Projections for the Infection Rate of SARS-CoV-2 in the City of Avalon

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In this brief, I present three possible projections for the infection rate that an outbreak of SARS-CoV-2 can take, in both cases per week and total caseload, given the possibility that a single infected, asymptomatic individual were to arrive in Avalon. The three possible scenarios are as follow: if an infected person were to arrive in Avalon and unknowingly spreads the virus, what are the projections for the infection rate if there were 1) no social distancing measures in place, 2) if restrictions were lifted, then social distancing measures were put back in place in response to a second wave of infections, and 3) if social distancing measures were kept in place as is currently defined by LA County. These projections are not time-dependent and can therefore be used to project the trajectory of cases when patient zero ($\mathbf{P_o}$) were to arrive on the island at time zero ($\mathbf{T_0}$) and what the infection rate would look like by these three policies. This brief is intended to help inform the City of Avalon and policymakers of the implications and repercussions of each policy action.

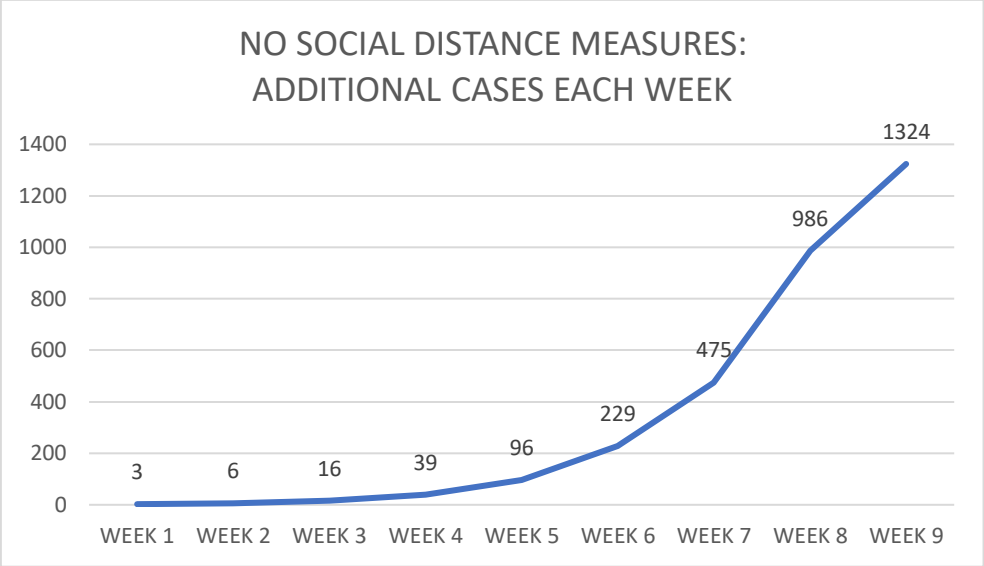
Scenario 1

The following projections highlight the number of infected resident per week, total number of cases, number of hospitalized individuals, and number of deaths we would see if an outbreak were to occur in the city of Avalon while no social distancing measures were in place. This is to say, if we were to let an outbreak spread through the city unchecked, this is the number of cases and deaths were would see in a nine week period.

