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Assessing inequities underlying racial disparities of COVID-19 mortality in Louisiana parishes

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High COVID-19 mortality among Black communities heightened the pandemic's devastation. In the state of Louisiana, the racial disparity associated with COVID-19 mortality was significant; Black Americans accounted for 50% of known COVID-19–related deaths while representing only 32% of the state's population. In this paper, we argue that structural racism resulted in a synergistic framework of cumulatively negative determinants of health that ultimately affected COVID-19 deaths in Louisiana Black communities. We identify the spatial distribution of social, environmental, and economic stressors across Louisiana parishes using hot spot analysis to develop aggregate stressors. Further, we examine the correlation between stressors, cumulative health risks, COVID-19 mortality, and the size of Black populations throughout Louisiana. We hypothesized that parishes with larger Black populations (percentages) would have larger stressor values and higher cumulative health risks as well as increased COVID-19 mortality rates. Our results suggest two categories of parishes. The first group has moderate levels of aggregate stress, high population densities, predominately Black populations, and high COVID-19 mortality. The second group of parishes has high aggregate stress, lower population densities, predominantly Black populations, and initially low COVID-19 mortality that increased over time. Our results suggest that structural racism and inequities led to severe disparities in initial COVID-19 effects among highly populated Black Louisiana communities and that as the virus moved into less densely populated Black communities, similar trends emerged.

COVID-19 | racial disparity | structural | justice

Significance

Black communities, both historically and contemporaneously, experience higher levels of underlying social, economic, and environmental stressors. These stressors contribute to stark and persistent racial disparities in wealth and health, particularly between White and Black Americans. We examine the role of stressors and risks in contributing to higher COVID-19 exposure for Black Louisianans. We find that Black communities in parishes with both higher and lower population densities experience higher levels of stressors, leading to greater COVID-19 mortality rates. Our work using the COVID-19 pandemic, particularly as observed in Louisiana, makes clear that communities with high levels of social, economic, and environmental racism are significantly more vulnerable to a public health crisis.

By March 2020, the novel coronavirus (COVID-19) had spread across the United States, first affecting large population hubs and then moving into smaller rural communities. With widespread effects by April 2020, it was clear that exposure to COVID-19 infection and mortality were not equal across US populations. Communities marginalized by race/ethnicity, poverty, health care, employment, and other variables were experiencing higher infection and mortality rates (1–4). Foreseeably, social, economic, and even environmental determinants of health have played a significant role in a community's risk to a natural disaster, and the COVID-19 pandemic seemed to be no different (5–7). We argue that the clustering of COVID-19 mortality is syndemic and arises at least partially from interactions with other infrastructure and community interactions.

COVID-19 Syndemic

Structural racism refers to the institutional policies and practices that shape opportunity and lead to discrimination in employment, education, housing, and many other social determinants of health. Historically and contemporaneously, structural racism in the United States has contributed to stark and persistent racial disparities in wealth and health, particularly between White and Black Americans. Pointedly, it has produced a synergistic system of inequity for Black populations. Black communities experience higher levels of underlying social, economic, and environmental stressors, including inadequate housing and lower rates of home ownership [e.g., nationally, the Black American homeownership rate has persisted at 42%, and a 20 to 30% gap between Black and White homeownership rates has persisted for more than 100 y (8)]; lower access to health care [e.g., in 2018, Black Americans' uninsured rate was 9.7% compared with 5.4% among White Americans (9)]; lower income and employment rates [the unemployment rate for Black Americans has been approximately twice the rate for White Americans (10)]; reduced air and water quality [Black Americans are 75% more likely than White people to live in "fence-line" communities (11)]; and high rates of racial profiling [e.g., Black individuals are three times more likely to be killed by the police in comparison with White individuals (12)].

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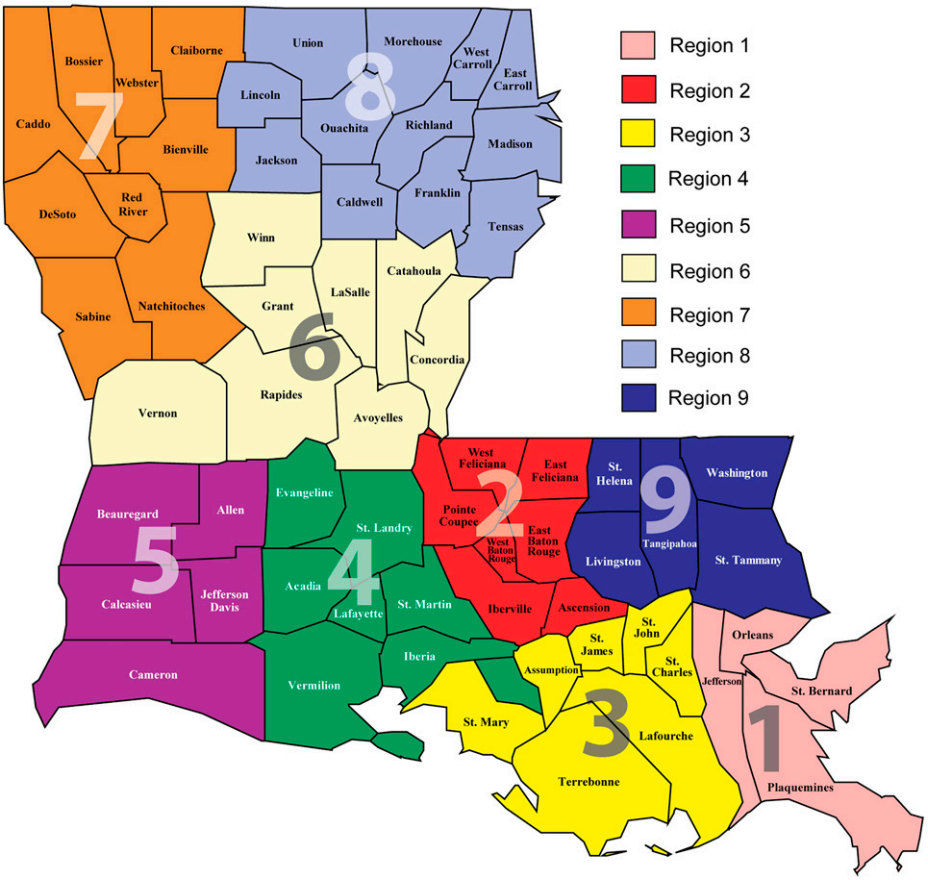

Fig. 1. Parishes and Louisiana Department of Health administrative regions in Louisiana.

These social determinants affect a wide range of health outcomes, including depressive symptoms, chronic illnesses (e.g., diabetes, asthma, obesity, and strokes), and functional limitations (3, 13, 14), often compounding to further increase the predisposition to comorbid disease (7, 15–17). The Centers for Disease Control and Prevention have identified that these outcomes increase the likelihood of becoming severely ill from COVID-19 (18). An infectious disease pandemic set off within a system of inequity can perpetuate, even heighten, substantial disparity in health risk (1, 13, 19, 20). The aggregation of these health consequences results in a syndemic, an exacerbated burden of disease for many Black communities (21).

