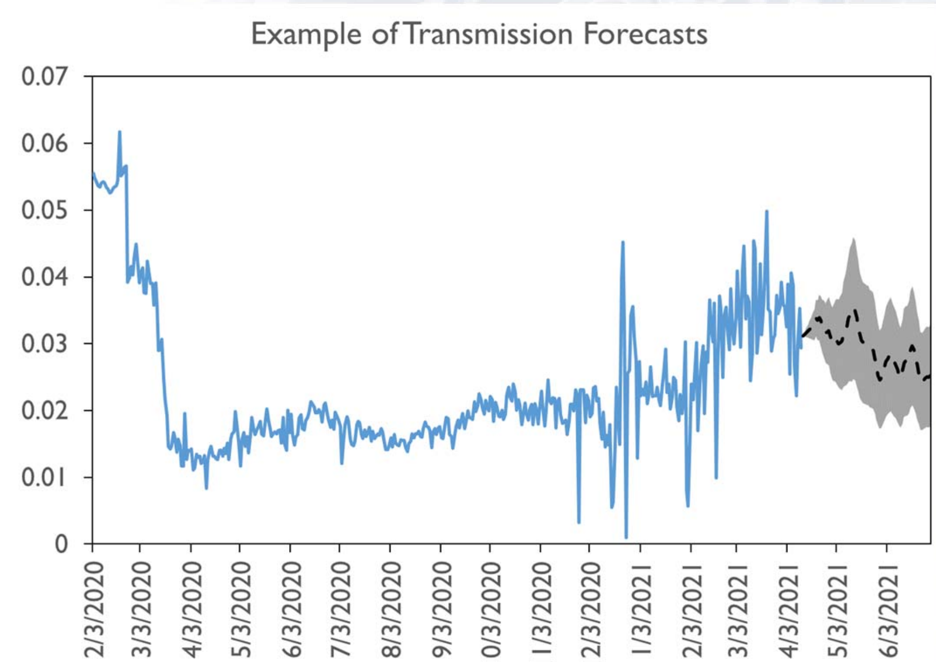
Combining Patient Movement and Humidity Data

Combining patient movement and humidity we derive an estimate of the transmission rate fit to the epidemic to this point and then forecast how this is likely to change based on future weather and behavior patterns