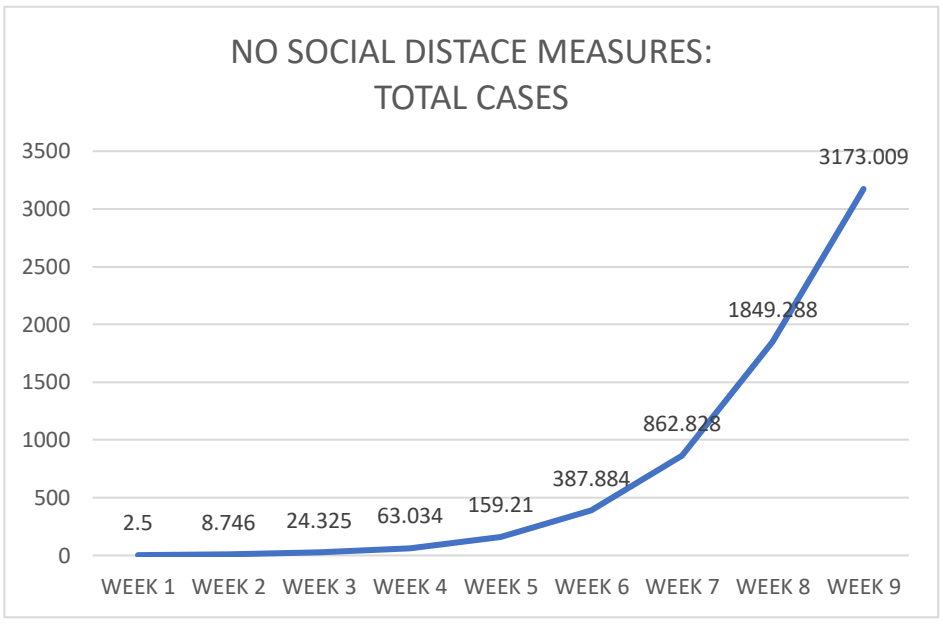
Using data from the American Community Survey 5-year estimates, the population of the City of Avalon was approximately 3,992 in the year 2018. It is well documented that the virus has an *average* infection rate ($\mathbf{R_0}$) of approximately 2.2-2.7, with a reproduction rate of approximately 6-7 days. This means that one person can infect 2.2-2.7 individuals per week. Given that an individual can be asymptomatic for 14 days, this creates the scenario where a single individuals can infect others unknowingly for up to two weeks. For the sake of this analysis, I will stick to more conservative estimate (in-line with other public health projects, like the IHME, LA County, and CDC models) and assume that each infected individual has approximately one week to infect others while they are in the incubation period and asymptomatic. For this analysis, each individual who becomes infected has the chance of infecting approximately 2.5 others. The first week, a single individual will arrive and infect 2.5 others. The following week each of those newly-infected individuals will infect 2.5 more individuals, each. As this cycle continues, the population of those infected increases exponentially each passing week. Given the small size of the island population, each week the virus has fewer and fewer hosts to infect, which decreases the infection rate of by

$$\mathbf{R = SR_0}$$

where **R** is the current infection rate, $\mathbf{R_0}$ is the original infection rate, and **S** is the percent of the population that has not been infected. As the population that has yet to be infected decreases, the infection rate slowly and linearly decreases.



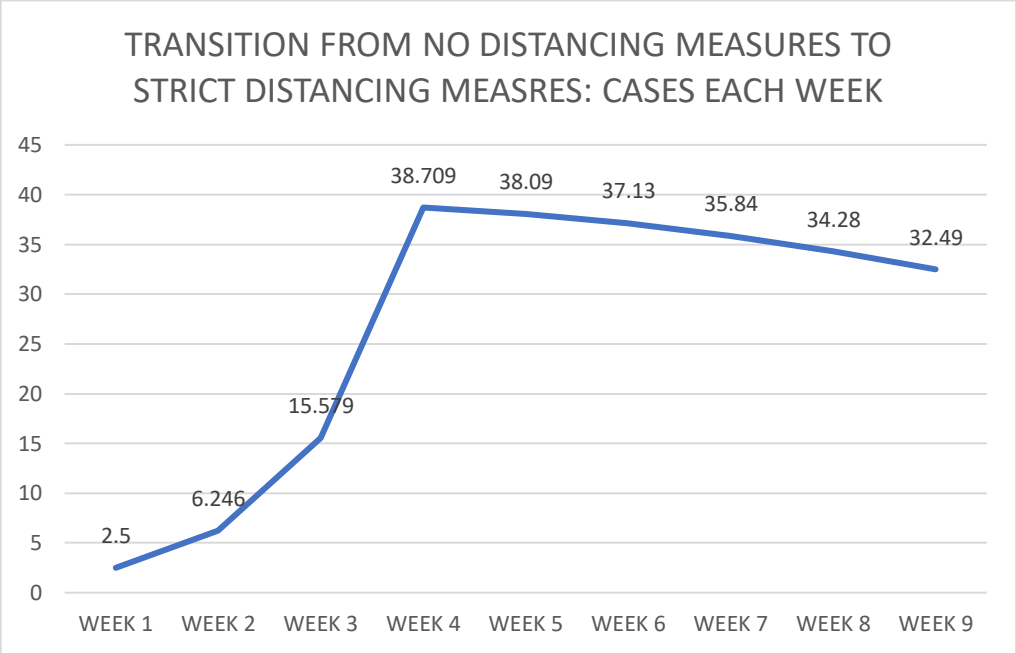
But, unfortunately, this slight decrease of the infection rate cannot offset the exponential growth of cases. By week nine, the new cases each week will have grown to 1,324. By the time we reach this point, the vast majority of the islands population will have been infected (as shown below by the total number of cases by week). By week nine, 3,172 of our 3,992 residents would be infected. We would reach heard immunity by this time, and the cases per week would fall exponentially because less than 21% of the population is at risk of infection and 79% of residents would be sick or recovering from the virus.



