Environmental Injustice in North Carolina's Hog Industry

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Rapid growth and the concentration of hog production in North Carolina have raised concerns of a disproportionate impact of pollution and offensive odors on poor and nonwhite communities. We analyzed the location and characteristics of 2,514 intensive hog operations in relation to racial, economic, and water source characteristics of census block groups, neighborhoods with an average of approximately 500 households each. We used Poisson regression to evaluate the extent to which relationships between environmental justice variables and the number of hog operations persisted after consideration of population density. There are 18.9 times as many hog operations in the highest quintile of poverty as compared to the lowest; however, adjustment for population density reduces the excess to 7.2. Hog operations are approximately 5 times as common in the highest three quintiles of the percentage nonwhite population as compared to the lowest, adjusted for population density. The excess of hog operations is greatest in areas with both high poverty and high percentage nonwhites. Operations run by corporate integrators are more concentrated in poor and nonwhite areas than are operations run by independent growers. Most hog operations, which use waste pits that can contaminate groundwater, are located in areas with high dependence on well water for drinking. Disproportionate impacts of intensive hog production on people of color and on the poor may impede improvements in economic and environmental conditions that are needed to address public health in areas which have high disease rates and low access to medical care as compared to other areas of the state. *Key words:* African Americans, environmental health, environmental justice, epidemiology, geographic information systems, rural health. *Environ Health Perspect* 108:225–231 (2000). [Online 8 February 2000]
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Environmental injustice refers to the disproportionate burden of pollution on people of color and the poor (*1–3*). In contrast to rural America's traditional image of unspoiled territory free of industrial pollution, poor rural communities have been targeted in recent years for urban, industrial, and military wastes that are unwanted by communities with larger populations and more political power (*4–6*). Other threats of environmental injustice in rural areas have come about because of the industrialization of agricultural activities (*7,8*). In this work we consider the environmental justice implications of the transformation of hog production in North Carolina from a system dominated by small independent farmers to large vertically integrated agribusiness production.

Between 1985 and 1998 North Carolina moved from fifteenth to second in hog production among U.S. states, with approximately 10 million head outnumbering the state's human population of approximately 7.5 million (*7,9*). The expansion of production has been accompanied by a declining number of operations and an increasing average size of operations (*10*). In 1998, market prices for hogs dropped to their lowest levels since the 1920s, which accelerated the demise of smaller independent producers. Most hogs are now produced by operators who work under contract to corporate integrators, which provide the management plan and own the animals, feed, and transportation; the operators own the land, buildings, and waste (*11*). In the past, hog production was dispersed throughout the state, but it has become consolidated in the coastal plain region, which concentrates waste and the potential for environmental damage in a region that is sensitive because of low-lying flood plains and high water tables (*10*).

Intensive swine production may pose environmental health dangers because of the high volume of waste, the chemical and microbial content of the waste, and the practice of using liquid waste management systems that are not isolated from the environment (*12*). In intensive hog production facilities, referred to as confined animal feeding operations (CAFOs), thousands of hogs are housed in large buildings. Waste is collected in cesspools for anaerobic decomposition and is subsequently sprayed on fields. Airborne emissions from confinement houses, cesspools, and spray fields contain ammonia, hydrogen sulfide, hundreds of volatile organic compounds, dusts, and endotoxins. These mixtures, which cause respiratory dysfunction in hog confinement-house workers (*13–28*) and possibly lower level symptoms in nearby residents (*29,30*), are highly obnoxious odorants that affect quality of life (*29–31*) and may be associated with mood disorders and lowered immune function (*32,33*).

Leaking cesspools and waste sprayed on fields can contaminate groundwater with nitrates and pathogens. The North Carolina State Health Department's (Raleigh, NC) well-testing program for the neighbors of intensive hog operations has documented elevated nitrates from hog operations (*34*). Groundwater contamination is a particular problem in eastern North Carolina because the water tables are high and many wells are shallow and unlined. No active population-based surveillance data are available to document pathogen contamination or the incidence of infections. Hog operations also contaminate surface waters, which may lead to high pathogen loads, eutrophication, and the promotion of algae and dinoflagellate growth (*35–39*).