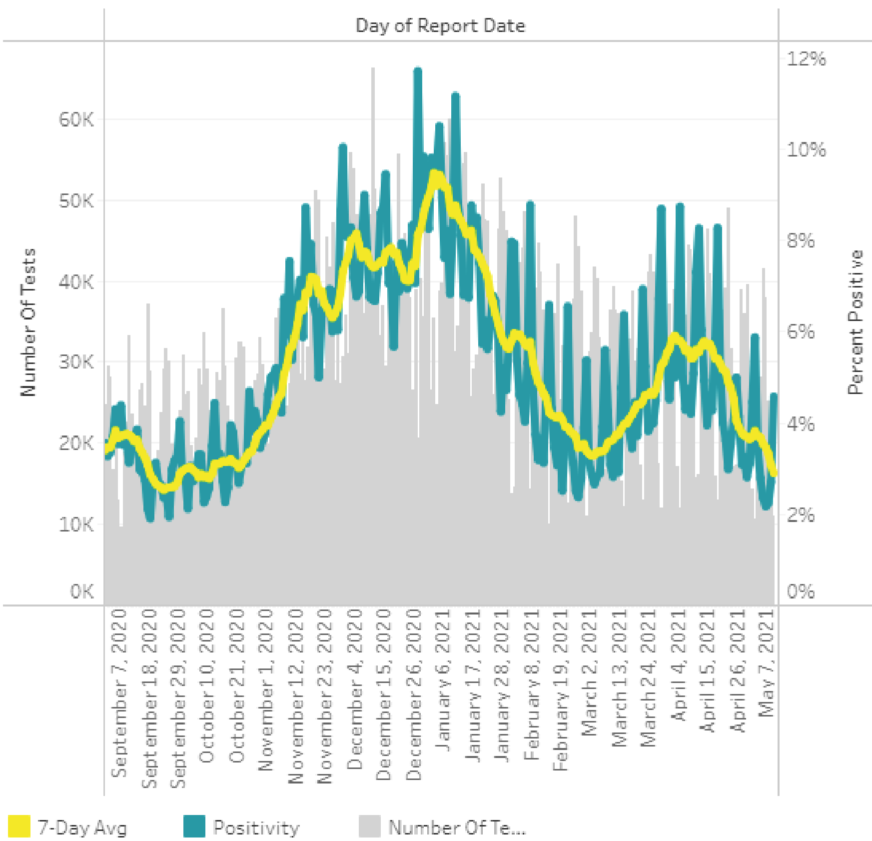


Current Data in Maryland

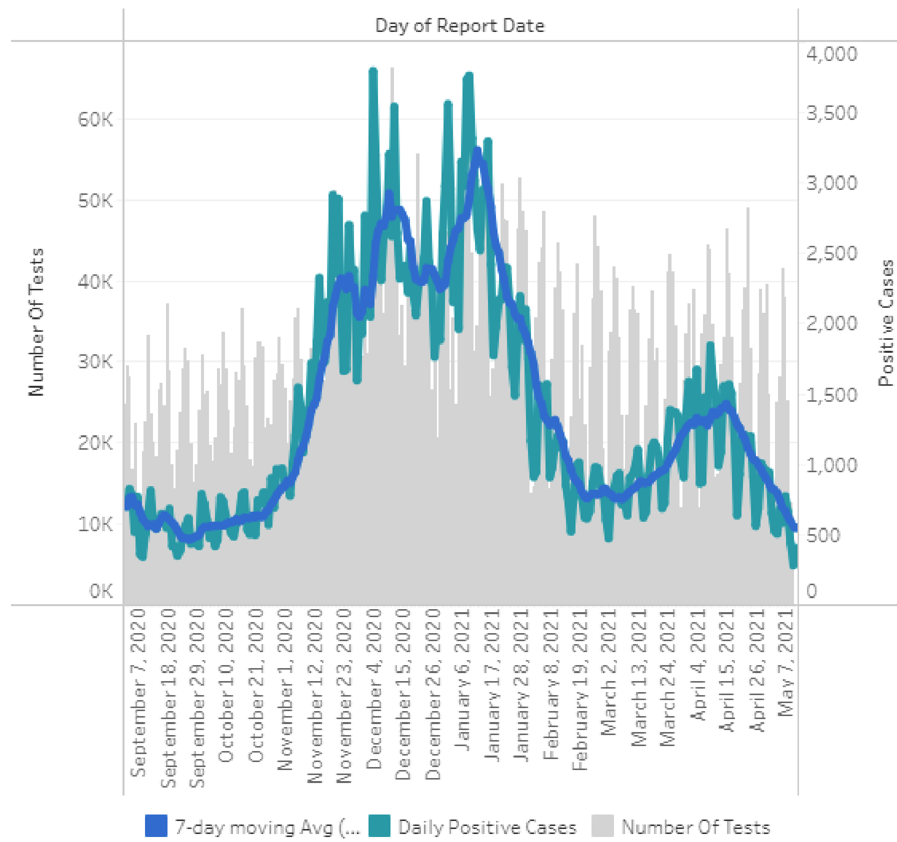
Cases have continued to decline, now at ~11.5 cases per 100K. Positivity has plateaued a bit, but that may be because testing has fallen.

5/12 Statewide

MD Positivity Rate



MD Cases



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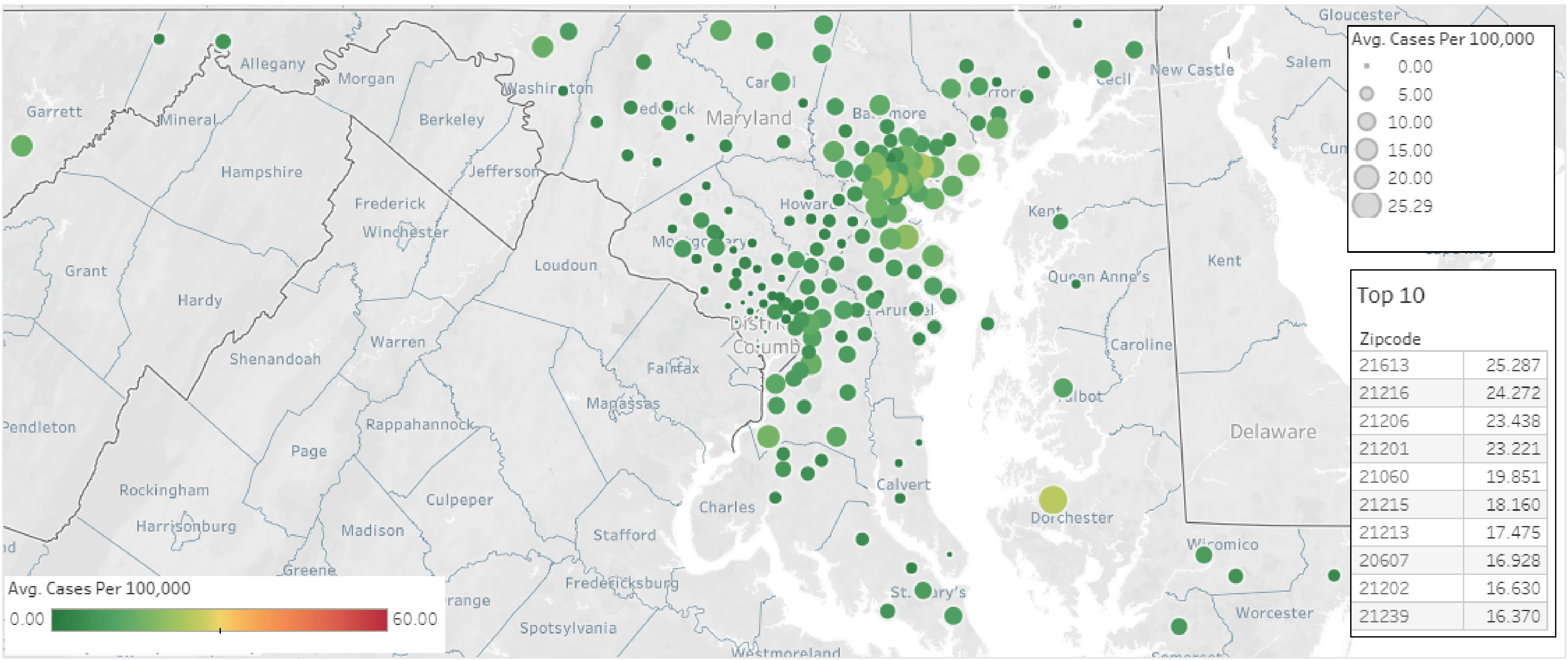
Case Geography

Zip codes with high case rates continued to be concentrated in Baltimore City/County region though rates have fallen recently.