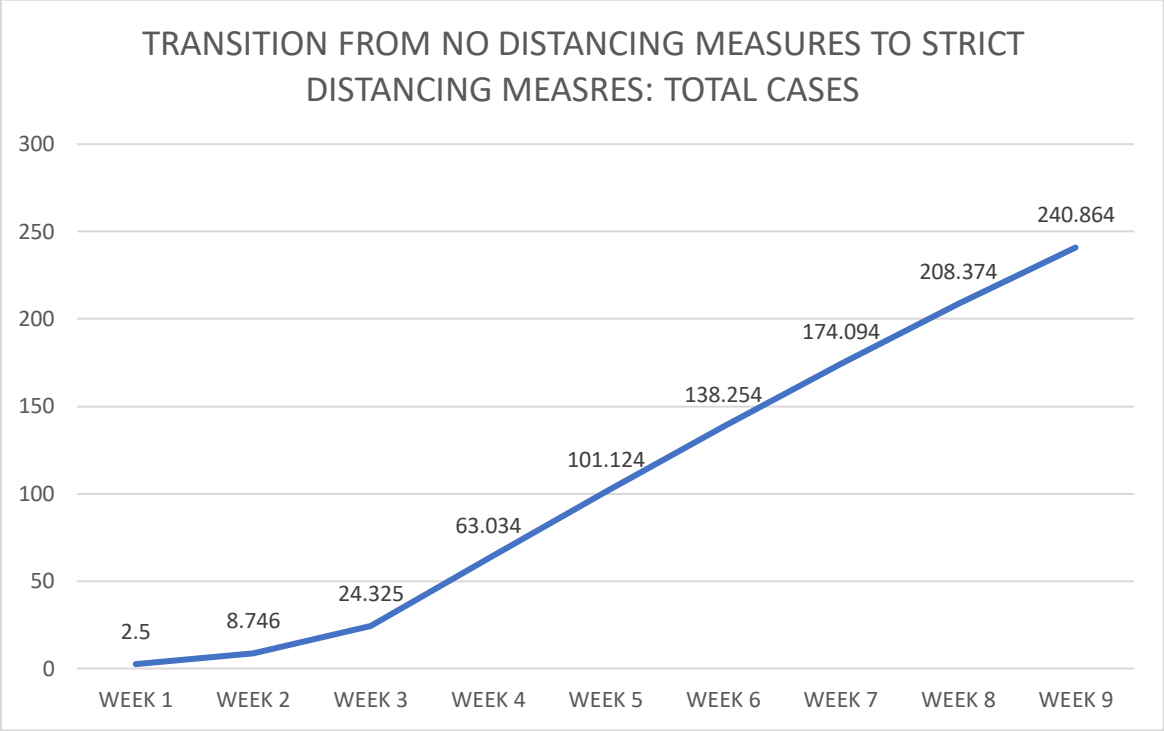
Given this (hopefully) unlikely scenario, by week nine approximately 481 residents would be hospitalized and 151.75 residents would be overcome by the virus. These numbers were estimated by using LA county's latest estimates of the percent of those infected who are hospitalized and those percent of those who will pass way—which is 15.17% and 4.7%, respectively. This would vastly overpower our local hospital's capacity and would overwhelm frontline workers. This immense loss would create extreme pressure on the systems that our residents rely on—like the Medical Center, Vons, the police force, and the fire department.