The coastal plain region of North Carolina is also part of the southern Black Belt, a region where the agricultural economy was first built on the basis of slave labor and where a majority of rural African Americans in the United States still reside. The concentration of hog production in this poor region of the state has therefore raised the issue of environmental injustice (*40*). As in the case of other environmental justice problems, the presence of this polluting industry is a threat to public health because it may lower land values and quality of life and impede healthier economic developments that are needed in communities which suffer from low wages, lack of access to medical care, and poor nutritional options. Environmental injustice in the North Carolina hog industry has previously been investigated for counties (*7,9*) and U.S. Census Bureau (Suitland, MD) block groups (*41*). Using data for census block groups (areas of approximately 500 households), we

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examined the extent to which hog CAFOs are located disproportionately in communities with high levels of poverty, high proportions of nonwhite persons, and high percentages of households dependent on well water. In addition, because agricultural activities are located in rural areas where land is inexpensive, and because many rural areas are poor and nonwhite, we also considered whether relationships between the locations of hog CAFOs and poverty, race, and well use can be explained by the rural nature of these areas.

Materials and Methods

We obtained a list of all animal operations registered with the North Carolina Division of Water Quality (DWQ; Raleigh, NC) as of February 1998. Animal operators report information on the number of head, species and type of animals, aspects of the liquid waste management system, the latitude and longitude coordinates of the facility, and the name of the corporate integrator, if any, with whom the operator has a contract. Swine operations are required to register with the DWQ if they have > 250 head and if they use a liquid waste management system. The steady state live weight (SSLW) of the herd was calculated by the DWQ as a function of the number of head of each type (breeding sows, farrow to wean pigs, wean to feeder pigs, feeder to finish hogs, boars, and gilts) and the average weight for each type hog. Finished hogs, ready for market, weigh approximately 240 lb.

Of the 3,039 animal operations in the database, 2,585 were swine operations (Figure 1). Facilities with missing data or head counts < 250 were excluded. We located the facilities within the state using latitude and longitude data. For 257 facilities, geographic coordinates placed the facility outside of the county of operation, outside the state, or the coordinates were missing. Missing and incorrect geocoordinates were corrected using local maps, geographic information systems software, and the driving instructions provided to state inspectors. The DWQ was contacted to provide information for operations that were missing road instructions or had incomplete instructions, and on those that were out of business. Operations with coordinates inside the correct county were not examined further. Three university-owned operations, which are not subject to the same commercial location considerations as other facilities, were excluded from the analysis. The remaining 2,514 swine CAFOs were included in the analysis (Figure 1).

We used geographic coordinates for the swine operations to locate the facilities within the boundaries of block groups. The number of facilities in each block group was the dependent variable in analyses quantifying the association between number of hog CAFOs and the characteristics of block groups. Because airborne emissions from hog CAFOs may affect the environment well beyond their boundaries, we also conducted analyses considering buffer zones of 1 and 2 miles, in which the count of operations for a block group consisted of the number of hog CAFOs that were within 1 or 2 miles of the block group's boundaries.

Information on race, poverty, and water source was obtained for 1990 census block groups, the smallest geographical unit for which economic and demographic data can be obtained and the unit most closely approximating neighborhoods or communities. The 1990 census provided the most recent block group level geographic information available, and corresponded to the time during which hog production in North Carolina began to accelerate rapidly. Three environmental justice variables of interest were defined as the percentage nonwhite population, the percent of persons in poverty, and the percent of households that used well water. We also obtained the total number of persons, land area in square miles, and population density for each block group.

Some areas of the state, including metropolitan areas, have no presence of the commercial swine production industry. These areas, including mostly white Appalachia and some largely African American areas in central cities of the Piedmont, could have skewed the evaluation of the relationship between hog operations and the environmental justice variables. Therefore, we excluded from the analysis 14 of the state's 100 counties that did not border a county with a hog CAFO and the state's five cities with 1990 populations > 100,000. The remainder of the state considered in the analysis included 4,177 block groups with a population of approximately 4.9 million persons.

Relationships between the environmental justice variables (poverty, race, and water source) and the presence of hog CAFOs were first evaluated by summing the total number of hog CAFOs in quintiles of the distribution of each environmental justice variable. Because quintiles have the same number of block groups by definition, the ratio of the number of hog CAFOs in each higher quintile as compared to the lowest quintile of the variable is equal to the prevalence ratio of the number of operations per block group at higher levels as compared to the lowest level. This unadjusted measure is referred to as a crude ratio.

We prepared maps to show the spatial distribution of the major study variables. Chloropleth maps of poverty, race, and population density are keyed to bar graphs indicating the numbers of block groups in each category. Because block groups vary greatly in land area and because the visual impact of the chloropleth map is influenced by land area, categories based on quintiles of block groups are not sensitive to the spatial distribution of the variables. Therefore, we chose category boundaries for maps to reflect the distribution of each variable.

Agricultural operations of all types are located in rural areas, where population density is low and land is inexpensive. Rural areas have higher poverty rates, much of the southern Black Belt is rural, and rural areas are often not served by municipal water systems.