Average cases per 100,000 residents last seven days by Zip code, 5/5/2021 to 5/12/2021

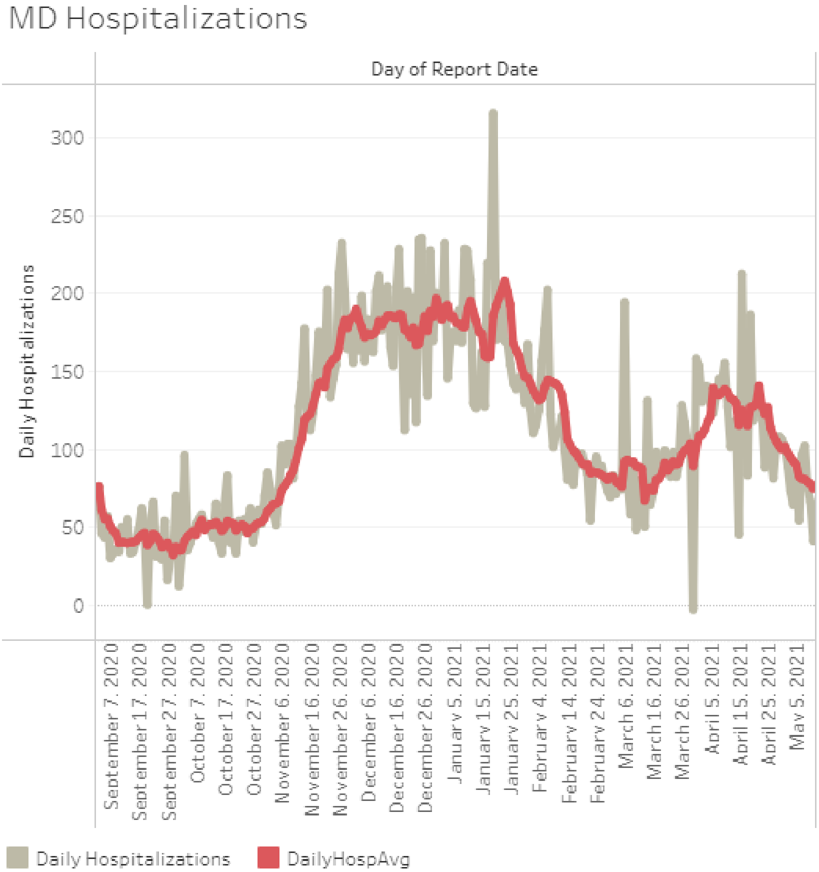


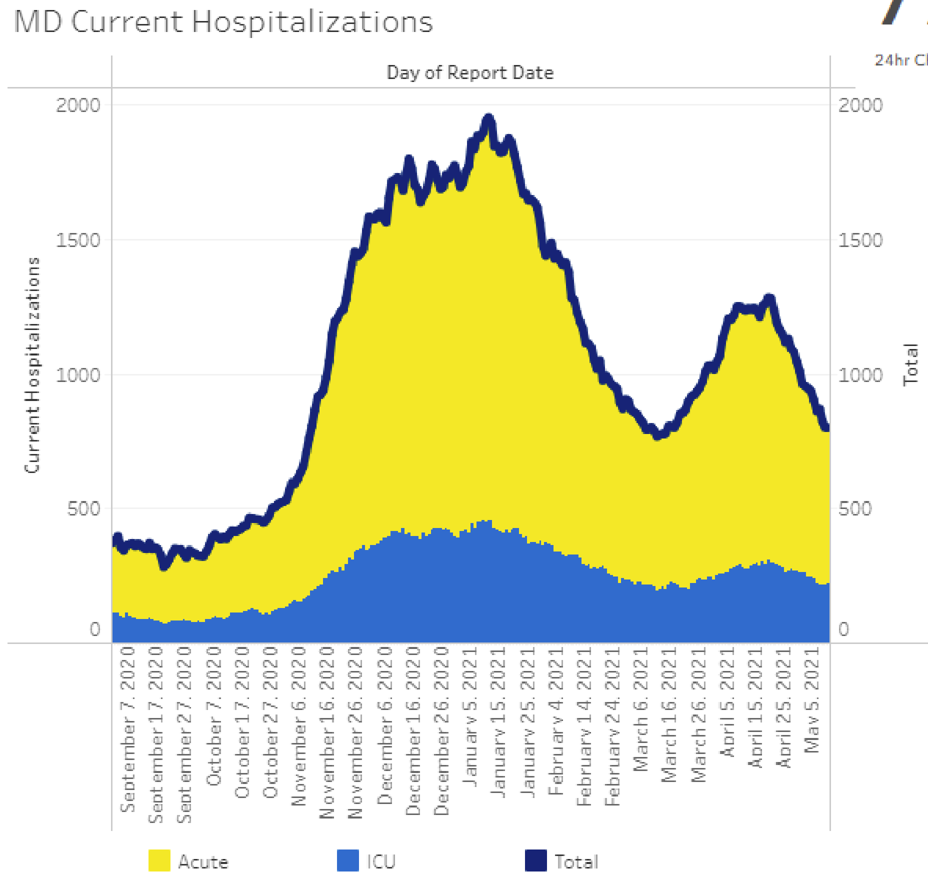
* Excludes zip codes with <10,000 residents

Maryland Hospitalization Numbers

Statewide, daily hospitalizations and occupancy have fallen rapidly as expected.