Scenario Two

The following projections highlight the number of infected resident per week, total number of cases, number of hospitalized individuals, and number of deaths we would see if an outbreak were to occur in the city of Avalon while no social distancing measures were in place and then the city were to swiftly enact social distancing measures in response to a small outbreak. This is to say, if an outbreak were to occur, it would take only one week for a single, asymptomatic individual to infect approximately 2.5 island residents. In the following week, those two individuals would infect 2.5 more, each. By the third week, these original infected residents would be exhibiting symptoms and hospital employees would update this increase in cases on the hospital's webpage. If the city of Avalon were to close off the island to the outside world within two weeks of those "2.5" residents becoming infected, the following is the projected infection rate of the virus.



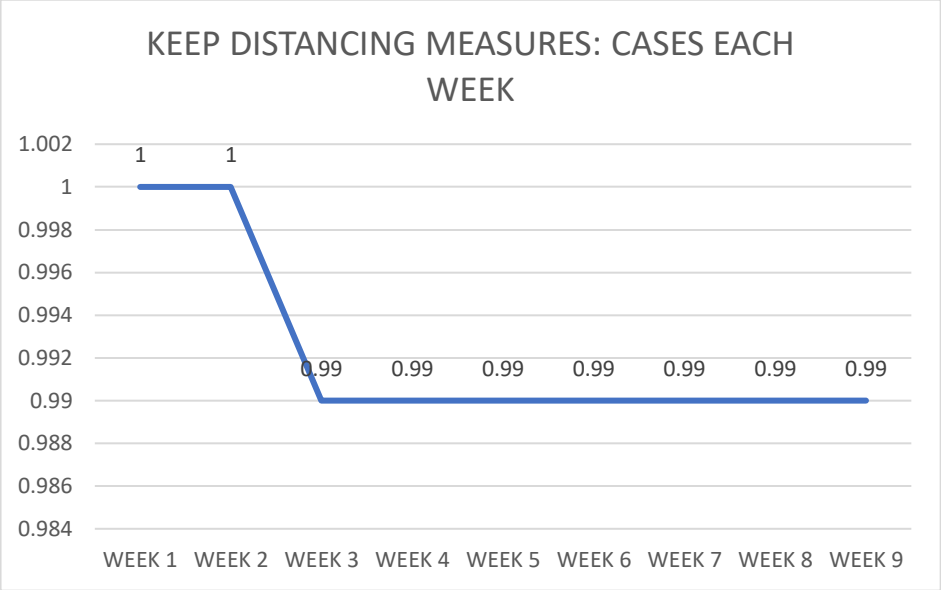
By week four, the social distancing measures would take effect and reduce the infection rate by approximately 60%. This sharp decrease would result in the phenomenon known as “flattening the curve,” which would change the infection rate from an exponential to a linear path. Although this plateau sharply stabilizes the number of cases per week, the total number of cases would still rise linearly (as seen below). By each week, an additional 30-40 individuals will become sick. By the end of the nine week period, 241 of our 3,992 residents would fall ill.



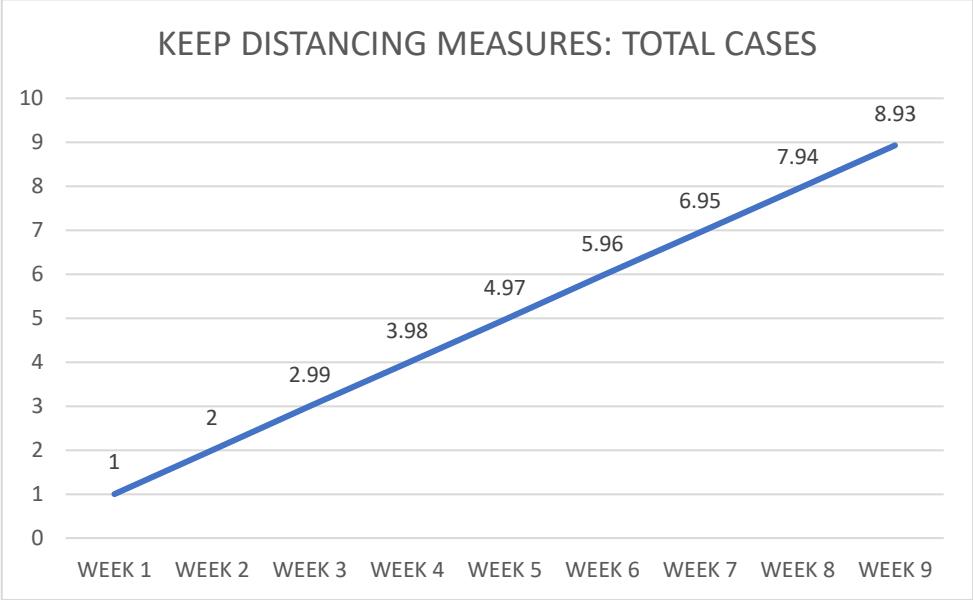
The momentum of the initial infection rate would keep our numbers rising, which is the trend many cities in the US saw as states began shutting down their states in late February and early March. By the end of week nine, approximately 38 resident would become hospitalized and 11.3 individuals would die. Although small in comparison to the previous scenario where the virus is left unchecked, the hospital would still become overwhelmed by week three and the city’s essential workers would be at risk of infection.