State of Louisiana

Unlike the overwhelming majority of states, Louisiana, located in the southeastern region of the United States, is composed of parishes and not counties. Under both French and Spanish order, Louisiana was officially Roman Catholic, and after the Louisiana Purchase in 1803, the territorial legislative council divided the emerging state of Louisiana into 12 counties that fell along church parish lines. However, on 31 March 1807, the territorial legislature created 19 parishes, which included those previously formed counties, and officially adopted the ecclesiastical term "parish" (22, 23). Louisiana today has 64 parishes, which in turn, make up nine Louisiana Department of Health (LDH) administrative regions (Fig. 1). County boards of commissioners typically govern counties; in contrast, the political structure of parishes is police juries. Police juries are responsible for the "execution of whatever concerns the interior and local police and for administration of the parish" (24). Elected by voters, the police jury is the legislative and executive government of the parish. While the boundaries within Louisiana still generally fall along church parish lines, each parish is unique with respect to social and community structure, including demographics and culture. Louisiana's population is composed of 32% Black Americans compared with an average of 13% in the entire country (25). In 2019, Louisiana's gross state product ranked 24th of 51, with manufacturing as the largest producing sector and oil and gas extraction as the eighth highest grossing sector in 2018. As of 2020, Louisiana is ranked eighth for US energy production and third for natural gas, and it accounts for one-fifth of the nation's refining capacity (26).

Coronavirus in Louisiana

The first report of a confirmed case of COVID-19 in Louisiana was 9 March 2020, occurring in Jefferson Parish outside the city of New Orleans. This was late in comparison with other states. Two days later, Louisiana Governor John Bel Edwards declared a public health emergency, closed all K to 12 public education, and banned gatherings of more than 250 people. On 1 April 2020, the Louisiana Department of Health reported over 2,500 COVID-19 cases, and by 14 April 2020, the state had over 15,000 cases, averaging 500 new cases per day, and more than 1,000 COVID-19–related deaths (27, 28). Similar to other areas in the United States, an alarming race-based disparity in COVID-19 mortality began to emerge quickly in Louisiana (29). Early analysis estimated that over 70% of all mortalities were among Black Louisianans, despite Black residents making up just 32% of the state's population (30, 31). In contrast to the rest of the country, the infection

and death rates in and throughout Louisiana were far worse. This was repeatedly reported with news headlines early in the pandemic and even as recent as February 2022, such as "New Orleans area has worst coronavirus death rate in U.S." (32), "This small Louisiana parish has the highest death rate per capita for coronavirus in the country" (33), "Louisiana has a higher rate of COVID-19 infections than every country but one" (34), and "States with the worst COVID-19 vaccination rates" (35). Importantly, the reported infection and death rates painted a very bleak picture in Louisiana, but they did not fully illustrate the disturbing disparities within these rates as well as the underlying health determinants driving the disparities, which disproportionately affected Black Louisianans. On 24 April 2020, the accumulating evidence of this large racial disparity prompted Governor Edwards to create the Health Equity Task Force, providing $500,000 from the governor's COVID-19 response fund to examine the causes of and solutions to COVID-19 racial disparities (36).

Despite the Task Force's efforts and subsequent recommendations, the racial disparity in mortality continued during the second COVID-19 wave in July and August 2020, with more than half of all mortalities occurring among Black residents (37), and then again for the country's fourth wave, led again by Louisiana with new COVID-19 cases (37, 38). As of 24 January 2022, Black Louisianans (32% of the Louisiana population) contributed to 36% of COVID-19 cases compared with White Louisianans (59% of Louisiana population), who contributed to 51% of COVID-19 cases (39). Furthermore, Black Louisianans contributed 3% over their population proportion in COVID-19 deaths compared with White Louisianans, who contributed to only 1% over their population as of 2 February 2022 (39). While the current difference in incidence and mortality excess between the Black and White communities in Louisiana may have approached population representation over time, it is vital to examine and contextualize the driving forces

Table 1. Categorized data descriptions, dates, and sources

Data category, index, and data description	Years	Source
Demographic		
Race, age, and population density	2014–2018	1
Aggregate and cumulative stressors		
Social housing index		
Home ownership	2014–2018	1
Severe housing problems	2012–2016, 2019	1
Housing crowding	2012–2016	1
Severe housing burden	2012–2016	1
Residential segregation	2014–2018	2
Food environment index score	2019	2
Health care access index		
Primary care physician ratio	2019	2
Rate of uninsured	2019	2
Preventable hospital stays	2019	2
Premature death rate for Black residents	2016–2018	1
Premature death rate	2016–2018	1
Low birth weight	2012–2018	1
Economic index		
Unemployment in May 2019	2019	1
Median household income	2020	1
Children in poverty	2019	1
Children in single-parent households	2019	2
All ages in poverty	2014–2018	1
Income inequality	2014–2018	1
Environmental quality index		
No. of TRIs	2018	3
Amount of toxic release (lbs)	2018	3
Air pollution (avg. daily PM2.5)	2019	2
Green space (total area)*	2020	4
Drinking water violations*	2015–2020	3
Cumulative health risk index†		
Overweight, stroke, asthma, and diabetes (% prevalence)	2017	2
Acute COVID-19 impact		
COVID-19 exposure index		
Positivity count	10/6/2020	2
Case count	10/6/2020	2
Mortality count	10/6/2020	5
Testing site location	10/6/2020	2
No. of testing sites	10/6/2020	2
No. of essential workers	10/6/2020	2
Change in unemployment	May 2019–2020	1

Sources are as follows: 1, US Census Bureau (25); 2, Louisiana Department of Health (27); 3, US Environmental Protection Agency (EPA) (41); 4, US EPA, Environmental Quality Index (EQI) (42); and 5, USAFacts (43).
*Local or point data.
†Scale is by region.

of the early disparities, particularly since Louisiana has the third worst vaccination rate as of 11 February 2022 (40).

In this paper, we examine the role of stressors and risks manifest through structural racism in contributing to higher COVID-19 rates for Black Louisianans. We hypothesize that parishes with high aggregate stressors (a multiplicity of social, health care, economic, and environmental stressors) will also experience high cumulative health risk, COVID-19 stress, and mortality rates. We begin by identifying aggregate stressors and cumulative health risk at the parish level and then, move to an assessment of the racial disparity in acute COVID-19 stressors and pandemic response. Using hot spot analysis, we examine the spatial clustering of stressors, cumulative health risk, COVID-19 mortality, and COVID-19 stress at the parish level. We find that structural racism and inequities led to severe disparities in initial COVID-19 impacts among highly populated areas of Louisiana.

Methods

We create four stressor indices representing the dimensions of social housing, health care access, economic, and environmental quality for each of Louisiana's 64 parishes (Table 1). We also derive a cumulative health risk index at the LDH level to represent rates of diabetes, asthma, obesity, and strokes (Table 1). Finally, we calculate a COVID-19 exposure index using measures of infection rates, unemployment increase, and number of essential workers. We use principal component analysis (PCA) to construct each of our indices and select the first component for our index (R Studio V.1.2.5033, package:prcomp). Our rationale for using only the first component is twofold. First, the literature is inconsistent with respect to the suitability and method for combining components (e.g., the first two components), and second, we argue that if we see a relationship between stressor and COVID-19 cases using only the first component, we would expect trends to be stronger using additional components. We discuss each index below and in Table 1. The indices are also shown in Fig. 2 as a heat map produced on a similar scale.

Stressors.

