Industrial Hog Operations in North Carolina Disproportionately Impact African-Americans, Hispanics and American Indians

Steve Wing and Jill Johnston
Department of Epidemiology
The University of North Carolina at Chapel Hill
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Summary

Background: In 2014, the North Carolina Department of Environment and Natural Resources (NC-DENR) issued a swine waste management general permit (the General Permit), which is expected to cover more than 2,000 industrial hog operations (IHOs). These facilities house animals in confinement, store their feces and urine in open pits, and apply the waste to surrounding fields. Air pollutants from the routine operation of confinement houses, cesspools, and waste sprayers affect nearby neighborhoods where they cause disruption of activities of daily living, stress, anxiety, mucous membrane irritation, respiratory conditions, reduced lung function, and acute blood pressure elevation. Prior studies showed that this industry disproportionately impacts people of color in NC, mostly African Americans.

Methods: We obtained records on the sizes and locations of permitted IHOs from NC-DENR and calculated the steady state live weight (SSLW) of hogs as an indicator of the amount of feces and urine produced at each IHO. We obtained block-level information on race and ethnicity from the 2010 census of the United States. We compared the proportions of people of color (POC), Blacks, Hispanics, and American Indians living within 3 miles of an IHO to the proportion of non-Hispanic Whites. We quantified relationships between race/ethnicity, presence of one or more IHOs, and the SSLW of IHOs, using Poisson regression and linear regression to adjust for rurality.

Results: Analyses based on a study area that excludes the state's five major cities and western counties that have no presence of this industry show that the proportion of POC living within 3 miles of an industrial hog operation is 1.52 times higher than the proportion of non-Hispanic Whites. The proportions of Blacks, Hispanics and American Indians living within 3 miles of an industrial hog operation are 1.54, 1.39 and 2.18 times higher, respectively, than the proportion of non-Hispanic Whites ($p<0.0001$). In census blocks with 80 or more percent people of color, the proportion of the population living within 3 miles of an industrial hog operation is 2.14 times higher than in blocks with no people of color. This excess increases to 3.30 times higher with adjustment for rurality. Adjusted for rurality, the SSLW of hogs within 3 miles of a census block increases, on average, 100,000, 64,000, 243,000, and 93,000 pounds for every 10 percent increase in POC, Black, Hispanic, and American Indian population ($p<0.0001$).

Conclusions: IHOs in NC disproportionately affect Black, Hispanic and American Indian residents. Although we did not examine poverty or wealth in this study, the results are consistent with previous research showing that NC's IHOs are relatively absent from low-poverty White communities. This spatial pattern is generally recognized as environmental racism.

Background

Swine production in North Carolina (NC) changed dramatically during the last decades of the 20th century. Between 1982 and 2006 the number of hog operations in the state declined precipitously while the hog population increased from approximately 2 to 10 million (Edwards and Driscoll 2009). Production became concentrated in eastern NC (Furuseth 1997).

Traditional NC producers raised small numbers of hogs, commonly fewer than 25, and hogs were one of several commercial crops on diversified farms (Edwards and Driscoll 2009). In contrast, industrial producers raise large numbers of hogs, often many thousands, in confinement houses that are designed to vent toxic gases and particles into the environment. Animal wastes are flushed into open cesspools and then sprayed on nearby fields. Pollutants emitted by IHOs include hydrogen sulfide, ammonia, a wide array of volatile organic compounds, and bioaerosols including endotoxins and other respiratory irritants (Cole et al. 2000) (Schiffman et al. 2001).

