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Comparative Analysis of COVID-19 Prevalence in Coastal Versus Inland Populations of North Carolina

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Statement of Significance

This study aimed to assess geographic trends in COVID-19 cases and deaths across North Carolina (NC). Our study found that population-adjusted COVID-19 cases and deaths were lower in the coastal region of NC during the study period, independent of demographic composition and population-density within the region. This represents an interesting correlational finding regarding COVID-19 transmission that deserves further investigation. One possible explanation for this finding is differing environmental conditions between the inland and coastal region.

Background: Existing literature has explored the geographic and spatial variations in COVID-19 prevalence. Some studies suggest that the transmission and total prevalence of COVID-19 is diminished in areas with low levels of air pollution, high humidity, and more sunlight. The coastal regions of NC are more likely to have these environmental characteristics than the inland regions. Given these trends, we analyzed and compared population-adjusted COVID-19 case and death counts in the coastal and inland regions of NC.

Methods: Time series data displaying the prevalence of population adjusted COVID-19 case and death counts from 15 March 2020 to 15 August 2020 were plotted for a variety of pre-established North Carolina regional and population density classifications. A local regression analysis was computed to further assess the observed relationships. Basic demographic characteristics were also compared for the coastal versus inland region.

Results: There were fewer population-adjusted COVID-19 cases and deaths in the coastal region (889 cases/100,000; 12.5 deaths/100,000) than in the inland region (1426 cases/100,000; 23.5 deaths/100,000) at the endpoint of this study. This trend is observed even when controlling for population density, and in the absence of significant demographic differences between the two regions.

Conclusions: The prevalence of population-adjusted COVID-19 cases and deaths was lower in coastal versus inland NC during this study period. Given that the NC coastal region is associated with lower pollution, higher humidity, and more exposure to sunlight, our findings suggest that more research should be done to explore the correlation between environmental variables and the spread of COVID-19.

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Supplemental content

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SARS-CoV-2 is a viral pathogen that clinically manifests as COVID-19. Beginning in early 2020, SARS-CoV-2 spread throughout the world, creating a global pandemic that has caused significant societal upheaval. In 2020 alone, COVID-19 caused approximately 375,000 deaths in the United States.[1] Many governments used non-pharmaceutical interventions (NPIs), such as mandatory stay-at-home orders and social distancing protocols, to reduce the spread of COVID-19. While NPIs did help mitigate the spread of the disease,[2] numerous studies have highlighted disparities in COVID-19 prevalence and severity that correlate with ethnic, regional and policy differences on a local, national, and global scale.[3–8] This study seeks to contribute to that body of literature by highlighting differences in COVID-19 prevalence across counties in the U.S. state of North Carolina (NC).

The growing number of papers reporting on geographic and spatial variations in COVID-19 prevalence are particularly salient to the aims of this study. In the case of airborne infectious diseases, spatial arrangements are believed to have a large impact on disease prevalence and transmission. As such, other studies have investigated the impact of churchgoing, the presence of superstores, and the implementation of movement restrictions on the spread of COVID-19.[69–11] In these works, space is linked with human behavior. In other words, people in different areas are subjected to different cultural and economic pressures. These pressures encourage people to engage in behaviors that increase or decrease the likelihood of contracting the virus.

In contrast, other researchers have linked space and disease transmission with climate and atmospheric conditions. Studies show that a variety of environmental conditions can impact the transmission of viral pathogens, such as SARS-CoV-2.[12] For example, a recent literature review concluded that higher levels of air pollution are associated with greater transmission of respiratory viruses and increased severity of active infections.[13] Other researchers found correlations between SARS-CoV-2 transmission and variables such as temperature, humidity, and air quality.[14–17] These findings are consistent with studies that have directly observed evidence of SARS-CoV-2 deactivation in the presence of sufficient solar radiation.[18,19] .