Social housing. As a proxy for social stress, a social housing index is created. Our social housing index captures six measures at the parish level: rate of homeownership (2014 to 2018), household crowding rates (2012 to 2016), household cost burden (2012 to 2016), percentage of households with severe housing problems (2012 to 2016, 2019), parish food availability index scores (2019), and finally, degree of racial segregation within the community (2014 to 2018) (Table 1). Studies on COVID-19 exposure suggest that housing insecurity and household crowding are directly related to higher COVID-19 rates due to their effect on occupant health and the household's ability to social distance (3). In addition, research has repeatedly shown that reduced access to healthy food directly relates to negative health outcomes (3, 44–47). We use racial segregation as a proxy for broader structural racism within the community (48).

Our PCA first component accounts for just under 57% of the variability (*SI Appendix*, Fig. A1). The first two components account for ∼75% of the variability and capture severity of housing (PC1, the first principal component) and overcrowding (PC2, the second principal component). We use the first principal component as our index, and parishes with higher social housing stress include Orleans (7.11), East Carroll (5.03), Lincoln (3.98), Natichotes (3.79), and Madison (2.83) (Fig. 2*A* and *SI Appendix*, Fig. B1).

Health care access. The health care access index captures six measures of accessibility, both structurally and financially, to medical care (Table 1). Lack of accessibility to health care within predominantly Black communities contributes to increased COVID-19 risk (13, 19, 49). High rates of uninsured residents combined with high rates of preventable hospital stays indicate that health care is financially inaccessible to the community. High primary care physician ratios and low numbers of hospitals indicate a physical distance between residents and medical care (Table 1). High premature death rates and low birth weights

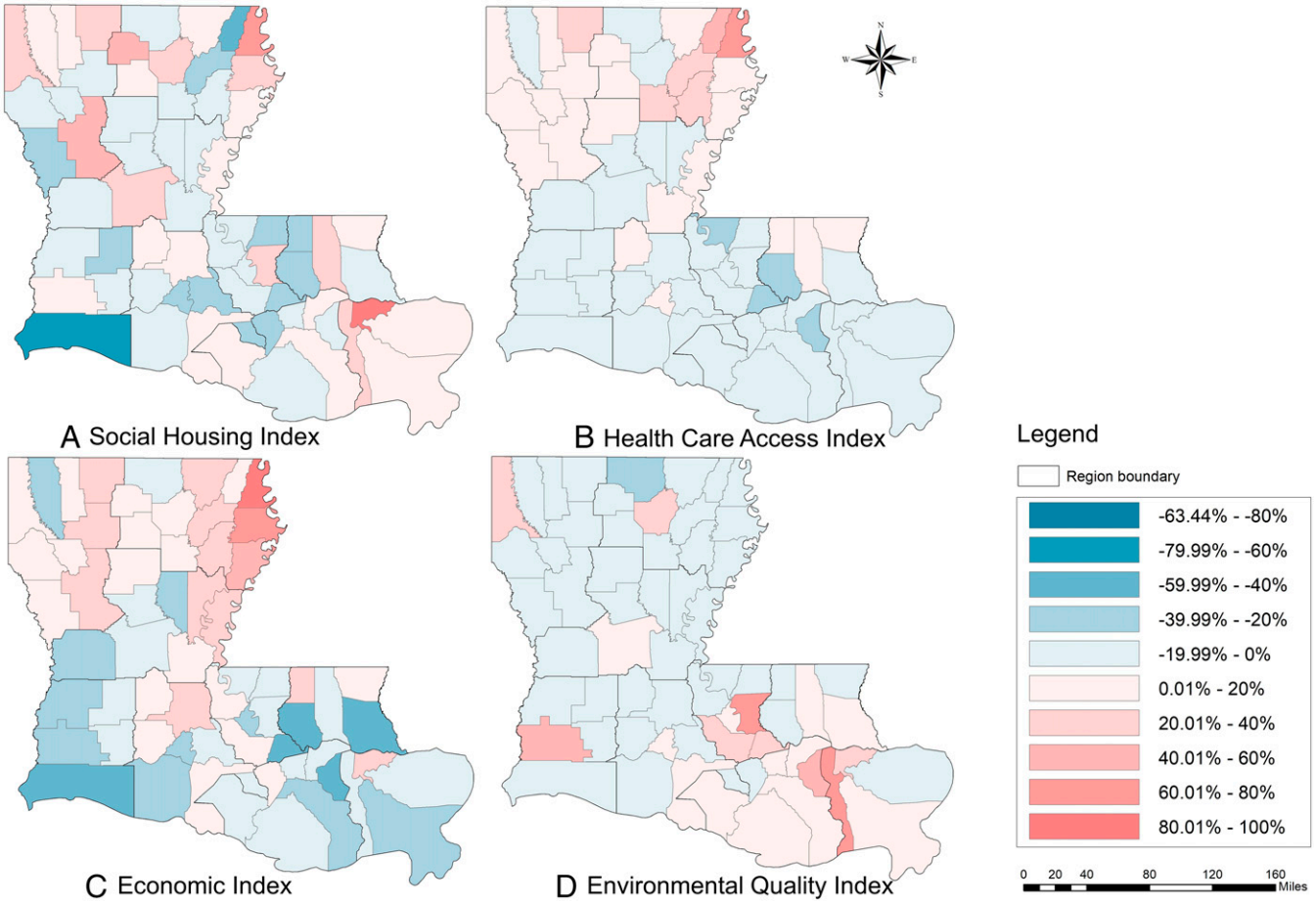

Fig. 2. The spatial distribution of (*A*) the social housing index, (*B*) the health care access index, (*C*) the economic index, and (*D*) the environmental quality index.

indicate that lifetime health care and treatment are poor within the community as well, indicating low availability or quality of care (50, 51).

Our first two PCA components combined account for about 60% of total variability and primarily capture premature death and low birth weight (PC1) as well as preventable hospital stays (PC2). The first PCA component accounts for ∼35% of the variability (*SI Appendix*, Fig. A2). We use the first principal component as our index, and parishes with the lowest access to health care include East Carroll (4.51), West Carroll (3.04), Richland (1.98), Caldwell (2.79), and Claiborne (2.33) (Fig. 2*B* and *SI Appendix*, Fig. B2).

Economic. The economic index includes six measures aimed at capturing household economic stress as well as childhood poverty, a key indicator of community stress (3, 44–47). To assess household economic stress, we again perform a PCA including unemployment rates (2019), median household income (2020), number of children in poverty (2019), number of children in single-parent households (2019), and indicators of parish income inequality and overall poverty rates (2014 to 2018).

The first PCA component explains just under 60% of the variability and primarily captures differences in the number of children in poverty and overall poverty rates between parishes. The second component explains an additional 15% of poverty and is related almost exclusively to 2020 unemployment rates. Combined, the first two components explain about 75% of all variability. The first component is used as the index score, and high economic stress is indicated by high index values (7.275 to 4.1228) (*SI Appendix*, Fig. A3). Parishes with the highest economic stress include East Carroll (7.28), Madison (4.87), and Tensas (4.12). Nearby parishes, such as Claiborne (2.15), Natichotes (2.14), and Morehouse (2.12) as well as Orleans (2.10), all have relatively high economic stress (Fig. 2*C* and *SI Appendix*, Fig. B3).