The negative impacts of particles and gases inside IHO confinements on worker health have been extensively described (Cole et al. 2000; Donham 1993; Donham et al. 1995; Donham et al. 2000; Donham 1990). Environmental pollutants from IHOs affect people who are more susceptible than workers due to young or old age, asthma or allergies, or other conditions. An extensive body of peer-reviewed scientific evidence shows that IHOs release contaminants into neighboring communities where they affect the health and quality of life of neighbors. Many of these studies have been conducted in NC. Hydrogen sulfide concentrations within 1.5 miles of IHOs in NC are associated with neighbors' ratings of hog odor and inability to engage in routine daily activities (Wing et al. 2008), increased stress and anxiety (Horton et al. 2009), irritation of the eyes, nose and throat, respiratory symptoms (Schinasi et al. 2011), and acute elevation of systolic blood pressure (Wing et al. 2013). A study of NC public middle school children who participated in an asthma survey, which was conducted by the NC Department of Health and Human Services, found that children attending schools within three miles of an IHO had more asthma-related symptoms, more doctor-diagnosed asthma, and more asthma-related medical visits than students who attended schools further away (Mirabelli et al. 2006). The same study reported a 23% higher prevalence of wheezing symptoms among children who attended schools where staff reported noticing livestock odor inside school buildings twice or more per month compared to children who attended schools where no livestock odor was reported (Mirabelli et al. 2006). Other studies in NC (Tajik et al. 2008) (Wing and Wolf 2000) (Bullers 2005) (Schiffman et al. 1995) and elsewhere (Donham et al. 2007) (Thu et al. 1997) (Radon et al. 2007) also document negative impacts of IHO air pollution on neighbors' health and quality of life.

Liquid contaminants from IHOs are released to the environment through leakage of animal waste storage pits, runoff from land application of liquid wastes, atmospheric deposition, and failure of the earthen walls of waste pits (Burkholder et al. 2007). Overflow of waste pits during heavy rain events results in massive spills of animal waste into neighboring communities and waterways. For example, in late September, 1999, 237 NC IHOs were located in flooded areas identified from satellite imagery provided by the NC Division of Emergency Management (Wing et al. 2002). Parasites, bacteria, viruses, nitrates, and other components of liquid IHO waste pose threats to human health (Burkholder et al. 2007; Cole et al. 2000).

Routine use of sub-therapeutic doses of antibiotics to promote weight gain of hogs promotes antibiotic resistance, making infections in humans more difficult to treat (Silbergeld et al. 2008). Airborne bacteria, including antibiotic resistant strains, have been isolated from IHO air emissions (Schulz et al. 2012) (Green et al. 2006) (Gibbs et al. 2006), and antibiotic resistant bacteria are associated with animal vectors near industrial animal operations, including flies (Graham et al. 2009), rodents (van de Giessen et al. 2009), and migratory geese that land on NC's IHO liquid waste pits (Cole et al. 2005). A recent medical records study from Pennsylvania shows that people living near IHO liquid waste application sites have elevated rates of infection with methicillin resistant *Staphylococcus aureus* (Casey et al. 2013). NC industrial livestock workers carry strains of *Staphylococcus aureus* that are associated with swine, including antibiotic resistant strains (Rinsky et al. 2013). These bacteria could be spread by liquid waste and airborne particles.

Using information from the United States Census of 1990 and locations of IHOs reported by the North Carolina Department of Environment and Natural Resources (NC-DENR) in 1998, we showed that the state's IHOs were disproportionately located in areas where more people of color (POC), primarily African Americans, live (Wing et al. 2000). We concluded that their disproportionate location in communities of color represented an environmental injustice. Since 1998 additional IHOs have obtained permission to operate and others are no longer in business. Additionally, between 1990 and 2010 the state's population size and spatial distribution changed due to births, deaths and migration. In this report we update our previous findings by evaluating whether IHOs operating under the general permit issued on March 7, 2014, will disproportionately impact POC, Blacks, Hispanics, and American Indians.

Materials and Methods

Lacking a list of the unique IHOs operating under the General Permit finalized in 2014, we used a list of all permitted industrial animal operations provided by NC-DENR on January 24, 2013 that we had prepared for prior research. First we excluded all non-swine operations from the list. Next we excluded swine operations with expired permits and permits with an allowable head count equal to zero. We also excluded permits that did not appear on a list of permitted animal operations published by DENR in January, 2014. We merged multiple permits issued for the same facilities to obtain a total head count for each operation. However the head count may be misleading as a measure of the pollution from each IHO because some facilities primarily house small pigs while others primarily house large hogs. We therefore calculated each facility's total steady state live weight (SSLW) using NC-DENR's formula based on the number and average weight of each growth stage of swine permitted at the facility. We interpret SSLW as a summary measure of the feces and urine produced by the swine of different growth stages at each facility.