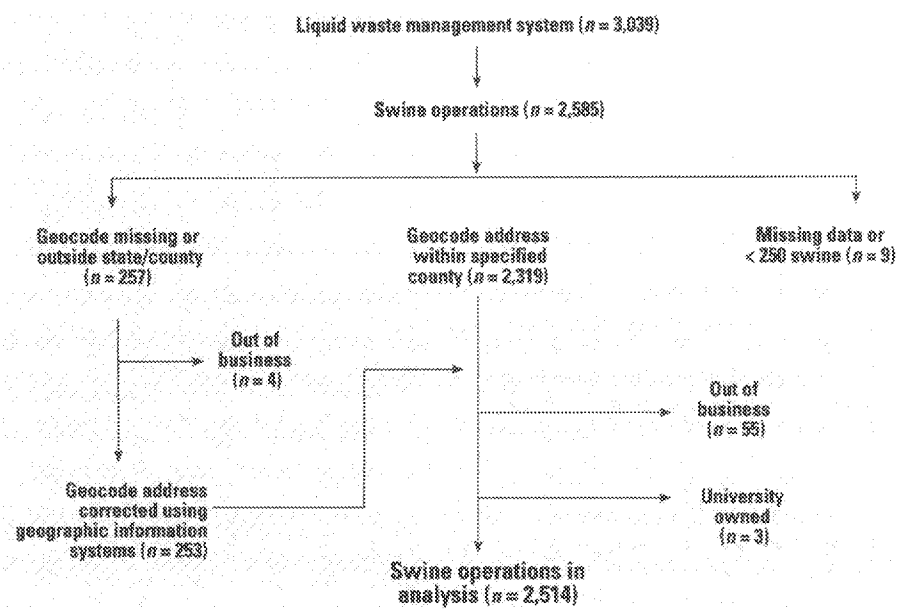

Figure 1. The identification of swine CAFOs from the DWQ data, February 1998.

It was therefore of interest to determine the extent to which excess numbers of hog operations in poor, nonwhite, and well-water-dependent communities could be considered a function of their low population density. We used Poisson regression to model the relationship between the natural log of population density and the number of hog operations per block group. We used linear, quadratic, and cubic terms for the log of population density to obtain an adequate fit of the model to the data. Higher order terms did little to improve the fit of the model.

Because Poisson models were overdispersed (model deviance/degrees of freedom > 1), we set the scale parameters for the models equal to the overdispersion values, which ranged from 1.6 to 1.8. We included indicator variables to represent each of the higher quintiles and we calculated the ratios of the number of hog CAFOs in block groups in each higher quintile of the environmental justice variables as compared to the lowest. We adjusted these ratios for population density using the cubic polynomial regression. Models were fit separately for operations under contract to corporate integrators and for those that were independent.

Results

Figure 2 shows the locations of hog CAFOs in North Carolina and the areas of the state excluded from the analysis. Each red dot represents one hog operation. The dense area of operations in the southeastern part of the state is centered on Duplin and Sampson Counties, the two largest hog-producing counties in the United States.

The size distribution of the 2,514 North Carolina hog CAFOs is shown in Table 1. The smallest 277 operations had an SSLW of < 100,000 lb each, which accounted for 11.0% of the operations and 1.4% of the state's SSLW. The SSLW of the largest 369 operations was ≥ 1 million pounds, which accounted for 14.7% of the operations and 44.4% of the SSLW in the state.

The geographic distribution of poverty is shown in Figure 3. Figure 3B shows the number of block groups in each category of poverty. For example, the categories with 0–5 and 5–10% persons in poverty each include approximately 1,000 block groups. Low-poverty areas predominate in the central Piedmont region of the state, whereas the higher poverty areas are located in the eastern coastal plain and in the northwest region (the edge of Appalachia).

Figure 4 shows the percentage nonwhite population. Most of the approximately 1,800 block groups with < 10% nonwhite population are located in the western part of the study area. These include 454 block groups that are 100% white. Areas with larger proportions of nonwhite population (mostly African Americans) are primarily in the eastern part of the state. An exception to the primarily African American makeup of the state's nonwhite population is Robeson County, located just southeast of the angle formed by the two straight lines along the central southern boundary of state. Robeson County is home to the Lumbee Indians and its population is approximately one-third Native American.