Environmental quality. Five measures are used to generate an environmental quality index score. The first measure is parish air quality measured as the average daily density of fine particulate matter in micrograms per cubic meter (PM2.5) in 2019. We also include the number and size of Toxic Release Inventory (TRI) sites (2018). These are locations with large amounts of toxic chemical waste production and release. Instances of drinking water violations between 2015 and 2020 are also included to indicate those parishes most likely to experience decline in drinking water quality. Finally, the amount of green space in each parish in 2020 was included as a way to assess access to outdoor recreation, clean air, and clean water.

Together, the first two components explain about 65% of variability. The first PCA component, which primarily indicates differences in the number and size of TRI facilities, explains just over 40% of variability (*SI Appendix*, Fig. A4). The cumulative number of drinking water violations and 2019 air pollution are captured in the second component, which explains about 25% of additional variability. The first component is used as the index score, and high environmental quality stress is indicated by a high index value (5.452 to 3.547) (Fig. 2*D* and *SI Appendix*, Fig. B4). Parishes with high environmental quality stress include Jefferson (4.52) and St. Charles (3.54) outside of New Orleans as well as East Baton Rouge (5.45) and Calcasieu (3.94) (Fig. 2*D* and *SI Appendix*, Fig. B4). Jefferson, St. Charles, and East Baton Rouge Parishes are located outside of Louisiana's two largest population hubs (New Orleans and Baton Rouge) along the Mississippi River, a transport and production hub.

Cumulative Health Risk. The cumulative health risk index captures the presence of preexisting rates of diabetes, obesity, stroke, and asthma across parishes. Preliminary research has shown that persons most at risk for COVID-19 mortality tend to have one or more preexisting conditions, including but not limited to those listed above (20). In the United States, Black residents experience higher rates of these preexisting conditions and have less access to health care, which compounds social precariousness (13, 49, 52).

The first two components of our PCA capture just over 80% of the variability. Component 1 captures the impact of asthma and diabetes (50% of variability), while component 2 captures the effect of obesity and stroke (30% of variability) (*SI Appendix*, Fig. A5).

COVID-19 Exposure. We assemble parish-level COVID-19 infection data from the LDH, which has been tracking COVID-19 testing, positivity rates, and negativity rates since 1 March 2020. Parish COVID-19 mortality data are available from the USA FACTS website (27). To compare COVID-19 infection data at the parish level, the total number of COVID-19 cases and the total number of COVID-19 mortalities for each parish, as of 1 October 2020, are standardized by the total parish population. To quantify acute stress related to the COVID-19 pandemic, we rely on the economic impact and magnitude of testing response. We measure economic impact by measuring the change in unemployment between May 2019 and May 2020 and the rate of essential workers. Early research has shown that vulnerable communities not only saw greater job loss but that many vulnerable populations were less able to social distance due to high rates of essential work (53).

Our first two components explain about 65% of the variability. The number of essential workers and change in unemployment rate are captured by component 1, which accounts for just over 40% of variability. COVID-19 mortality and positive case rate are captured by component 2, which accounts for just over 25% of the variability (*SI Appendix*, Fig. A6).

Hot Spot Analysis. To identify high concentrations of stressors, health risks, and COVID-19 exposure, we use hot spot analysis (54, 55). We identify statistically significant spatial clusters of high values (hot spots) and low values (cold spots) using the local Getis–Ord G^* statistic (56). The G_i^* statistic measures the variation in local spatial autocorrelation varied over the study area at each data point. We use the G_i^* statistic to evaluate the degree to which each parish is proximate to other parishes with similarly high or low values within a specific geographical neighborhood. We use ArcMap 10.6 to create an output feature class with a *z* score, *P* value, and confidence-level bin field for each variable (social housing, health care access, economic, environmental quality, cumulative health risk, and COVID-19 exposure indices). We also apply the Anselin Local Moran's *I* to identify spatial clusters of features with high or low values and spatial outliers (57). We organize the results into four types of fields: HH (High-High, cluster of high values), LL (Low-Low, cluster of low values), HL (High-Low, a high value surrounded by low values), and LH (Low-High, a low value surrounded by high values). Statistical significance is the 95% confidence level.

Results

To understand our results, it is helpful to first contextualize the general demographics of the state (Fig. 3). As we noted earlier,

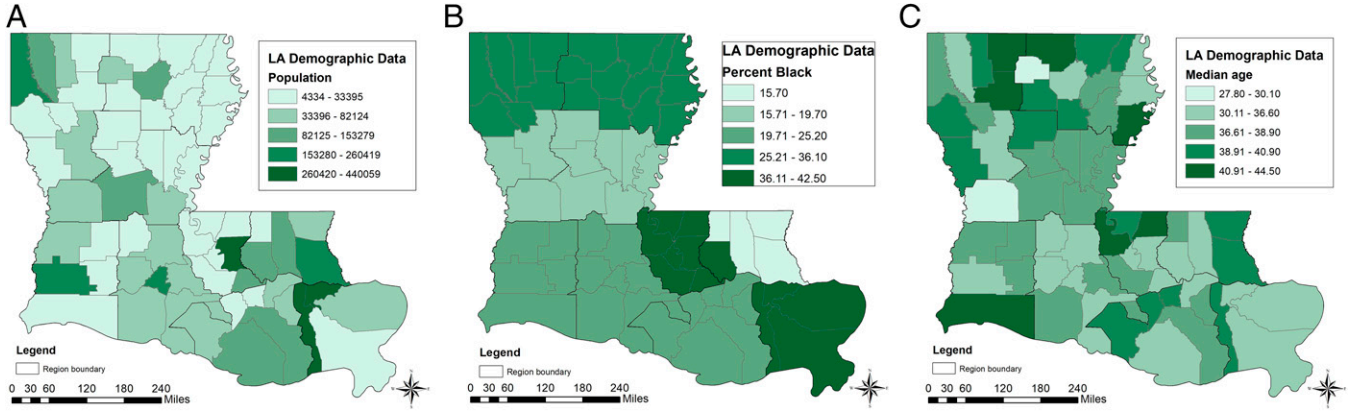

Fig. 3. The spatial distribution of (*A*) population, (*B*) percentage of Black residents, and (*C*) median age in Louisiana.

Louisiana has nine regions with varying demographics and economic conditions. The parishes vary in both age and population characteristics (Fig. 3). For example, there are fewer than 12,000 people in nine of the parishes: Tensas (4,334), East Carroll (6,861), Cameron (6,973), Red River (8,442), Catahoula (9,494), Caldwell (9,918), St. Helena (10,132), West Carroll (10,830), and Madison (10,951). Only seven parishes have greater than 200,000 people, and these include Calcasieu (203,436), Caddo (240,204), Lafayette (244,390), St. Tammany (260,419), Orleans (390,144), Jefferson (432,493), and East Baton Rouge (440,059). The median age in the majority of parishes is below 40 y old; Lincoln (27.8) and Vernon (30.1) are the youngest parishes (Fig. 3).

Region 1, which includes Orleans, Jefferson, Plaquemines, and St. Bernard Parishes, is composed of 42.5% Black residents; this is the highest percentage in the state (Fig. 3*B*). Region 2, consisting of West and East Feliciana, East and West Baton Rouge, Ascension, and Pointe Coupee Parishes, ranks second in terms of the percentage of Black population (38.3%). Regions 7 (northwestern Louisiana) and 8 (northeastern Louisiana) follow with 36.1 and 32.7% Black residents, respectively (Fig. 3*B*).