Following the protocol provided in our previous study we excluded facilities operated by research institutions because they are subject to different location and management decisions than are commercial operations (Wing et al. 2000). Finally, we excluded facilities that do not hold a certificate of coverage to operate under the General Permit because they operate under individual permits or National Pollutant Discharge Elimination System general permits. The resulting facilities should closely approximate those expected to seek to continue operating under

the renewed General Permit. The renewed General Permit takes effect on October 1, 2014, at which time we plan to update the list created for this research.

The vulnerability of people of any race/ethnicity to having polluting facilities nearby can be affected by the race and ethnicity of other people in their community. For example, African-Americans who live in areas primarily populated by non-Hispanic Whites have, generally, a lower susceptibility to being near polluting facilities than African-Americans who live in areas primarily populated by Hispanics or American Indians. We therefore conducted our primary analyses of disproportionate impact using the POC category. We also conducted analyses for specific racial/ethnic categories. We defined the following racial/ethnic categories: non-Hispanic White (non-Hispanics who identified as White and no other race), POC (all people not categorized as non-Hispanic white), Black (people who identified themselves as African-American or Black with or without any other race), Hispanic of any race, and American Indian (people who identified themselves as American Indian with or without any other race). We used block-level race/ethnicity-specific population counts from the US Census of 2010.

As large-scale agricultural facilities, IHOs are not located in major cities. Following the protocol adopted in our prior research, we defined a study area for our primary analyses that excluded census blocks in the five major metropolitan areas of NC (Charlotte, Winston Salem, Greensboro, Durham and Raleigh) as well as 19 western counties that neither have an IHO nor border a county that has an IHO. We conducted additional analyses for the entire state.

We considered residents of blocks to be affected by IHOs within three miles of the block centroid. Blocks were categorized as either having, or not having, an IHO within three miles. Additionally, we calculated the total permitted SSLW of hogs within three miles of the centroid of each block as a measure of the total potential influence of pollutants from nearby IHOs on the residents of the block.

As in our prior study, we also calculated the population density of each block, defined as the number of people per square mile. Population density is a measure of rurality, which is strongly related to the availability of land for agriculture and the price of land. Racial/ethnic groups in NC differ in their urban vs. rural residence, making them differentially susceptible to types of polluting facilities that locate in rural vs. urban locations. For example, a larger proportion of non-Hispanic Whites in NC live in remote rural areas than do Blacks, the racial comparison is affected not only by the susceptibility of Whites vs. Blacks to IHOs, but also by differences in whether they live in rural vs. urban areas. By adjusting for population density (or rurality), we compare racial vulnerability to IHOs for racial groups within each level of rurality. This adjustment is analogous to other statistical adjustments in epidemiology, as when the death rates of two countries are compared: even though death rates at every age may be higher in a poor than a rich country, the poor country may have a lower overall death rate simply because it has a younger age distribution. In that case, age-adjustment is used to compare mortality in the two countries just as we use density-adjustment to compare the proximity to IHOs in areas with different racial/ethnic make-up.

We used weighted Poisson regression to quantify relationships between race/ethnicity and the presence of one or more IHOs within three miles of a block. We used weighted linear regression to quantify relationships between race/ethnicity and the SSLW of hogs permitted within three miles of a block. We used census block populations as weights. In density-adjusted models we included variables for the natural log of population density raised to the first, second and third power. As in our prior analysis, this cubic model fit the data well and additional power terms added little to the model fit (Wing et al. 2000). For the two largest racial/ethnic groups other than non-Hispanic Whites, POC and Blacks, we categorized race/ethnicity in groups of blocks 20% in width compared to blocks with no POC using indicator variables. Due to smaller numbers in these categories we did not fit models with indicator variables for Hispanics and American Indians. We also considered the percent of population of each race/ethnicity as a continuous variable, estimating the added burden of IHOs for a 10% increase in the population.