Table 2 presents the characteristics of block groups in relation to the environmental justice variables. Larger numbers of persons in the lowest categories of poverty live in a smaller land area, which results in higher population densities in areas with less poverty. Block groups in the lowest quintile of poverty contained only 43 hog CAFOs with 17.5 million lb of hogs, an average of 406.8 thousand lb/operation. In comparison, there are 225 hog operations in the second quintile

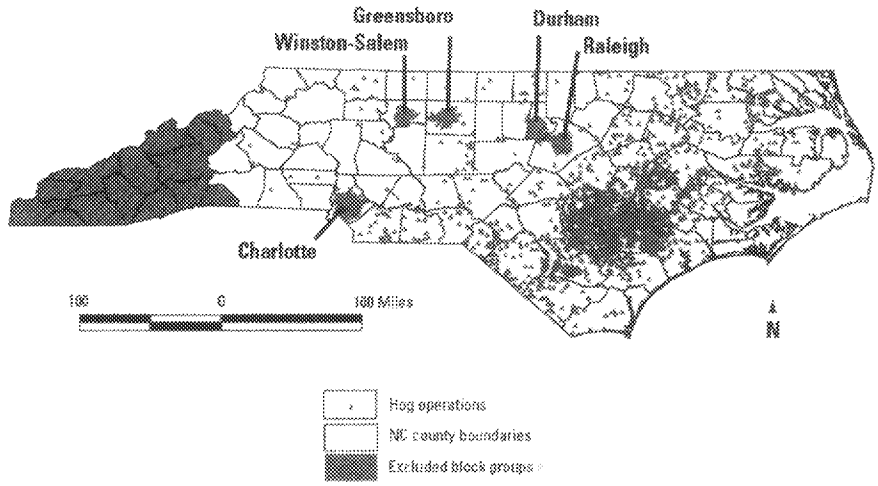

Figure 2. North Carolina study areas and locations of intensive hog operations, 1998.

Table 1. SSLW of North Carolina hog CAFOs, 1998.

SSLW (millions of pounds)	Operations (*n*)	Operations (%)	Cumulative SSLW (millions of pounds)	SSLW (%)
0.02 to < 0.10	277	11.0	20.8	1.4
0.10 to < 0.25	583	23.2	97.6	6.8
0.25 to < 0.50	708	28.2	268.2	18.6
0.50 to < 1.0	577	23.0	414.5	28.8
1.0 to < 10.1	369	14.7	639.7	44.4
Total	2,514	100	1,440.8	100

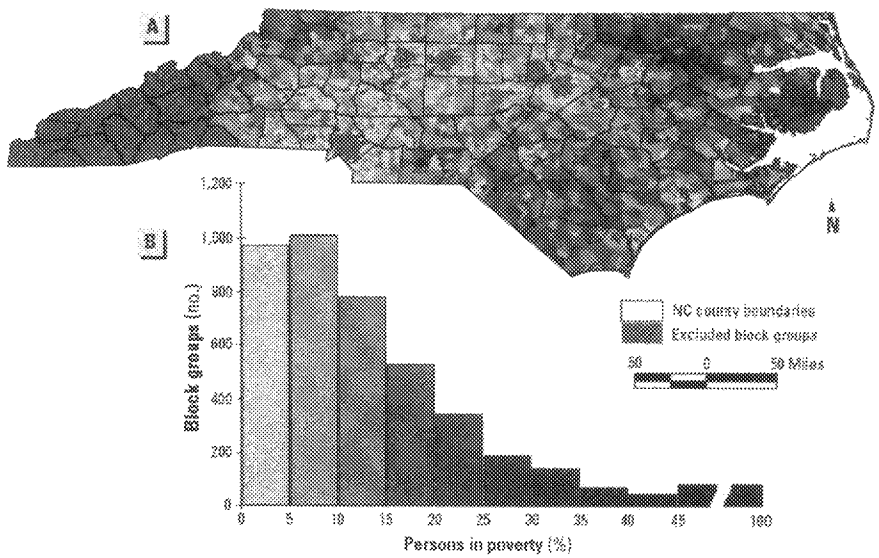

Figure 3. (*A*) The percent of persons in poverty in North Carolina, 1990. (*B*) The number of block groups in each category of poverty.

of poverty, 585 in the third, and > 800 in the fourth and fifth quintiles. Increases in total SSLW in areas with higher poverty levels are due to both larger numbers of operations and higher SSLW per operation.

Table 2 also shows the distribution of persons, land area, and hog operations for categories of the percentage nonwhite population. Population densities are lowest in the fourth and fifth quintiles of the percentage nonwhite variable. The 123 hog CAFOs in the lowest quintile have an SSLW of 48 million lb. The number of hog CAFOs in higher quintiles of the percentage nonwhite population increases to a maximum of 820 in the fourth quintile. The largest SSLW is in the highest quintile, 513 million lb, and the average size of operations increases with increases in the percentage nonwhite population.

Table 2 also presents information for block groups in quintiles of percentage of households using well water. This variable is most clearly related to population density, which declines from 1,315.4 persons/square mile in areas where < 1% of households have well water to 53.9/square mile in areas where > 85% of households have well water. Only five hog CAFOs, with a total SSLW of 1.2 million lb, are found in the lowest quintile of well-water use. Almost half of all hog CAFOs are located in block groups where > 85% of households have well water.