Spatial Clustering. Looking at the spatial clustering of the indices, we see similar patterns across all four indices (Fig. 4), with several parishes repeatedly identified as hot spots. High social housing stress occurs in the parishes (Jefferson, Orleans, St. Tammany, and St. Charles) surrounding the city of New Orleans (Fig. 4*A*). Between 2014 and 2019, Orleans Parish consistently had the highest severe housing problems score, a metric put out by the County Health Rankings that considers overcrowding, lack of plumbing, incomplete kitchen facilities, and household cost burden (58). Lincoln, Natichotes, East Baton Rouge, Jefferson, and Madison were all in the top 10% of parishes with severe housing problems in 2019. East Carroll, Madison, Tensas, and Lincoln had the lowest access to healthy food, as low food environment scores indicate; this metric is published by the County Health Rankings and considers distance to a grocery store and percentage of the population lacking a reliable food source (59). The percentage of homeownership is lowest in Naticholes (45%), Orleans (47%), and East Carroll (49%) Parishes. These parishes also overlap with many of the parishes with poor health care access. Spatial hot spots center around East Carroll, West Carroll, Madison, Tensas, Richland, and Franklin Parishes (Fig. 4*B*). These parishes have high primary care physician ratios, lower numbers of preventable hospital stays, fewer babies born at low birth weights, high rates of insurance, and lower premature death rates.

High economic stress hot spots occur in the parishes proximate to East Carroll (Fig. 4*C*). In East Carroll, Madison, and Tensas Parishes, high economic stress coincides with low median household incomes ($27,000 to $29,000), high rates of childhood poverty (5 to 7%), and large numbers of children in single-parent households (5 to 8%). Income inequality and unemployment rates are also relatively high in these parishes. The high economic stress observed in Orleans is largely due to a very high unemployment rate in 2020 (19.8%), but the parish also has the highest income inequality of any parish and relatively high rates of childhood poverty (3.9%).

Finally, parishes with high environmental quality stress include Jefferson and St. Charles, outside of New Orleans, as well as East Baton Rouge and Calcasieu. Jefferson, St. Charles, and East Baton Rouge Parishes are located proximate to Louisiana's two largest population hubs (New Orleans and Baton Rouge) along the Mississippi River, a transport and production hub, where a large number of TRI facilities drive environmental quality stress (Fig. 4*D*). Associated with these facilities are the large amounts of TRI outputs, indicating a high level of production. High environmental quality stress in Calcasieu Parish is similarly coincident with a large number of TRI facilities and a large TRI output. These parishes have high environmental quality

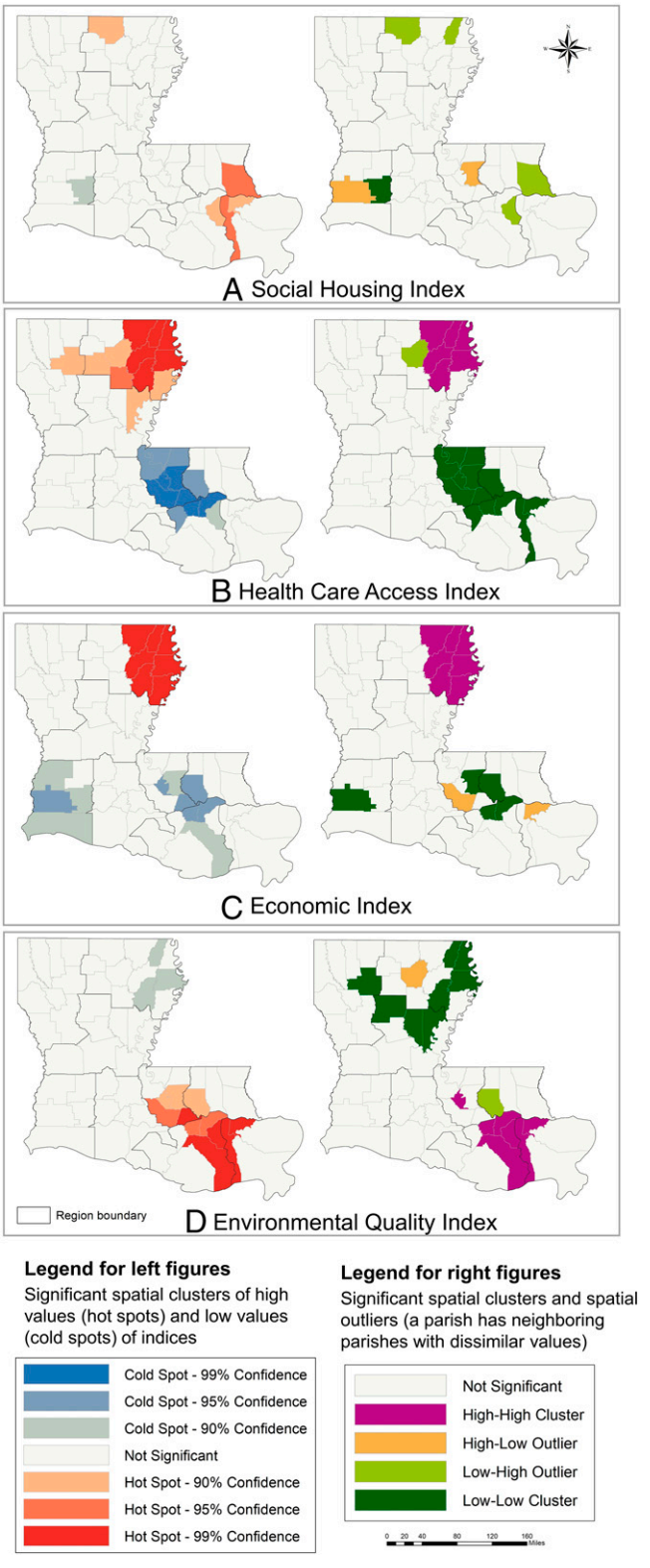

Fig. 4. Hot spot analysis and spatial outliers of (*A*) the social housing index, (*B*) the health care access index, (*C*) the economic index, and (*D*) the environmental quality index.

stress despite access to green spaces and comparatively good air quality as well as relatively few water quality violations. Ascension, Bossier, and Caddo Parishes have the worst air quality, indicated by high average PM2.5 values (10 to 10.3 μg/m). Union, Ouachita, Winn, St. Tammany, Jackson, and Sabine Parishes all have over 800 cumulative water quality violation points.

Hot spot parishes associated with high social housing, health care access, and economic stress are also parishes with a high percentage of Black population (Fig. 5), including East Carroll, Madison, Orleans, and St. John the Baptist. Parishes with a high Black population have severe social housing problems and poor health care access. These parishes also show higher stress in terms of low income and high employment rates. There are also hot spot parishes with high Black population percentages and relatively low environmental stress (e.g., East Carroll, Madison, and St. John the Baptist). Parishes around Jefferson, St. Charles, and Ascension have low percentages of Black population but high environmental quality stress, which is associated with elevated TRI outputs. In short, parishes with larger Black populations also tend to exhibit other significant and generally long-term stressors.