This study involves neither random sampling nor randomization of exposure to IHOs, therefore statistical significance testing is inappropriate and confidence intervals do not correspond to the probability that the true values of measures of association are within the interval. However, the US-EPA considers statistical significance in its assessment of environmental racism. We therefore report p-values for differences in proportions of each racial/ethnic group within 3 miles of an IHO using t-tests. We report 95% confidence intervals (CIs) as measures of precision of the associations estimated from regression models. 95% CIs that exclude the null value (1.0 for ratios and 0.0 for differences) are commonly considered to be statistically significant at $p<0.05$.

Results

We estimate that 2,055 IHOs were operating under the General Permit in January 2014, and that they were permitted to house approximately 1.2 billion pounds of swine (Table 1). The 160 (7.7%) IHOs permitted to house between 20 and 100 thousand pounds accounted for only 1% of the total permitted SSLW. The 342 (17.2%) IHOs permitted to house between 1 and 10.2 million pounds accounted for 46.5% of the total.

Table 2 shows that there are over 6.5 million residents of the study area. Approximately 986,000 (15.1%) of these live in census blocks whose centroid is within 3 miles of an IHO that operates under the General Permit. This includes 602,380 non-Hispanic Whites and 383,522 POC. 13.1% of non-Hispanic Whites and 19.9% of POC in the study area live in blocks within 3 miles of an IHO.

Based on the study area population in Table 2, Table 3 shows ratios of percentage of POC living within 3 miles of an IHO compared to the percentage of non-Hispanic Whites living within 3 miles of an IHO. The percentage of POC living within 3 miles of an IHO is 1.52 times higher than the percentage of non-Hispanic Whites. The percentages of Blacks, Hispanics and American Indians living within 3 miles of an IHO are 1.54, 1.39 and 2.18 times higher, respectively, than non-Hispanic Whites. If residents of the study area had been randomized to live within 3 miles of an IHO, the probabilities of observing differences of these magnitudes or greater are less than 0.0001; the observed differences are considered to be highly statistically significant.

We calculated these same ratios based on the entire state population of 9,535,483. The percentages of POC, Blacks, Hispanics and American Indians living within 3 miles of an IHO are 1.38, 1.40, 1.26 and 2.39 times higher than the percentage of non-Hispanic Whites, respectively. These ratios are considered to be highly statistically significant.

Figure 2 shows the percent of people living within 3 miles of an IHO in relation to the percent of people of color in blocks. In areas with less than 20% POC, just over 10% of the population lives within 3 miles of an IHO. In areas with 60-80% POC, over 20% of the population lives so close to an IHO. In areas with more than 80% POC, more than a quarter of the population lives within 3 miles of an IHO.

Table 4 presents ratios of the percent of people living within 3 miles of an IHO in blocks with >0 to <20%, 20 to <40%, 40 to <60%, 60 to <80% and 80 to 100% POC compared to blocks with no POC. The total population in these categories ranges from 526,305 in blocks with 60 to <80% POC to 2,577,015 in blocks with >0 to <20% POC. Ratios are statistically significantly elevated for all areas with more than 40% POC with or without adjustment for rurality. Ratios on the right side of Table 4 are adjusted for rurality. These ratios increase with the percentage POC. The highest ratios occur in areas with more than 80% POC, where over three times as many people live near IHOs, adjusted for rurality, compared to areas with no POC. These excesses are considered to be highly statistically significant.

Table 5 shows the results of analyses for Blacks parallel results to in Table 4 for all POC. Although ratios are somewhat lower for Blacks than POC, the percent of people living within 3 miles of an IHO is statistically significantly elevated in all groups of blocks that are more than 40% Black, with or without adjustment for rurality. In areas that are 80% or more Black, twice as many people live within 3 miles of an IHO compared to areas with no Blacks, a disparity that increases to three times more with adjustment for rurality. These excesses are considered to be highly statistically significant.