Considering the wide array of factors that can lead to regional disparities in COVID-19 prevalence, we sought to analyze and compare population-adjusted COVID-19 case and death counts across NC. The differences between the coastal and inland areas serve as the foundation of this analysis due to existing research on the correlations between environmental variables and COVID-19, as well as the documented climactic and atmospheric variations between the regions.[20–23] Thus, we present a descriptive study that observes trends in COVID-19 case and death rates in coastal versus inland NC. We also include related regional demographic, population density and socioeconomic data in our analysis given that these variables have been demonstrated to impact COVID-19 prevalence and clinical outcomes.[4,24]

Methods

NC counties were categorized according to preexisting zones. Specifically, the NC Coastal Area Management Act (CAMA) was used to define the coastal region of NC (n = 20). CAMA defines coastal counties as those "that (in whole or in part) are adjacent to, adjoining, intersected by or bounded by the Atlantic Ocean (extending offshore to the limits of State jurisdiction, as may be identified by rule of the Commission for purposes of this Article, but in no event less than three geographical miles offshore) or any coastal sound."[25] The inland region of the state was defined as all counties not included in the coastal region (n = 80). Population density estimates were established in accordance with NC Rural Center classifications, which designate 6 counties as urban, 14 as suburban, and the remaining 80 counties as rural.[26] All coastal counties were designated as rural, except for New Hanover County, which was classified as urban. No coastal counties were classified as suburban.

An analysis of the demographic characteristics of the coastal versus inland region was performed using county level demographic data obtained from SimplyAnalytics. This service aggregates and curates a variety of data obtained from the United States Census Bureau and other sources, such as state governments, non-profits, and the Dun & Bradstreet Corporation. Data from SimplyAnalytics are widely used by businesses and universities.[27] All population data used in this study is based on 2019 population estimates. The regional average of several demographic characteristics associated with COVID-19 prevalence and outcomes were calculated, including racial composition, household income, and the proportion of people over 65 years of age. T-tests were performed in Python to calculate Z-scores for each of these variables. These variables were selected because prior work has demonstrated a strong association between these factors and overall COVID-19 outcomes.[4,28,29] Further description of these relationships is provided in the discussion.

COVID-19 confirmed cases, death count, and county population data used in this study were retrieved from USA Facts under a Creative Commons license.[30] USAFacts compiles data daily from local, state, and national public health agencies. The US CDC considers this data to be reliable and makes it accessible from the organization's website.[31] Data was analyzed in Microsoft Excel by sorting case and death counts by the categories described below, then adjusted for population to ensure appropriate comparison. Population adjustment was accomplished by calculating cases or deaths per 100,000 residents. Further analysis was performed by calculating a local regression analysis based on a plot containing the daily case or death density for every county in the specified region. Case density was defined as cases/100,000 residents, and death density was defined as deaths/100,000 residents.

COVID-19 case count and death totals from 22 January 2020 to 15 August 2020 were obtained from USAFacts for all US counties. The relevant data was then extracted from this dataset. The first COVID-19 case was reported in NC on March 3rd, 2020.[32] Only data from 15 March 2020 to 15 August 2020 is presented in our analyses due to negligible population-adjusted case and death counts in NC between 3 March 2020 and 15 March 2020. All analyses are displayed on a logarithmic scale.

Results

Figure 1 below displays the mean proportion of white and black residents, residents over the age of 65, and median household income for coastal versus inland counties. All coastal means are less than one standard deviation away from the inland means, suggesting that the differences are not statistically significant.

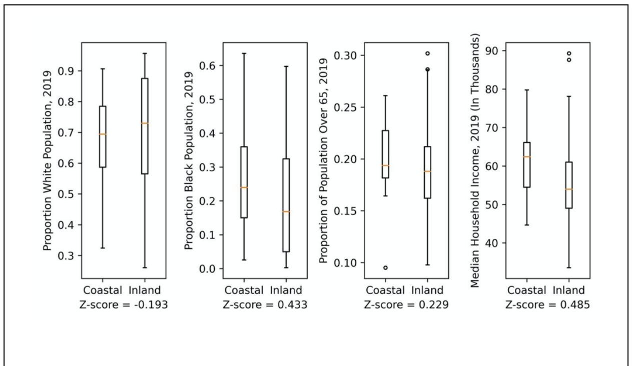


Figure 1. Box plots displaying the percentage of persons identifying as White, personas identifying as Black, people over the age of 65, and median household income in the inland versus coastal region of NC. Z-scores comparing the coastal region mean to the inland region mean are shown for each variable.