Although Table 2 shows clearly that there are more hog CAFOs in areas with higher percentages of persons in poverty, nonwhite persons, and households that use wells, it also shows that areas with the highest levels of these characteristics have lower population density, indicating that they are more rural areas. Population density is generally low throughout the eastern part of the state as compared to much of the Piedmont (Figure 5). Figure 6 shows that the number of hog operations per block group is strongly related to population density and that the observed number of operations per block group is predicted well by a cubic polynomial on a log–log scale. The number of operations per block group is lowest at the highest density, reaches a peak at approximately 20 persons/square mile, and declines somewhat at the lowest levels of density. The total number of operations in each category, shown in Figure 6 beside the observed values for the number of operations per block group, shows that the vast majority of operations are in block groups with fewer than 100 persons/square mile.

Table 3 summarizes the relationship between environmental justice variables and the presence of hog CAFOs in terms of the ratio of the number of operations per block group among block groups in the higher quintiles as compared to the lowest quintiles. The crude ratio of the number of operations per block group can be calculated from the data in Table 2. The ratio, adjusted for population density, is shown in the second column under each variable in Table 3. The large ratios for the higher levels of poverty, which vary from 5 to 20, are substantially reduced with adjustment for the rural nature of those areas. Adjusted ratios increase in a stepwise fashion with higher levels of poverty, from 3.0 in the second quintile to 7.2 in the highest.

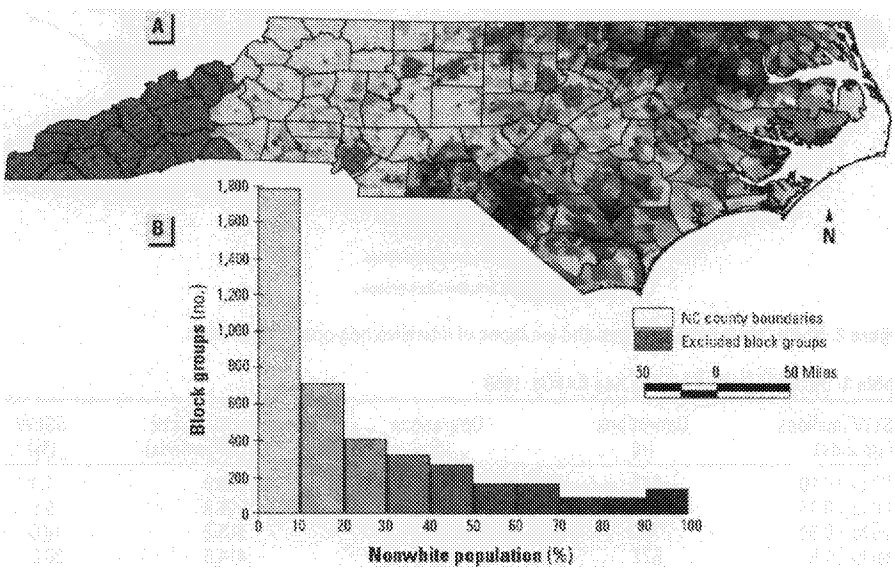

Figure 4. (*A*) The percentage nonwhite population in North Carolina, 1990. (*B*) The number of block groups in each category of the percentage nonwhite population.

Table 2. Characteristics of block groups in relation to poverty, race, and water source.

Characteristic	Block groups (*n*)	No. persons (thousands)	Land area (thousands of square miles)	Population density (people per square mile)	Total operations	Pounds of hogs (millions)	SSLW per operation (thousands)
Poverty (%)							
0 to < 4.9	835	1,118	4.7	238.0	43	17.5	406.8
4.9 to < 8.8	835	1,069	7.2	148.0	225	100.6	447.0
8.8 to < 13.6	836	966	9.4	103.0	585	284.9	486.9
13.6 to < 21.0	835	930	11.3	82.1	850	503.6	592.5
21.0 to 100	836	853	9.4	90.5	811	534.3	658.8
Nonwhite (%)							
0 to < 2.3	835	840	7.3	114.5	123	48.0	390.2
2.3 to < 9.3	835	1,048	6.3	165.2	165	78.1	473.6
9.3 to < 20.8	836	1,039	8.0	129.5	623	306.2	491.5
20.8 to < 44.2	835	1,103	10.5	105.5	820	495.5	604.3
44.2 to 100	836	907	9.9	91.7	783	513.0	655.1
Well water (%)							
0 to < 1.0	835	897	0.7	1,315.4	5	1.2	246.0
1.0 to < 16.4	835	1,068	3.4	314.4	185	91.6	495.1
16.4 to < 46.1	836	1,039	8.3	124.5	386	205.9	533.4
46.1 to < 85.5	835	1,020	12.7	80.5	734	450.5	613.7
85.5 to 100	836	914	17.0	53.9	1,204	691.6	574.4
Total[a]	4,177	4,937	42.1	117.4	2,514	1,440.8	573.1

[a]Sum for each variable.