Scenario 3

The following projections highlight the number of infected resident per week, total number of cases, number of hospitalized individuals, and number of deaths we would see if an outbreak were to occur in the city of Avalon while our current social distancing measures were in place. This is to say, if an outbreak were to occur within the next month by a single traveler, this is the trend we should expect.



It is well documented by LA County public health officials (and by public health experts around the world) that social distancing measures are a very effective tool against fighting the spread of SARS-CoV-2. It is estimated that social distancing, in the current form that we know of it here in LA County, and mask-use can reduce the infection rate by up to 60%. Taking this into account, if a single, asymptomatic individual were to arrive in Avalon, that person would only infect one other person. Each week, infected individuals would only infect one other person, keeping the cases per week stable at 1 resident.

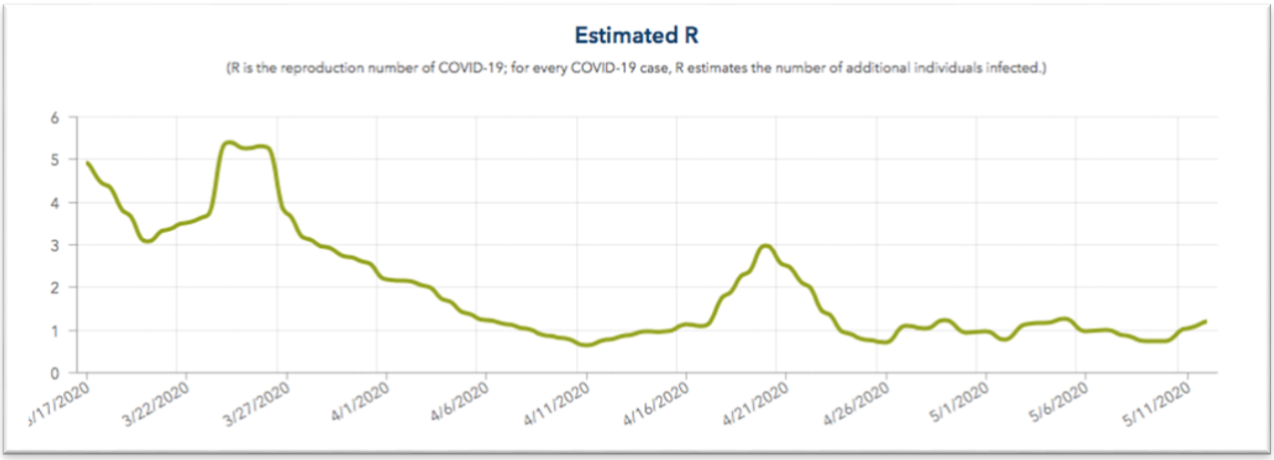


By the end of week nine, approximately 9 residents would fall ill. 1 resident would require hospitalization, and approximately 0 would pass away.

Evidence from LA County

These results were reached using the assumption that 1) the $\mathbf{R_0}$ value of the initial spread of the unchecked virus is 2.5, 2) the effects of social distancing would yield a **60% reduction** in the infection rate, and 3) that this this reduction would be realized because ALL island residents and tourists would be following LA County Safer-at-home orders at a **100% participation rate**.