As of 15 August 2020, the population-adjusted COVID-19 case total was 889 cases/100,000 residents in the coastal region, versus 1426 cases/100,000 residents in the inland region. Furthermore, the population-adjusted death total was found to be 12.5 deaths/100,000 residents in the coastal region versus 23.2 deaths/100,000 residents in the inland region. These statistics are noted in Figure 2, which also shows coastal versus inland affiliation as defined by CAMA and population-density affiliations as defined by the

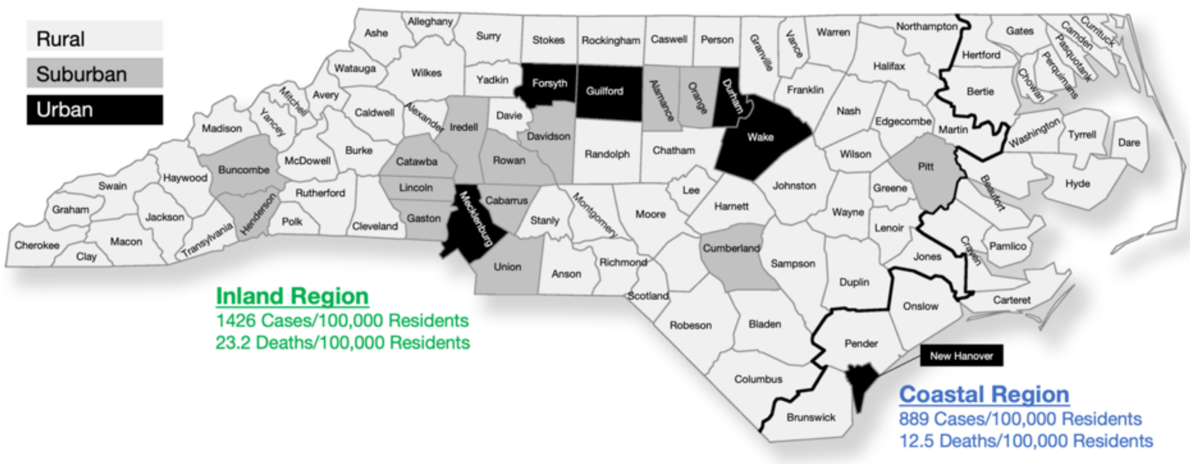


Figure 2. Map of NC with coastal versus inland and population-density affiliations by county, plus a comparison of cumulativeCOVID-19 cases and deaths per 100,000 residents in the coastal versus inland region of NC on 15 August 2020.

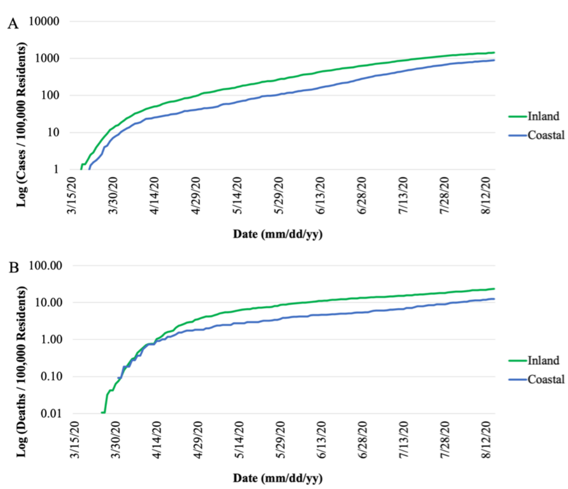


Figure 3. Cumulative prevalence of COVID-19 cases (3A) anddeaths (3B) per 100,000 residents between 15 March 2020 and 15 August 2020 forNC inland versus coastal region.

NC Rural Center. The time series plot in Figure 3 below shows that this disparity in COVID-19 cases (3A) and deaths (3B) per 100,000 residents for the coastal versus inland region has persisted through much of the study period.