Crude ratios for the percentage nonwhite population are smaller than the crude ratios for the percent of persons in poverty, ranging from 1.3 in the second quintile to 6.7 in the fourth quintile. Furthermore, the ratios are less affected by adjustment for population density. The ratio for the second quintile increases to 1.9, whereas ratios in the fourth and fifth quintiles are somewhat decreased. Adjusting for population density, the third, fourth, and fifth quintiles of the percentage nonwhite population have approximately 5 times as many hog CAFOs as those in the lowest quintile.

Hog CAFOs show a strong and monotonically increasing relationship to the percent of households using well water, with prevalence ratios ranging from 37.0 in the second to 240.8 in the fifth quintile. Most of this strong relationship, however, can be explained by the lower population density of areas with a high dependence on wells. Adjusted ratios in higher quintiles as compared to the lowest range between 4 and 5.

Table 4 shows the prevalence ratios for hog CAFOs in block groups cross-classified by poverty and the percentage nonwhite population, adjusted for population density. Block groups in the 0–5% poverty and 0–2% nonwhite population category are considered the referent group. Table 4 shows that increases in the percentage nonwhite population have little effect on number of hog operations among block groups in the lowest poverty group. Similarly, only modest increases in the numbers of operations are seen with increasing poverty levels among block groups in the lowest percent nonwhite category. However, prevalence ratios increase dramatically in areas with higher proportions of poor and nonwhite persons, reaching a ratio of 9 times as many operations in block groups with ≥ 12% poverty and ≥ 10% nonwhite population, adjusted for population density.

Most of the growth in NC pork production during the 1990s has been in large operations managed for corporate integrators rather than in independent operations. Therefore, we repeated the analyses for poverty and race separately for operations that listed corporate integrators on their permit applications (n = 1,603) and those that did not (n = 911). Prevalence ratios for integrator and independent CAFOs, adjusted for population density, are shown in Table 5. Although there is an excess of both types of operations in areas with greater percentages of poor and nonwhite populations, the excess is substantially larger for integrator operations at every level of poverty and race. Among the areas in the poorest quintile of block groups there are 20 times more integrator CAFOs than in the least-poor quintile, adjusted for differences in population density, whereas the excess of independent CAFOs in those areas is only 3.5 times. Similarly, block groups in the highest three quintiles of the percentage nonwhite population show an excess of integrator operations of 7 to 8 times, whereas the excess of independent operations is approximately 3 times.

Our analyses reported above consider only populations within the block groups containing hog CAFOs as potentially affected. However, airborne emissions and water pollution from CAFOs may travel some distance. Therefore, we reclassified the number of hog CAFOs in each block group considering 1- and 2-mile buffers around each operation. In these analyses, the number of hog operations in a block group is considered the number within the block group's boundaries plus the number within 1 or 2 miles of the block group, under the assumption that CAFOs located within 1 or 2 miles may impact the populations of neighboring block groups. We conducted analyses for the percent of persons in poverty and the percentage nonwhite population using the cubic polynomial model to adjust for population density. The ratios for the percent of persons in poverty were somewhat reduced, ranging between 2.2 and 5.9 under 1 and 2-mile buffers, as compared to a range of 3.0–7.2 with no buffer (Table 3). The ratios for the percentage nonwhite population were similar to ratios using a zero buffer, ranging from 1.9 to 5.3.

Discussion

We examined the locations of North Carolina's approximately 2,500 intensive hog confinement facilities in relation to poverty levels, race, and household water source of neighboring populations. These facilities are located disproportionately in communities with higher levels of poverty, higher proportions of nonwhite persons, and higher dependence on wells for household water supply. The disproportionate location of hog CAFOs in these areas raises numerous public health and social justice issues (*7,9,42,43*). Intensive swine production and its attendant pollution are concentrated in areas of North Carolina that have the highest disease rates (*44,45*), the least access to medical care, and the greatest need for positive economic development and better educational systems (*46*). The adverse effects of hog CAFOs on the quality of life and on community aesthetics (*29–31*) threaten the community economic and social developments that are fundamental to improved public health (*47*).