Evidence from longitudinal data analysis from the University of Pennsylvania suggest that these estimates are conservative. Below is the realized **R** value for LA County for the last two months:



As seen in the graph, the **R** value varies significantly across time. In mid-March, the estimated **R** varies from 3-5.5, which is much larger in magnitude than the assumed 2.5 measure of the $\mathbf{R_0}$ value used in this brief. As the state of California began implementing tougher and tougher restrictions, the **R** value began falling. Only from mid- to late-April did LA County see another surge in the infection rate, which happened to coincide with a 1) increase in testing in the area and 2) an indication from Gov. Newsom that California was on a path to re-opening up on 4/14/2020.

Similar to what is seen in scenario 3, LA County has seen an infection rate (**R**) hovering around 1 for the last month in response to social distancing orders and other public health orders. This has resulted in a stabilization in cases per week in the area and has given the hospital system time to properly respond, in terms of hospital personnel, ICU beds, and other resources.

Additionally, we would assume that, realistically, not all island resident would follow social distancing and public health orders perfectly, so the effect of this policy would be somewhere below our idealized 60% estimate.

Discussion

The analysis I presented is for a closed system, which means that this is the path the infection rate would take **if a single asymptomatic individual were to arrive in Avalon and infect another individual unknowingly**. One person. This doesn't account for multiple infected individuals entering our city, which would increase the initial number of infected (and is what we would realistically see) and raise the initial $\mathbf{R_0}$ value (estimated to be 2.5). This would create a momentum in the number of infected which would result in a few additional cases per week, and many more total cases, regardless of which of the three scenarios we are in. Tourism is essential to the life of our island economy, but it will also vastly increase the number of cases on the island if proper screening measures and strict social distancing policies are not in place. Business owners and workers will have to come up with innovative strategies to combat the spread of the virus when we do inevitably (and hopefully slowly and methodically) open back up to the outside world. Measures like requiring masks, 6 feet of distance between patrons, and temperature checks for those riding the express (no-contact temperature readers on Amazon start at $68) can help slow the rate of infection.

If we keep our current mitigation measures and remain closed to the outside world (which has been our strategy for the last couple months and will most probably continue for a few more), we could remain in the unique situation we are in now: no present cases and a very low probability of an infected person(s) arriving and resulting in an outbreak. The first outbreak that occurred was the best possible scenario our town could've experienced. Their common sense and complete isolation from the rest of the community stopped the outbreak dead in its tracks. Perhaps next time we will not be so luckily and the person will interact with one or two people before noticing any symptoms. If that is the case, I hope city officials and policymakers take into consideration the findings of this brief to help inform our future strategies.

Realistically, the path of the infection rate will fall somewhere between scenario 1 and scenario 2 when we open back up to the world before a vaccine is readily available (which will take many months, if not years). I would expect to see multiple, small-scaled outbreaks coming in waves as we ease up restrictions. Additionally, the conservative estimates (like my assumption that ALL residents would follow social distancing measures which would result in a 60% reduction in the infection rate) I noted throughout the brief could result in an underestimate in the number of total cases we would experience in any given scenario. The island population has many young, health residents; but we also have a slightly larger elderly population than the rest of the United States, which could result in more hospitalizations and deaths. Additionally, we see that this virus is disproportionately impacting Hispanic residents; La County estimates that, among deaths, those who identify as Hispanic/Latino die at higher rates than their white counterparts—at a ratio of 10:6, respectively.

I hope, if nothing else, this analysis will allow those in power to grapple with the inevitable effects their choices will cause on island residents and their loved ones. Currently, it is not a matter of if, but when an outbreak will occur. We cannot fool ourselves into thinking that we will be spared from this virus for the next one to two years (if not more). We need policy

measures in place to mitigate the spread of this infection to provide healthcare personnel more time to properly and effectively control an outbreak. We will only have a week or two to change the exponential surge in cases to a linear, more stable increase.

Here is some relevant information on my data and methods if you would like to understand how I arrived at my results. Also reach out to me at calvarezcaraveo@urban.org for inquiries and for additional projections and scenarios.

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