Confirmed Cases
454,271
24hr Change: +471





Currently Hospitalized
770
24hr Change: -29

As noted two weeks ago, the falling case rates and positivity rates predicted the fall in hospitalizations. Given continued declines in these metrics, hospitalization numbers should continue to fall

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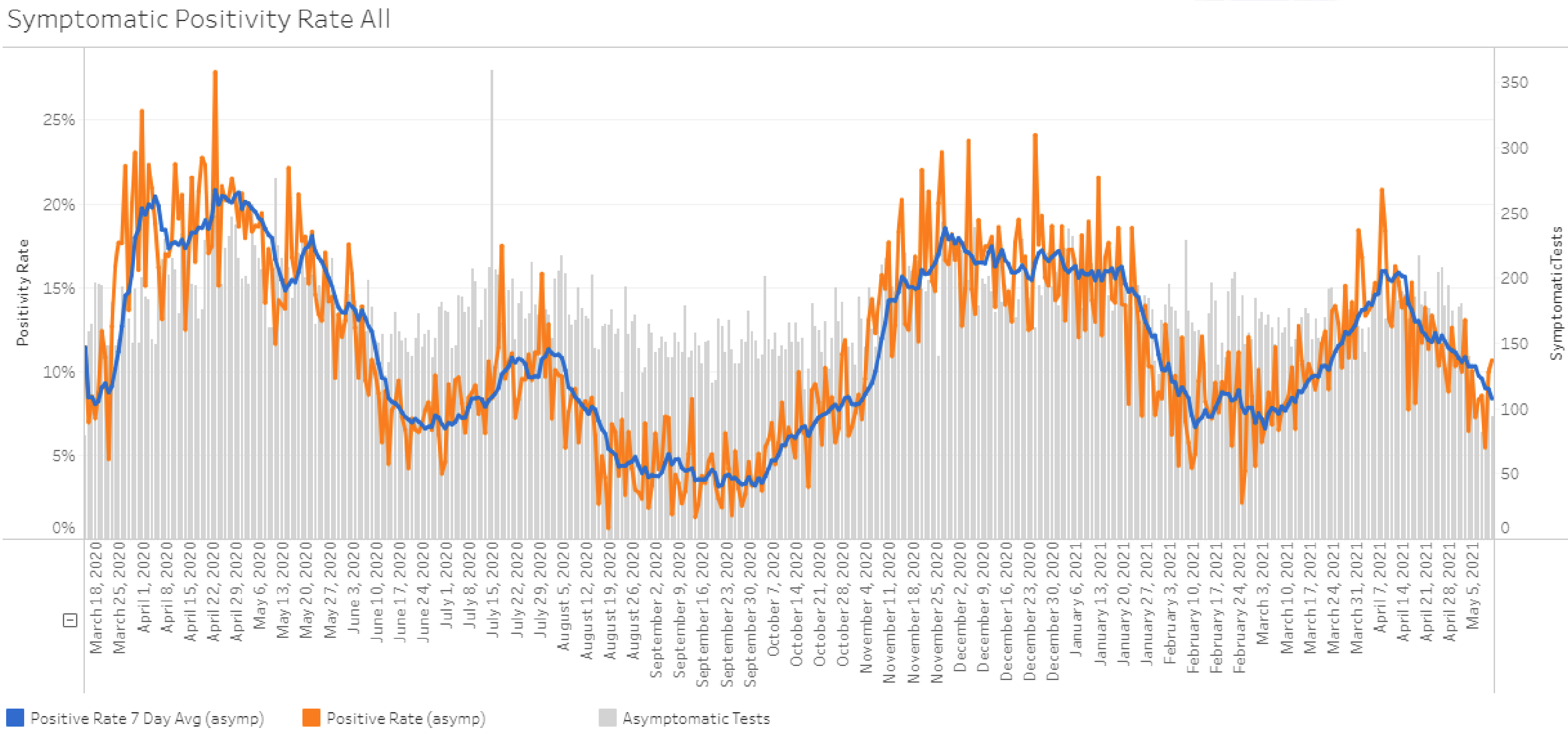
Current Data at JHHS:

Symptomatic Positivity Rate



The symptomatic rate was a leading indicator of the Fall surge, and the rising rates in March were again the leading indicator of a surge in cases and hospitalizations. This continues to fall, suggesting there is limited risk of rising cases/hospitalizations in the near term, and that cases and hospitalizations should continue to fall in the next few weeks.