This study did not address siting decisions for particular hog operations. The reasons why a facility is located in a specific place are, in some ways, particular to the historical situation, business climate, local culture, and personal or family decision making. However, the pattern of location of industries reflects institutional factors and the political and economic power of local populations.

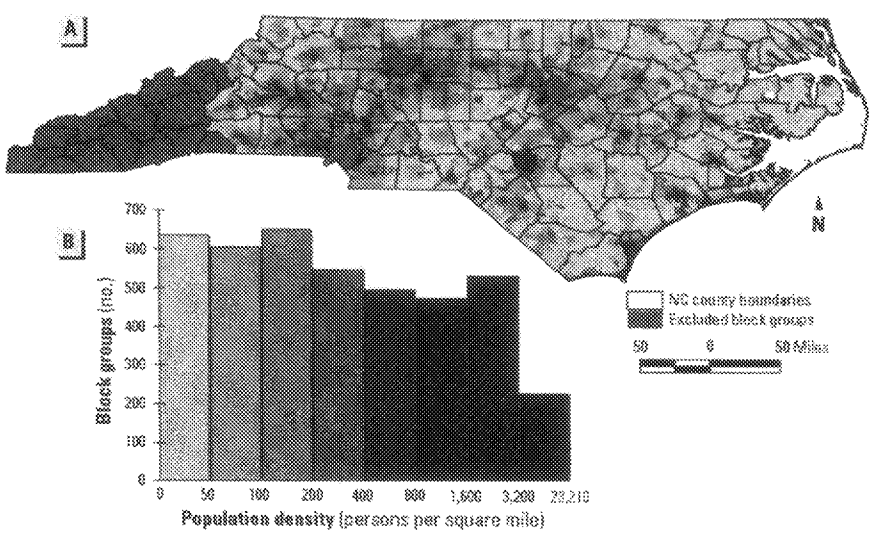

Figure 5. (*A*) North Carolina population density, 1990. (*B*) The number of block groups in each category of population density.

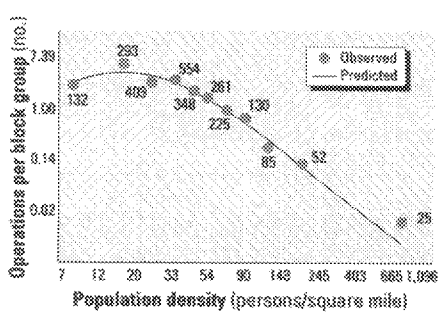

Figure 6. Number of operations per block group in relation to population density.

Table 3. Crude and adjusted prevalence ratios of numbers of hog CAFOs per block group for quintiles of poverty, nonwhite population, and well-water source.

	Poverty (%)		Nonwhite (%)		Well water (%)	
Quintile	Crude ratio[a]	Adjusted ratio[b]	Crude ratio[a]	Adjusted ratio[b]	Crude ratio[a]	Adjusted ratio[b]
I	1.0	1.0	1.0	1.0	1.0	1.0
II	5.2	3.0	1.3	1.9	37.0	4.9
III	13.6	5.5	5.1	5.1	77.2	4.2
IV	19.8	6.4	6.7	5.1	146.8	4.2
V	18.9	7.2	6.4	4.7	240.8	4.7

[a]Unadjusted ratio of number of operations, higher quintile as compared to the first quintile. [b]Adjusted for population density, cubic polynomial.

These institutional inequalities are critically important issues to consider in addressing the public health problem of the disproportionate burden of polluting industries among poor and nonwhite populations (*1,2,5,40,48*).

Both poverty and race are strongly related to the location of hog operations, as shown in Tables 2 and 3. However, the combination of the two characteristics is of particular interest (Table 4). Increasing levels of poverty have only a modest effect in block groups with < 2% nonwhite populations. Similarly, increasing levels of nonwhite populations have little effect on the prevalence of hog operations among the block groups with < 5% poverty. It is the combination of a high percentage nonwhite populations and high poverty levels that is associated with the greatest excess of hog CAFOs, reaching a prevalence ratio of almost 10 for block groups with ≥ 12% poverty and ≥ 10% nonwhite population as compared to block groups with < 5% poverty and < 2% nonwhite population.

The industrialization of agriculture has brought about not only changes in size, but also in ownership. All of the hog operations considered in this research are large and fall under state regulations for intensive livestock operations. However, among these large operations, some are owned and operated by independent farmers who make their own management decisions. Other operations are owned by or are operated under contract with large agribusiness integrators that own and control the animals, feed, veterinary supplies, transportation, financing, and marketing of the product. Although both types of operations are large and industrialized, integrator operations have been responsible for most of the recent expansion of the industry (*7*). Because of their corporate structures, they may be in the best position to locate facilities based on economic considerations such as proximity to other operations, transportation routes, and slaughterhouses, as well as low land prices and the low local political power of host communities. Furthermore, there is a net decrease in jobs in regions where hog production has been industrialized because of the displacement of the independent producers who purchased locally (*49*). The concentration of hog CAFOs in poor and nonwhite areas is much greater for integrator than for independent operations (Table 5). Because the industry is moving rapidly toward greater economic concentration while family-owned businesses are in decline (*9,10,50*), the evidence of greater environmental injustice for integrator operations suggests that this problem may increase in the future.