COVID-19 Exposure and Cumulative Health Risk Hot Spots. We examined the cumulative health risk, finding that it is highest in regions 6 and 8, which include much of northeastern and central Louisiana, as well as some parts of region 7, which includes northwestern Louisiana. The cumulative health risk high–high clusters or hot spots in region 8 and part of region 6 are related to high underlying rates of stroke, asthma, obesity, and diabetes. The cumulative health risk is also relatively high in region 1 outside of New Orleans. Regions 4 and 9 have the lowest cumulative health risks (cold spots) in Louisiana (Fig. 6*A*).

Parishes with high COVID-19 exposure stress include Jefferson, Orleans, and East Baton Rouge. We also see a hot spot outside of New Orleans, including Jefferson and Orleans Parishes (Fig. 6*B*). This high stress is driven by a high COVID-19 caseload and a high number of deaths. These high numbers are not surprising as these three parishes have the highest population density within the state (60). These parishes also have a high percentage of Black population. In addition to having high numbers of COVID-19 cases and deaths, Orleans, Jefferson, and East Baton Rouge have a large population of essential workers and unemployment rates that increased dramatically. East Baton Rouge has the highest number of essential workers (77,000) followed by Jefferson (47,000), Lafayette (45,000), and Orleans (42,000). Essential workers include those working in energy, agriculture, critical retail (grocery stores), construction, transportation, social services, childcare, and medical fields. In Orleans Parish, unemployment increased 15.2% between May 2019 and May 2020.

Fig. 7 shows the relationship between cumulative health risk and COVID-19 exposure indices and the percentage of Black residents. Parishes with larger Black populations have higher health risks, including parishes like East Carroll, Madison, Tensas, and Orleans. These parishes have a low population density but a higher percentage Black population. The COVID-19 exposure index is relatively low in East Carroll and Madison due to low population density. Parishes with high population density but low percentage of Black residents include Jefferson, La Salle, and Calcasieu, and all show a high COVID-19 exposure index.

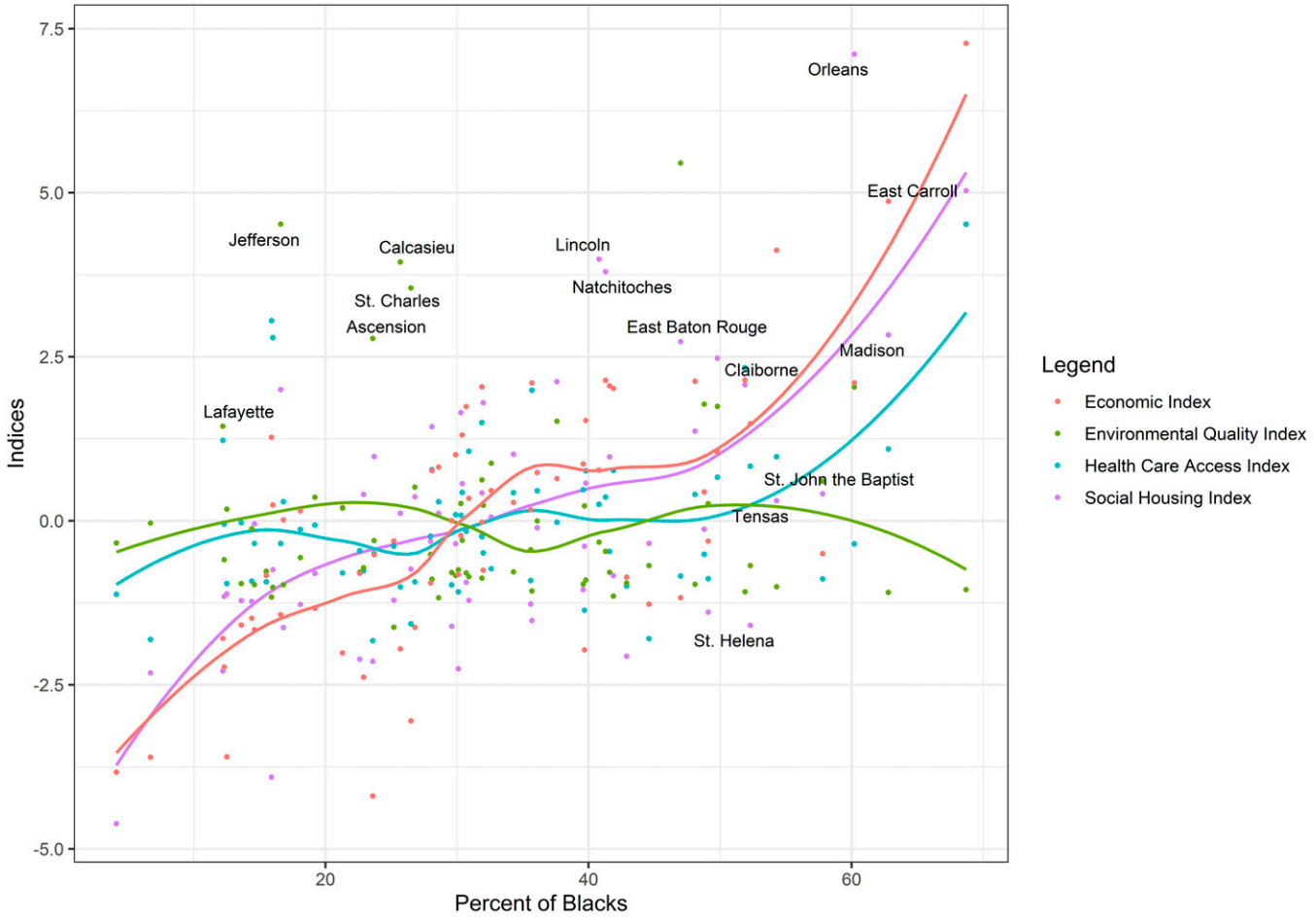

Fig. 5. Relationship between the percentage of Black residents and aggregated stressors.

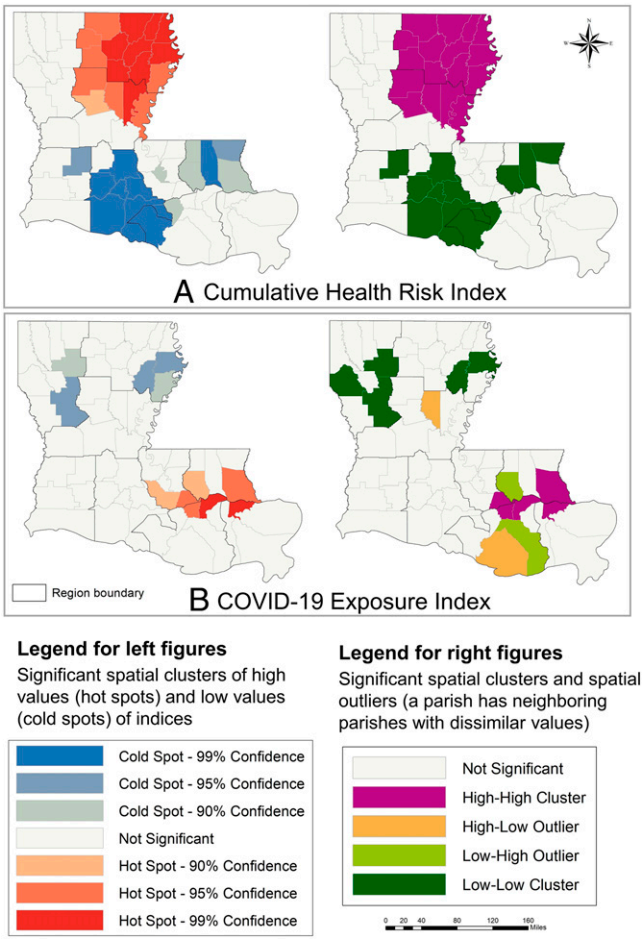

Fig. 6. Hot spot analysis and spatial outliers of (*A*) the cumulative health risk index and (*B*) the COVID-19 exposure index.