Table 6 presents the increased percent of the population living within 3 miles of an IHO for each additional 10 percent of the population of POC, Blacks, Hispanics, and American Indians. This analysis is similar to the results in Tables 4 and 5, but rather than using categories, the relationship between race/ethnicity and proximity to IHOs is modelled as a linear function. For every ten percent increase in POC, the proportion of people residing within 3 miles of an IHO increases, on average, by 10.7%. These values are 9.4, 8.5, and 16.2 for Blacks, Hispanics, and American Indians, respectively. Adjusting for rurality, 14.8% more people reside within 3 miles of an IHO for each additional ten percent POC. Adjusted values are 13.0, 16.3 and 11.8 for Blacks, Hispanics and American Indians, respectively. These linear relationships between race/ethnicity and living near IHOs are considered to be highly statistically significant.

Table 7 shows the difference in SSLW of hogs within 3 miles of residents of blocks with >0 to <20%, 20 to <40%, 40 to <60%, 60 to <80% and 80 to 100% POC compared to blocks with no POC. Blocks in categories with more than 20% POC have, on average, between 177 and 510 thousand pounds more hogs within 3 miles than blocks with no POC. Adjusting for population density, blocks with more than 60 percent POC have, on average, more than three-quarters of a

million pounds more hogs permitted within 3 miles than areas with no POC. These excesses are considered to be highly statistically significant.

Table 8 presents parallel results for percentage Black population. As for POC, areas with more than 20% Black residents have an excess SSLW of hogs compared to areas with no Black residents, and differences are greater with adjustment for rurality. Adjusted for population density, blocks with more than 40% Black residents have between 493,000 and 620,000 more pounds of hogs within 3 miles than areas with no Black residents. These excesses are considered to be highly statistically significant.

Table 9 provides the average additional SSLW of hogs permitted in areas with POC for each percent increase in specific racial/ethnic categories. Adjusted for population density, the permitted SSLW of hogs within 3 miles of blocks increases 100, 64, 242, and 92 thousand pounds for each ten percent increase in POC, Black, Hispanic, and American Indian population, respectively. These linear relationships between race/ethnicity and SSLW are considered to be highly statistically significant.

Figure 3 depicts the data analyzed above. Each dot represents an IHO that was operating under the General Permit in 2014. IHOs are concentrated in NC's Coastal Plain Region, between the Piedmont and Tidewater. The red areas of Figure 3 indicate that this region has more people of color than other parts of the study area.

Conclusion

IHOs operating under the NC-DENR General Permit in 2014 are disproportionately located near communities of color. The disparities are considered to be highly statistically significant for Blacks, Hispanics, American Indians, and all POC. IHOs pollute local ground and surface water. They routinely emit air pollutants that negatively impact the quality of life and health of nearby residents. In addition to their well-documented effects on physical, mental and social well-being, residents of areas with a high density of IHOs, and especially residents of color, have been subjected to intimidation including threats of legal action, violence, and job loss (Wing 2002). The industry's close ties with local and state government officials help it to avoid regulation that could protect neighbors, and creates barriers to democracy in rural communities of color (Thu 2001, 2003). These discriminatory impacts could be reduced by decreasing the density of production and use of technologies that prevent releases of pollutants.

References

Bullers S. 2005. Environmental Stressors, Perceived Control, and Health: The Case of Residents Near Large-Scale Hog Farms in Eastern North Carolina. Human Ecology 33:1-16.

Burkholder J, Libra B, Weyer P, Heathcote S, Kolpin D, Thorne PS, et al. 2007. Impacts of Waste from Concentrated Animal Feeding Operations on Water Quality. Environ. Health Perspect. 115:308-312.

Casey JA, Curriero FC, Cosgrove SE, Nachman KE, Schwartz BS. 2013. High-Density Livestock Operations, Crop Field Application of Manure, and Risk of Community-Associated Methicillin-Resistant Staphylococcus Aureus Infection in Pennsylvania. JAMA Internal Medicine 173:1980-1990.