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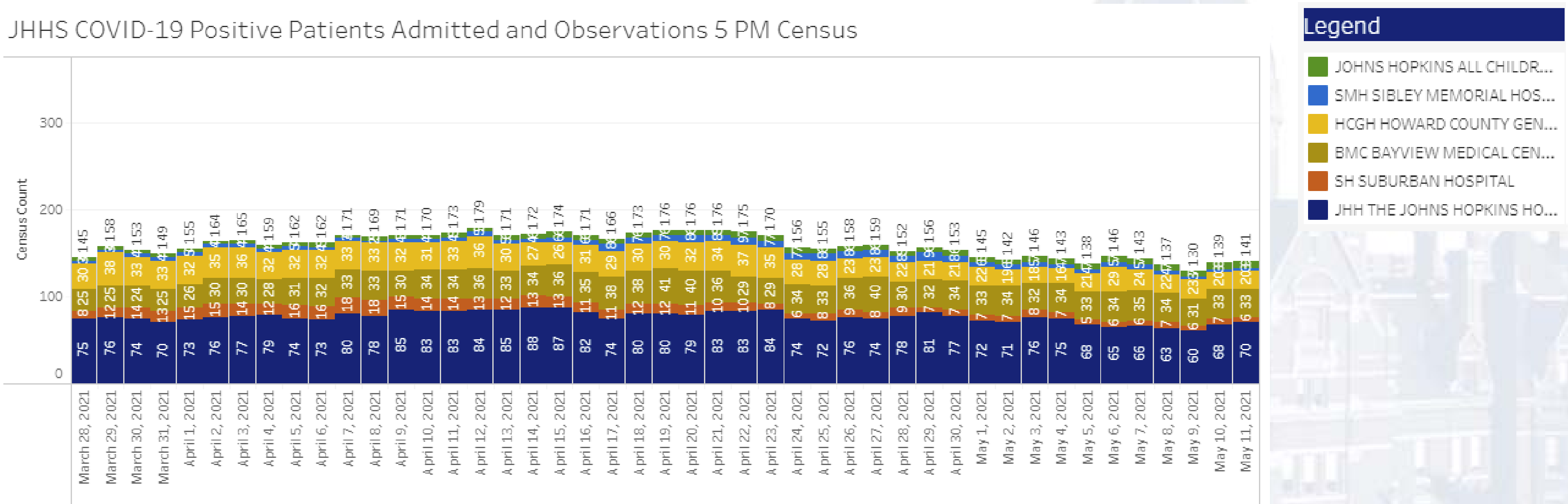
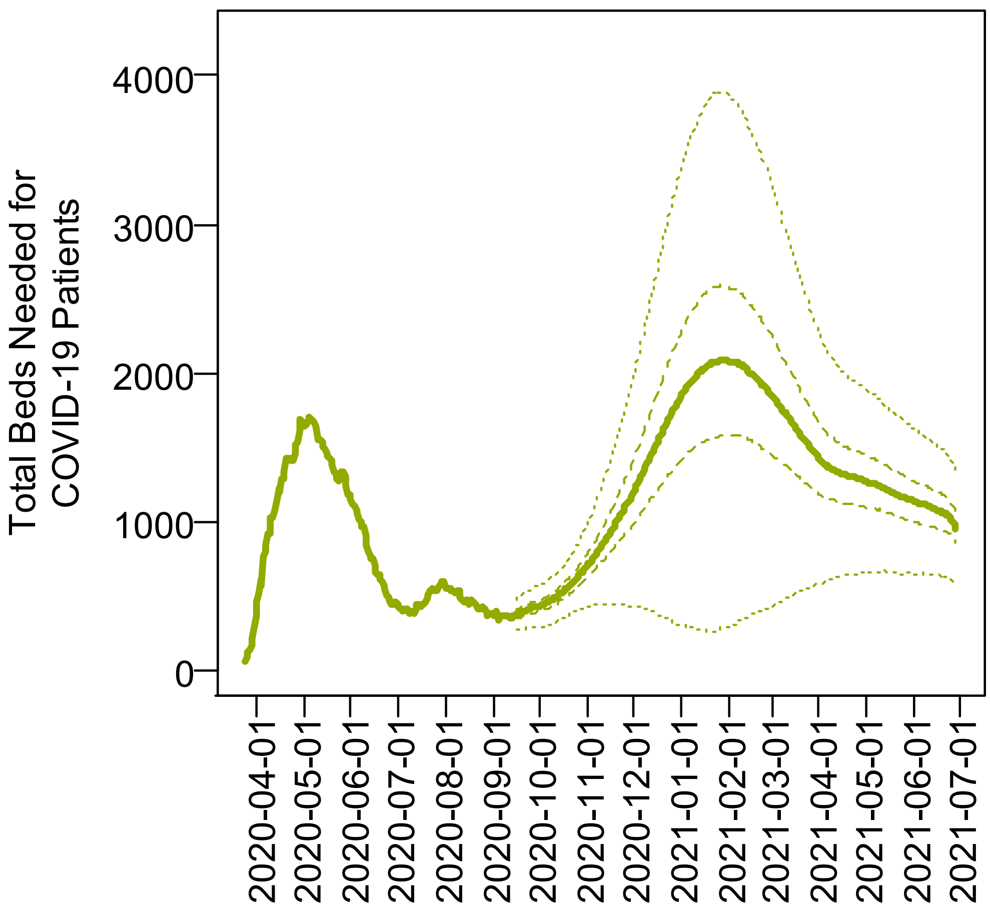
JHHS Hospital Data