Discussion

Environmental Racism. While Benjamin F. Chavis coined the term "environmental racism," Robert D. Bullard gave its shape and definition as "any policy, practice or directive that differentially affects or disadvantages (where intended or unintended) individuals, groups or communities based on race" (61). Over the course of generations, environmental racism has disproportionately affected the health and well-being of low-income communities and Black, Indigenous, and people of color (BIPOC) communities. The COVID-19 pandemic, particularly as demonstrated in Louisiana, illustrates the pervasiveness of racism through systems and institutions and demonstrates how communities experiencing environmental racism were significantly more vulnerable to this additional public health crisis (61). As demographic data were released early in the pandemic, it became increasingly clear that Black communities across the country were contracting and dying at disparate rates from COVID-19. At one point in April 2020, 70% of the COVID-19 deaths in Louisiana were among Black Americans (62). The interlocking and deleterious harms of environmental racism as well as the inseparable effects of many social determinants of health contribute to higher incidence and mortality rates in Black communities.

Our hot spot analysis clearly identifies two main groups of parishes. The first group is located outside of Louisiana's two main population centers, New Orleans and Baton Rouge. Both of these metropolitan areas have populations above 200,000 and higher percentages of Black residents (greater than 38%). The parishes include East Baton Rouge, Orleans, and Jefferson, and these parishes exhibit either high environmental quality stress or high social housing stress (e.g., Orleans) and relatively high cumulative health risk. Additionally, these parishes have high acute COVID-19 exposure driven by a large number of COVID-19 cases, a large number of COVID-19 deaths, a high number of essential workers, and significant unemployment.

The acute COVID-19 stress seen in these parishes is reflective of early COVID-19 spread within Louisiana's main population hubs. The COVID-19 pandemic hit New Orleans and the surrounding parishes of Orleans and Jefferson early and severely, partially due to continued Mardi Gras celebrations in the city of New Orleans during late February and early March (27, 31). High numbers of COVID-19 cases quickly followed in Baton Rouge and its surroundings parishes. Mortality rates in these parishes remained consistently higher than those in other parishes, even as the COVID-19 virus spread throughout the state (27). As of October 2020, COVID-19 mortality rates in Orleans (4.5%) remained high, while rates in Jefferson (3.2%) and East Baton Rouge (2.8%) declined. Despite lowered rates within these parishes, the spread of the virus can be seen by elevated mortality rates in nearby parishes, such as St. John the Baptist (6.5%), St. James (4.8%), Iberville (4%), and West Baton Rouge (4.4%). Interestingly, these river parishes, including St. James and St. John the Baptist, along with St. Charles sit in an area referred to as Cancer Alley. Historically known as "Plantation Country," the location where enslaved Africans were forced to labor, the new moniker came to be because of the area's 150 pollution-emitting oil refineries, plastics plants, and chemical facilities. The EPA has reported that the cancer risks in the predominately Black American district of St. James could be 105 cases per million compared with 60 to 75 per million in predominantly White districts, and in St. John the Baptist, the cancer risk is 15 times over the EPA's acceptable limit (63–65). As of October 2020, mortality rates in smaller population hubs, such as Lafayette, and more rural areas, such as Red River and Bienville, began to rise rapidly. In Lafayette Parish, mortality rates hit an astonishing 25%, and in northwestern Louisiana, mortality rates in Red River and Bienville Parishes rose to just over 6%, all of which indicates increased community spread among lower-population parishes.

The stressors in this first group of parishes are primarily environmental quality, resulting from high levels of industry and subsequent pollution production. While these parishes have low overall economic, social housing, and health care access stress, key measures of inequity, including income inequity, racial segregation, and housing metrics such as household crowding and safety, all indicate deeper structural inequity (Table 2). For example, while Orleans Parish has low economic stress, it is ranked first in income inequality, has the greatest number of severe housing problems indicating household crowding and low safety, and also, has the second to lowest rate of homeownership. It is also the fourth most segregated parish. As of 18 November 2020, Orleans Parish also continued to show a large racial disparity in COVID-19–related deaths, with 72% of deaths being among its 42.5% Black residents (66). It should be noted that although Hurricane Katrina occurred more than 15 y ago, the devastation to New Orleans still resonates today (67). Research has found that underserved communities are more vulnerable to natural disasters and more likely to experience greater damage, injuries, and mortalities and slower recovery rates (61, 68). Jefferson Parish has a high rate of uninsured, the fifth highest number of severe housing