This study was conducted using census block groups as the units of analysis. These areas, averaging approximately 500 households, are the smallest unit for which population data are available from the U.S. census and should provide better sensitivity and specificity to the characteristics of populations in greatest proximity to hog operations than would larger geographic units. The most recent block group data available are from 1990; more recent economic data from other sources are not available with this level of geographic detail. In any case, 1990 is an appropriate year for which to measure socioeconomic characteristics in our study of the location of hog operations because the period of rapid growth in the industry began in the late 1980s.

We depended on data from the DWQ for information on the locations and characteristics of intensive livestock operations in February 1998. Because a moratorium on the construction of new industrial operations was imposed by the North Carolina General Assembly in March 1997 (*7*) and has not yet been lifted (as of 1999), information from 1998 remains relevant. However, the validity of analyses reported here depend on the quality of information recorded by the state. We detected and corrected hundreds of errors in latitude/longitude coordinates for North Carolina hog CAFOs that were not located in the correct county according to the database (Figure 1). The extent of within-county errors in the data is unknown. Information on the size of the operation depends on the quality of data provided by the operator. The database contains information on a number of other characteristics of interest, such as the start date of the operation, the size and number of cesspools, and the acreage of spray fields. Unfortunately, these data were too incomplete to use in our analyses. Future studies of environmental justice and public health impacts of this industry would benefit from more complete and accurate data.

The public health implications of environmental injustice in the North Carolina hog industry are of special concern. Exposures in the environment of confinement houses are clearly related to impaired respiratory function, occupational asthma, and organic dust syndrome (*51*). This is an occupational health concern in areas with a large industry presence. In addition, environmental exposures to airborne emissions from hog CAFOs may be associated with respiratory effects (*29,30*) and impaired mood (*32,33*) in neighboring populations. Groundwater from hog CAFOs has been contaminated by nitrates in North Carolina (*34*). This is a special concern considering the findings presented here, which show that approximately half of the hog CAFOs are located in block groups of the state where > 85% of households depend on well water for drinking (Table 2). The eastern coastal plain of the state where most operations are located (Figure 1) has sandy soils and high water tables that facilitate the movement of water pollution from cesspools and

Table 4. Adjusted prevalence ratios[a] of the numbers of hog CAFOs per block group for block groups classified by poverty and nonwhite population.

	Nonwhite (%)		
Poverty (%)	0 to < 2	2 to < 10	10 to 100
0 to <5	1.0[b] (264)[c]	1.4 (335)	1.1 (254)
5 to < 12	1.8 (341)	3.6 (419)	7.0 (635)
12 to 100	1.7 (186)	3.1 (202)	9.6 (1,541)

[a]Adjusted for population density, cubic polynomial. [b]Referent group. [c]Number of block groups in parentheses.

Table 5. Adjusted prevalence ratios[a] of the numbers of hog CAFOs per block group for quintiles of poverty and nonwhite population: integrators and independents.

	Poverty (%)		Nonwhite (%)	
Quintile	Integrators	Independents	Integrators	Independents
I	1.0[b]	1.0[b]	1.0[b]	1.0[b]
II	7.2	1.9	2.4	1.5
III	16.2	2.7	7.5	3.4
IV	17.7	3.5	8.0	2.9
V	20.7	3.5	7.0	3.0

[a]Adjusted for population density, cubic polynomial. [b]Referent group.

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spray fields into groundwater, and older rural homes occupied by the poor and people of color often have shallow wells with less protection from contamination. Surface water pollution is a concern because of the spread of microbial contamination and the nutrient loading of rivers and estuaries.

Community concerns about environmental injustice in the distribution of hog operations in North Carolina are real. Predominantly poor and nonwhite communities that host a disproportionate number of hog CAFOs have a great need for positive economic development, environmentally sound industry, and better schools and medical care. Such community resources are important to public health (*47*). However, future prospects for these communities are threatened by an industry that produces highly obnoxious odors and reduces the quality of life for neighbors (*29–31*), which can hamper the growth of cleaner industries, reduce land values, and contribute to loss of locally owned land (*9,40*). Our findings should be taken into consideration as growth, technological change, and environmental remediation in the industry are considered.

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