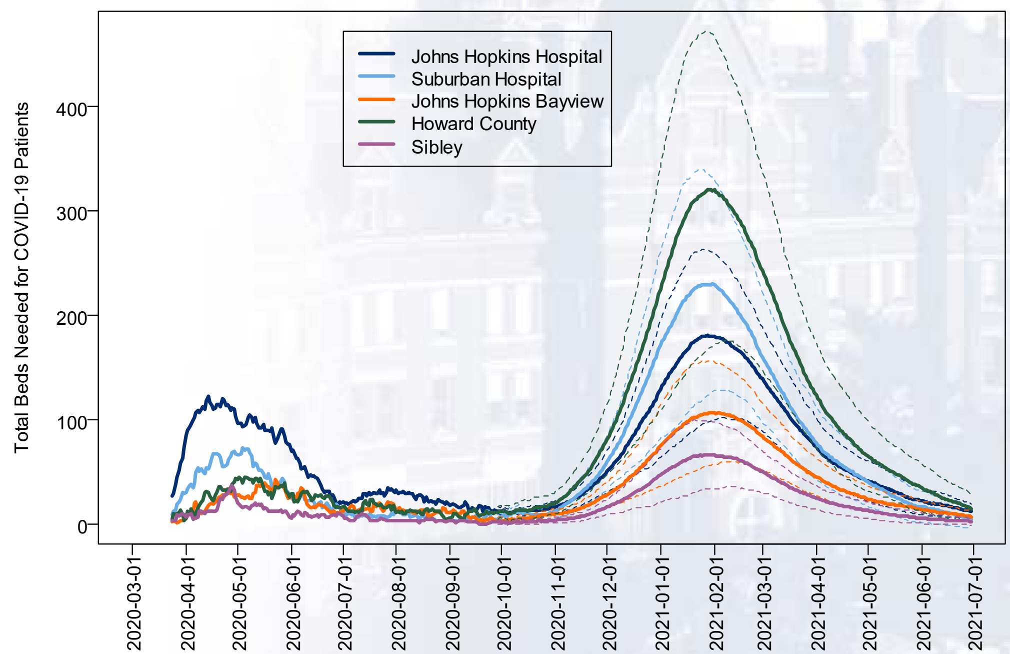


Given that the majority of cases are in the City, the COVID+ population has persisted at JHH, but overall appears to be starting to fall across the system.

Prior Forecasts

Estimates from August forecast the peak, but did not account for vaccination





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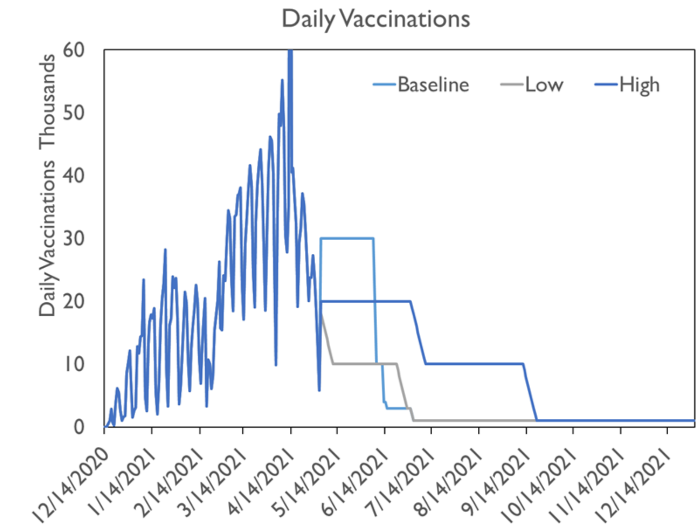
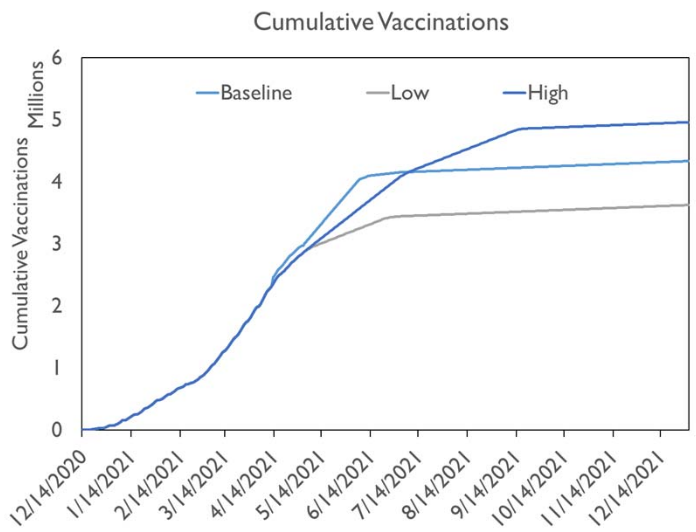
Model Inputs: Vaccination





We assume that a low, baseline, and high percentage of eligible individuals (>12 should be approved soon) refuse to get vaccinated by the end of June.

In addition we assess different vaccination paces in the short term. The big difference though is the total percentage of people vaccinated by September, which is assumed to range from a low of 60% to a high of 83%