A local regression analysis comparing population-adjusted COVID-19 cases and deaths per 100,000 residents per day in the NC coastal versus inland region can be seen below in Figure 4. This figure demonstrates that population-adjusted cases (4A) and deaths (4B) increased at a slower rate in the coastal region for most of the duration of the pandemic.

A similar local regression analysis is presented in Figure 5 below. Cumulative population adjusted cases and deaths are compared for rural inland (n = 61), suburban inland (n = 14), and urban inland (n = 5) versus rural coastal (n = 19) and urban coastal (n = 1) counties. It is important to note that the coastal region does not have any suburban counties, and the lone urban county (New Hanover) experienced fewer population-adjusted cases and deaths than the 5 urban inland

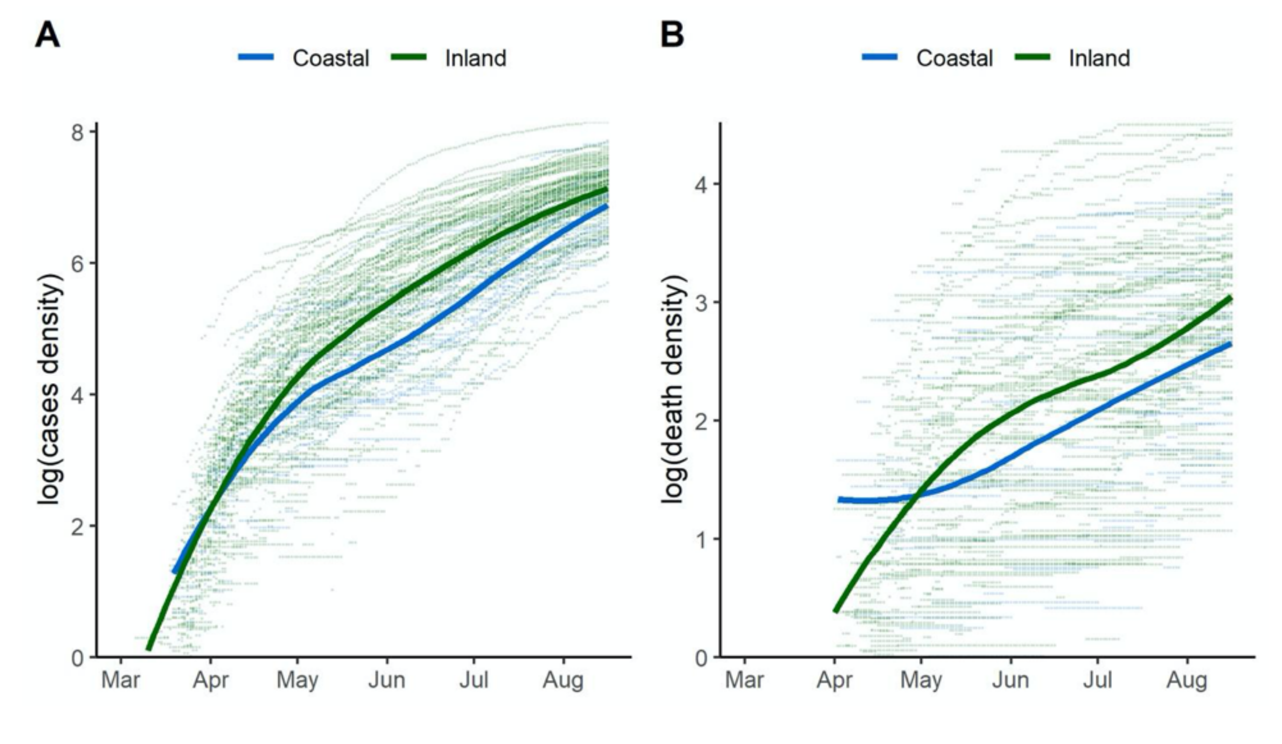


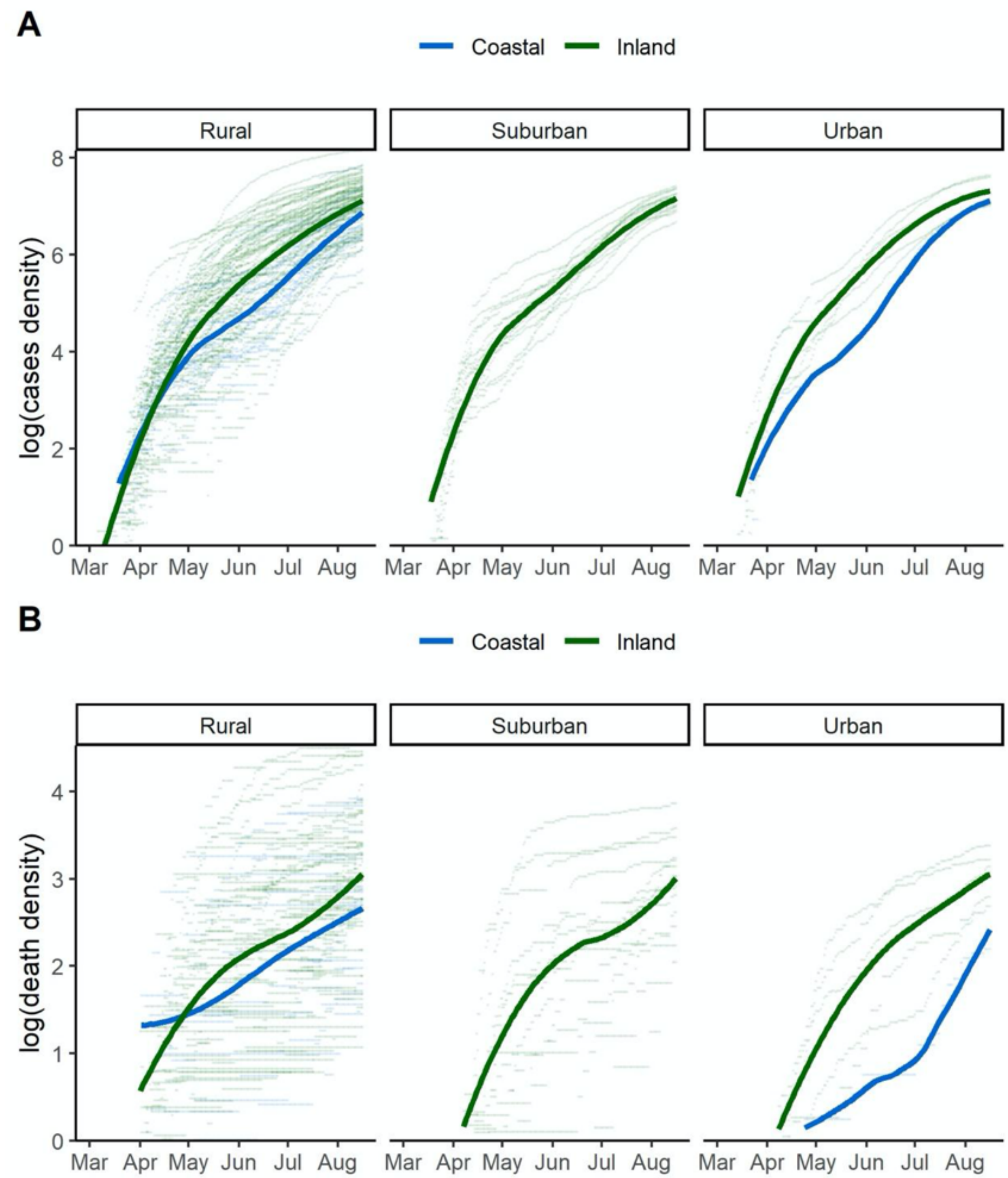
Figure 4. Local regression analysisdemonstrating average new COVID-19 cases/100,000 residents/day anddeaths/100,000 residents/day. Each point on the graph represents the log of thecase or death density for an individual county on a specific date which wasutilized in calculating the displayed regression line.

counties. Specifically, New Hanover County experienced 1148 cases/100,000 residents and 9.0 deaths/100,000 residents, compared to an average of 1542 cases/100,000 residents and 21.2 deaths/100,000 residents in the 5 inland urban counties as of 15 August 2020.