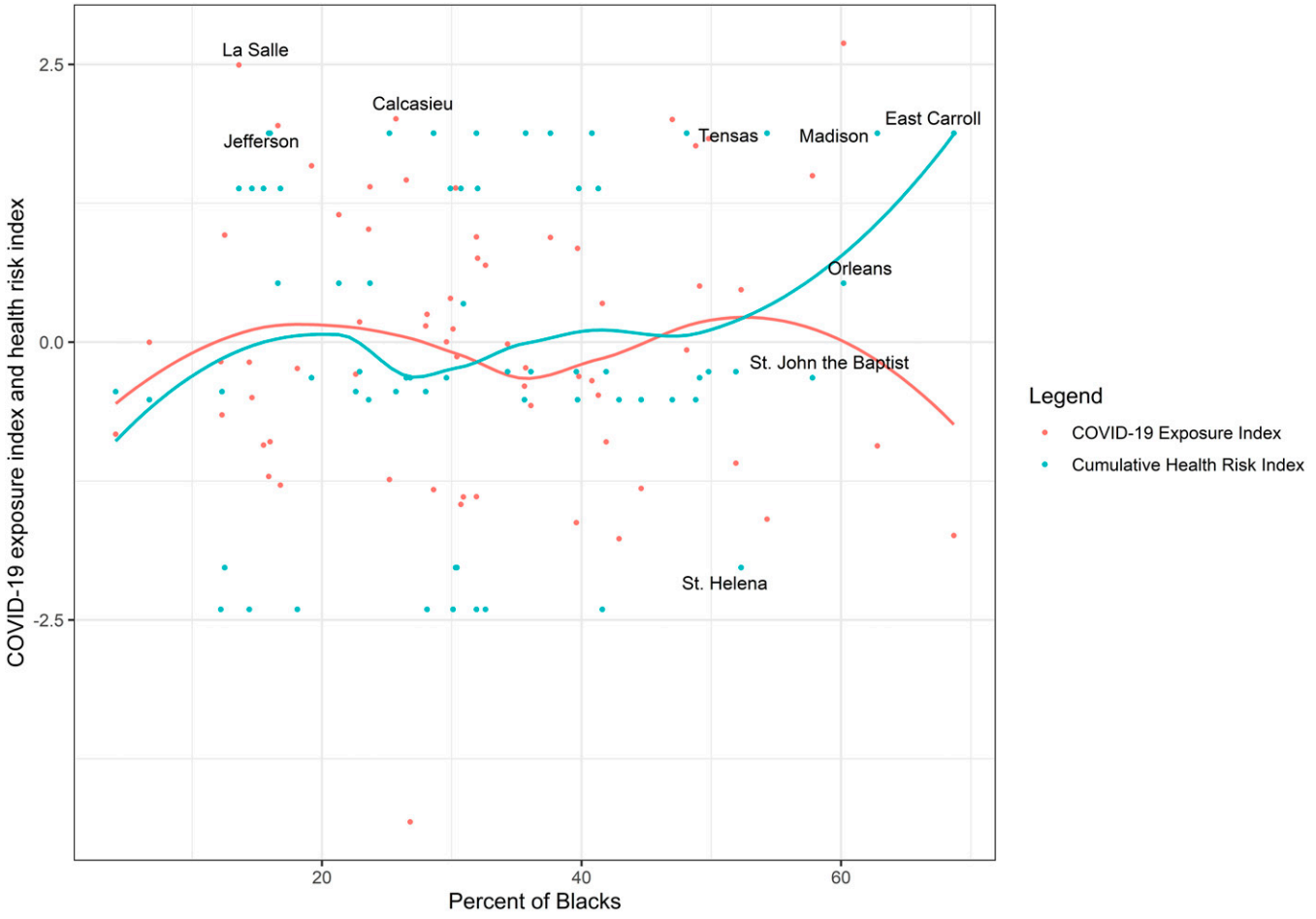

Fig. 7. Relationship between the percentage of Black residents, the cumulative health risk, and the COVID-19 index.

problems, and relatively high residential segregation as well as a high number of TRI facilities with a large TRI output. As of 1 December 2020, 44.4% of COVID-19–related deaths in Jefferson Parish have been among Black residents, which represents a smaller but significant disparity in COVID-19 mortality within the parish (69). Finally, East Baton Rouge has high residential segregation and is ranked fourth for severe housing problems statewide. In East Baton Rouge, 55.8% of deaths have been among Black residents, again representing a racial disparity in COVID-19 deaths smaller than that of Orleans but still significant based on parish demographics (69).

The second type of parishes identified in our hot spot analysis has low population density, fewer than 12,000 people, and a population that is over 32% Black residents (above the state average) as well as many aggregate stressors and high cumulative health risk. These parishes include Tensas, East Carroll, and Madison. East Carroll has high economic, health care access, and social housing stress for all of Louisiana. Specifically, East Carroll has the highest rate of childhood and adult poverty as well as the highest number of children in single-parent households. The parish also has high income inequality and the lowest median household income. The parish has the highest number of preventable hospital stays, the highest number of babies born at low birth weights, and a high number of premature deaths for Black residents. Finally, East Carroll ranks third for severe housing problems and third in residential segregation, has low access to healthy foods, and low rates of homeownership. Madison Parish similarly experiences high rates of childhood and adult poverty and low median household income as well as numerous preventable hospital stays, a high number of babies born at low birth weights, and high rates of preventable deaths among Black and White residents. The parish also has numerous severe housing problems, low access to healthy food, and significant residential segregation. Tensas has low access to healthy food, low median household income, high rates of poverty for both children and adults, and high rates of uninsured.

As of October 2020, these parishes had only experienced moderate or low COVID-19 exposure stress accompanied by moderate or low COVID-19 mortality. In November 2020, East Carroll and Madison Parishes experienced a sharp increase in COVID-19 infection and mortality. As of 1 December 2020, East Carroll has the highest number of cases as well as the highest mortality rate in all of Louisiana. Madison is ranked sixth (28). This suggests that as the pandemic progressed to more rural parishes, these parishes became central areas of COVID-19 infection and death. Of note, these parishes have the highest percentage Black populations for all parishes with lower than 15,000 residents, which suggests a continuation of racial disparities in COVID-19 exposure and mortality during the second wave of COVID-19 infection in Louisiana.

Conclusions

Using hot spot analysis, we identify parishes in two main groups. The first group has moderate to high levels of aggregate stress, specifically high environmental quality stress, but only certain drivers of social housing and economic inequity. The parishes also have high cumulative health risk, high population

Table 2. Summary of parishes with high aggregate stress identified by hot spot analysis

Hot spot–identified parish group and parish	Population	Black (%)	Environmental quality	Social housing	Economic index	Health care access	Health risk	Total	COVID-19 exposure
High–population density parishes									
East Baton Rouge	440,059	38.3	5.45	2.73	−1.17	−0.84	−0.52	5.66	2.00
Orleans	390,144	42.5	2.04	7.11	2.10	−0.35	0.53	11.43	2.69
Jefferson	432,493	42.5	4.52	1.99	−1.43	−0.35	0.53	5.27	1.95
Low–population density parishes									
Tensas	4,334	32.7	−1.00	0.31	4.12	0.98	1.88	6.29	−1.59
East Carroll	6,861	32.7	−1.05	5.03	7.27	4.52	1.88	17.65	−1.74
Madison	10,951	32.7	−1.09	2.83	4.87	1.09	1.88	9.58	−0.93

High–population density parishes have high social housing index scores and high environmental quality index scores, which drive a high aggregate stress score. These parishes also have large Black populations and high COVID-19 exposure as of October 2020. Low–population density parishes have particularly high economic index scores as well as high social housing scores, high health care access scores, and high health risk index scores contributing to high aggregate stress scores. These parishes have the highest percentage of Black population for all the parishes with under 12,000 residents and experienced strong COVID-19 exposure in the winter of 2020.

densities, and predominantly Black populations as well as overall high COVID-19 exposure stress and mortality rates (as of October 2020). This group includes Orleans, Jefferson, and East Baton Rouge Parishes, which all had high COVID-19 infection rates and spread during the early months of the pandemic (March and April 2020). The second group of parishes has high aggregate stress, including high economic, social housing, and health care access stress, and high cumulative health risk. These parishes (East Carroll, Madison, and Tensas) have low population densities, predominantly Black populations, and initially low but growing COVID-19 exposure stress and mortality. As COVID-19 continues to spread in these parishes, signs of possible racial disparities in COVID-19 mortality are beginning to show.

This research provides a foundation for quantifying structural and environmental racism. Cumulatively, our results highlight how generations of structural and environmental racism in Louisiana have left Black and other BIPOC communities particularly vulnerable to natural disasters, such as the COVID-19 pandemic. This observation echoes a pattern of other environmental and natural disasters for Louisiana both past and present. Future work should expand the geographic extent of our analysis.

In turn, we make clear that support systems must be robust to ensure that BIPOC communities do not continue to suffer disproportionately. Policy makers would do well to address a lack of safe and affordable housing as well the availability of health care facilities. This includes both spatial and monetary barriers to health care access. High levels of environmental quality stress representing low air quality, unreliable drinking water safety, high output of toxic release, and lack of green space must be a high priority for policy makers, particularly in highly populated parishes. Environmental quality stress in these parishes should also be addressed within the context of a changing climate, which has repeatedly left Louisiana BIPOC communities at risk.

Data Availability. All study data are included in the article and/or *SI Appendix*.

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