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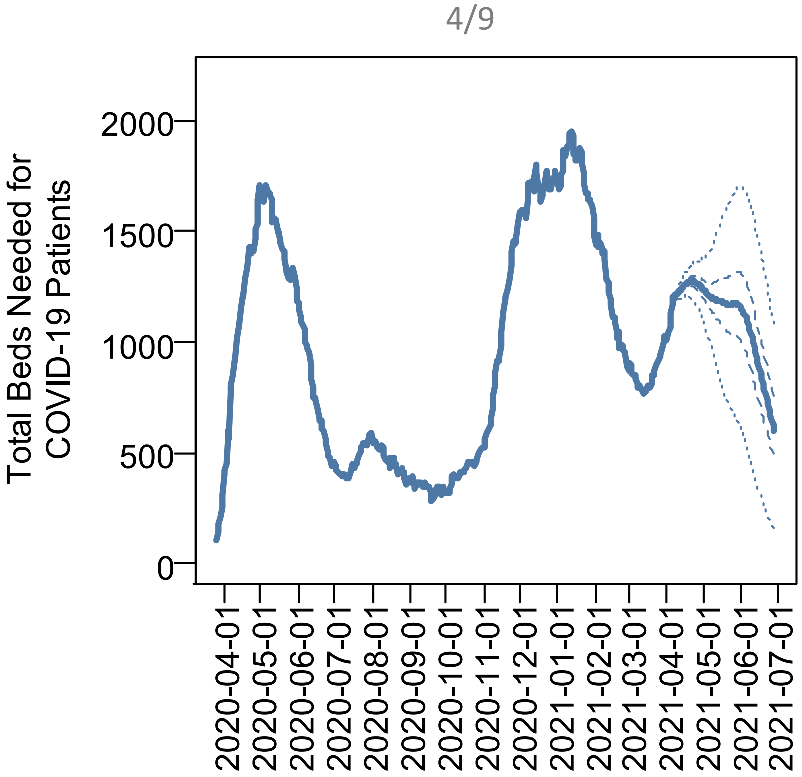
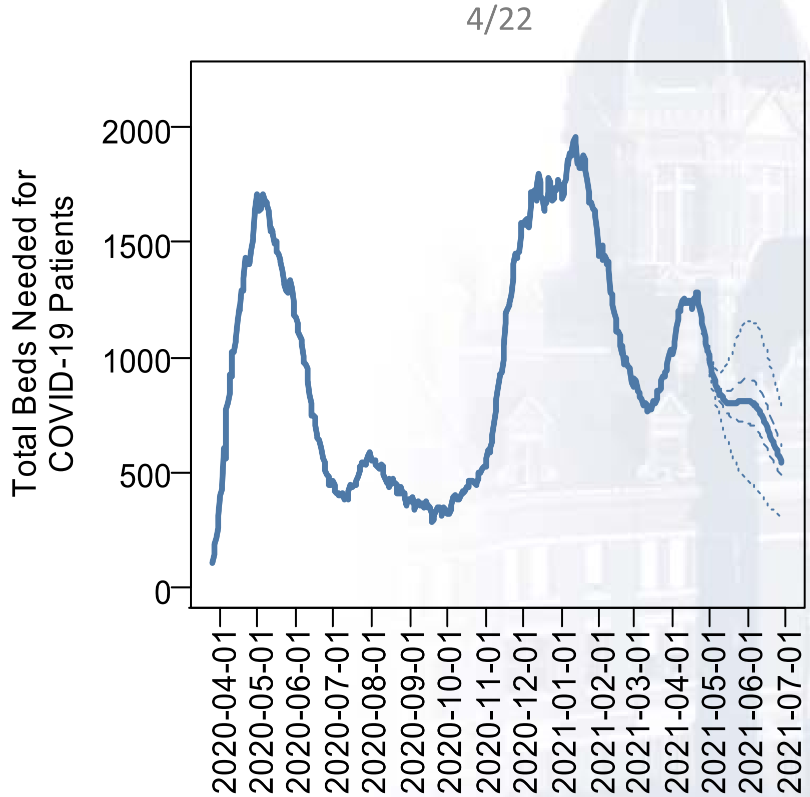
Prior Model Results

Reference from prior projections





For the last month the data has accorded with the most optimistic scenarios, with hospitalizations falling below 1000 by early May. Uncertainty around the impact of reopening as well as how quickly absolute humidity may increase (as spring in Baltimore can be variable) led to a more conservative medium term estimate, but all signs pointed toward dramatic falloffs, either optimistically by late May or with a minor surge as society re-opened, later in June.

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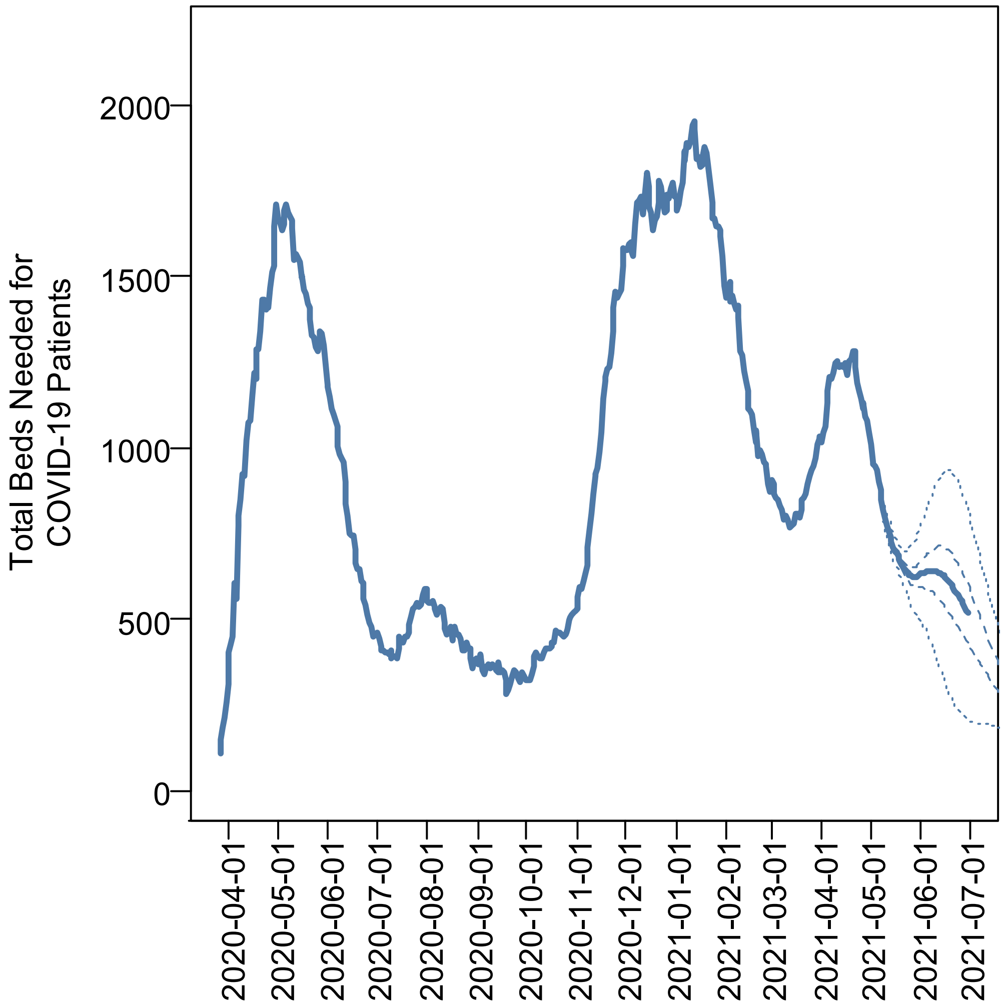
Model Results – 5/6/2021