Discussion

We observed that the prevalence of population-adjusted cases and deaths was lower in the NC coastal region when compared to the inland region of the state. Given that 19 of the 20 counties in CAMA are classified as rural, one possible explanation for this trend is that COVID-19 cases and deaths are less prevalent in all rural counties. However, the results displayed in Figure 5 suggest this is not the case, given that population-adjusted cases and deaths increased at a slower rate in the coastal region in all population density stratifications. Furthermore, the same trend holds for the lone coastal urban county when compared to the five urban inland counties.

As discussed in the introduction, some existing research has correlated COVID-19 transmission with differences in geographic location, demographics, public health policy, and human behavior. Analyses of previous disease outbreaks have shown that the social and cultural context in which a disease spreads can alter the efficacy of some interventions and influence the pathways of disease transmission. Societal structures and the idiosyncrasies of human behavior influence travel, as well as interactions with other humans, the healthcare system, and the environment.[33–35] In regards to demographics, COVID-19 is known to have a greater impact on elderly populations and



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racial minorities.[4,8,29]

Given the findings discussed above, it is possible that demographic or socioeconomic factors played a role in creating the coastal versus inland disparity demonstrated in this study. However, based on the data presented in Figure 1, there is no statistically significant difference in the proportion of white residents, black residents, residents over the age of 65, or median household income for the coastal versus inland region. Thus, we find it unlikely that the observed differences in population-adjusted COVID-19 cases and deaths in the coastal versus inland region can solely be explained by differences in regional demographics or socioeconomic status.

Although this study controlled for several variables, we were not able to account for policy or behavioral differences across regions. Our use of a retrospective database generally increases the likelihood of confounders influencing the results. For example, we did not consider regional differences in COVID-19 testing and reporting. At the height of the pandemic, shortages of tests and testing supplies were documented both globally and domestically. Results from the Indiana based COVID-19 Random Sample Study suggest that the testing regime in that state detected only one out of every 10 infections.[36–38] It is possible limitations in testing within the state of North Carolina influenced the reported COVID-19 prevalence data. Furthermore, local news reporting suggest that some beaches were closed early in the pandemic, though many locations began to reopen in the month of May.[39–41] It is possible that these actions and other local public health policy affected outcomes. Similarly, local compliance with public health guidelines was not accounted for in our analysis.

Although the potential confounders discussed above may have contributed to the trends observed in this paper, one possible explanation for these results is environmental differences in coastal versus inland NC. Currently, the available evidence shows that a variety of environmental conditions can impact the transmission of viral pathogens, such as SARS-CoV-2. Most notably, lower levels of air pollution, higher relative air humidity, and higher sunlight have been associated with lower transmission and diffusion of SARS-CoV-2.[12,14,42–45] Some evidence suggests that NC coastal counties may be more likely to have these characteristics.[20,21]

Ultimately, further research is needed to fully explain these trends or demonstrate a causal link between the climate and COVID-19 prevalence in NC counties. Future work could advance our understanding of the observations presented in this study by correlating COVID-19 prevalence with retrospective analyses of temperature, humidity, UV radiation exposure and public health policy in different counties.

Conclusion

We conclude that the prevalence of population-adjusted COVID-19 cases and deaths has been lower in coastal NC between 15 March 2020 and 15 August 2020. Furthermore, we note that the rate of increase in population-adjusted cases and deaths has been slower in coastal, as compared to inland, regions of NC for much of the pandemic. This study suggests that population-level COVID-19 transmission may be impacted by environmental conditions. However, further analysis is needed to demonstrate a causal link between weather/climate and COVID-19 transmission.

Limitations Statement

This is a descriptive study and, as such, it does not purport to describe a causal link between any variables. Additionally, the decentralized implementation of NPIs and the varying degrees of compliance with these measures at the local and state level limit the degree to which we can make generalizable statements about COVID-19 transmission in the state of NC.

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