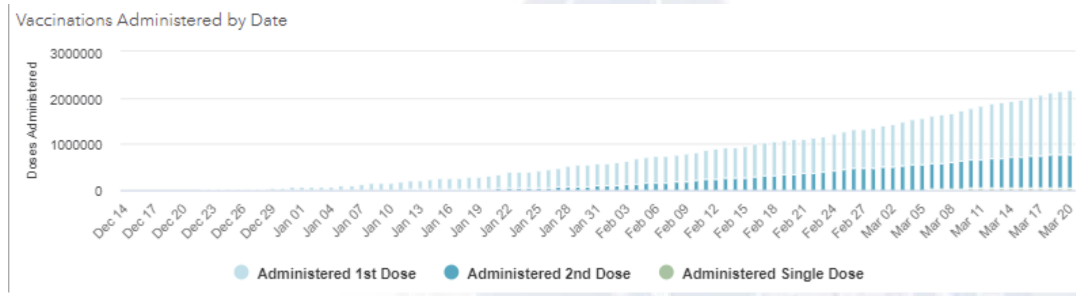
Current scenario projections are all similar in the short-term (so only a single scenario is shown). Faster/Slower reopening has only relatively minor impacts on the projected epidemic values between now and the end of June. The vast majority of the uncertainty relates to humidity expectations and uncertainty around the underlying transmission rate.

The most optimistic of the runs has hospitalizations falling below 500 by early June while the more moderate result suggests the end of June.

Herd Immunity?

As of 5/6/21 there have been 451,267 confirmed cases in Maryland. Assuming that testing is only capturing ~50% of cases (and slightly higher in March-May) that results in an estimated 961,514 cases or ~16% of population.

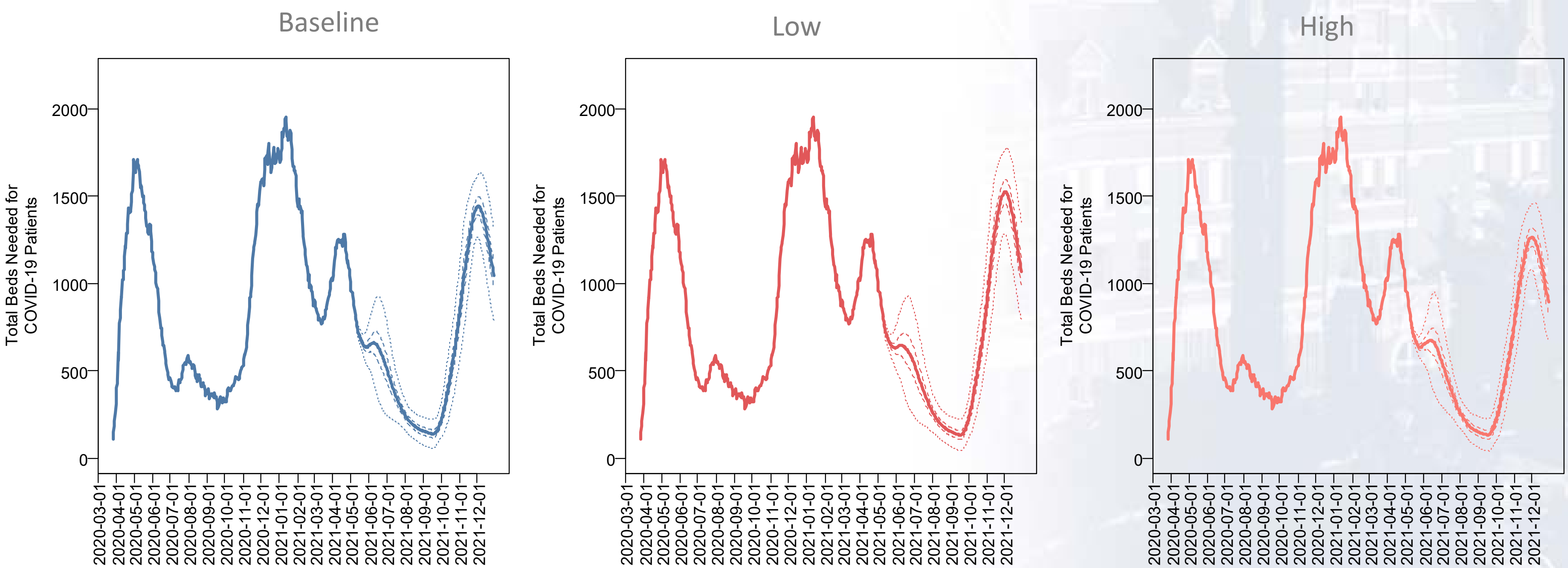
Current reported serology for the state is 16.8% (36,005 of 213,764)



- Approximately 3,125,612 with at least some protection (first shot).
- Depending on the percentage of individuals that have been both infected and vaccinated, total state immunity level is between 50-60%

Forecasts into the Fall/Winter

Can the virus come back?



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