Cole D, Todd L, Wing S. 2000. Concentrated Swine Feeding Operations and Public Health: A Review of Occupational and Community Health Effects. Environ. Health Perspect. 108:685-699.

Cole D, Drum DJ, Stalknecht DE, White DG, Lee MD, Ayers S, et al. 2005. Free-living Canada Geese and Antimicrobial Resistance. Emerging Infectious Diseases 11:935-938.

Donham K. 1993. Respiratory Disease Hazards to Workers in Livestock and Poultry Confinement Structures. Seminars in Respiratory Medicine 14:49-59.

Donham K, Reynolds S, Whitten P, Merchant J, Burmeister L, Popendorf W. 1995. Respiratory Dysfunction in Swine Production Facility Workers: Dose-response Relationships of Environmental Exposures and Pulmonary Function. American Journal of Industrial Medicine 27:405-418.

Donham K, Cumro D, Reynolds S, Merchant J. 2000. Dose-Response Relationships Between Occupational Aerosol Exposures and Cross-Shift Declines of Lung Function in Poultry Workers: Recommendations for Exposure Limits. Journal of Occupational and Environmental Medicine 42:260-269.

Donham KJ. 1990. Health Effects from Work in Swine Confinement Buildings. American Journal of Industrial Medicine 17:17-25.

Donham KJ, Wing S, Osterberg D, Flora JL, Hodne C, Thu KM, et al. 2007. Community Health and Socioeconomic Issues Surrounding Concentrated Animal Feeding Operations. Environ. Health Perspect. 115:317-320.

Edwards B, Driscoll A. 2009. From Farms to Factories: The Environmental Consequences of Swine Industrialization in North Carolina. In: Twenty Lessons in Environmental Sociology, (Gould K, Lewis T, eds). New York: Oxford University Press, 153-175.

Furuseth O. 1997. Restructuring of Hog Farming in North Carolina: Explosion and Implosion. Professional Geographer 49:391-403.

Gibbs SG, Green CF, Tarwater PM, Mota LC, Mena KD, Scarpino PV. 2006. Isolation of Antibiotic-Resistant Bacteria from the Air Plume Downwind of a Swine Confined or Concentrated Animal Feeding Operation. Environ. Health Perspect. 114:1032-1037.

Graham JP, Price LB, Evans SL, Graczyk TK, Silbergeld EK. 2009. Antibiotic Resistant Enterococci and Staphylococci Isolated from Flies Collected near Confined Poultry Feeding Operations. Sci Total Environ 407:2701-10.

Green CF, Gibbs SG, Tarwater PM, Mota LC, Scarpino PV. 2006. Bacterial Plume Emanating from the Air Surrounding Swine Confinement Operations. Journal of Occupational and Environmental Hygiene 3:9-15.

Horton RA, Wing S, Marshall SW, Brownley KA. 2009. Malodor as a Trigger of Stress and Negative Mood in Neighbors of Industrial Hog Operations. American Journal of Public Health 99 Suppl 3:S610-615.

Mirabelli MC, Wing S, Marshall SW, Wilcosky TC. 2006. Asthma Symptoms Among Adolescents Who Attend Public Schools that are Located Near Confined Swine Feeding Operations. Pediatrics 118:e66-75.

Radon K, Schulze A, Ehrenstein V, van Strien RT, Praml G, Nowak D. 2007. Environmental Exposure to Confined Animal Feeding Operations and Respiratory Health of Neighboring Residents. Epidemiology 18:300-308.

Rinsky JL, Nadimpalli M, Wing S, Hall D, Baron D, Price LB, et al. 2013. Livestock-Associated Methicillin and Multidrug Resistant Staphylococcus Aureus Is Present Among Industrial, Not Antibiotic-Free Livestock Operation Workers in North Carolina. PloS One 8:e67641.

Schiffman S, Bennett J, Raymer J. 2001. Quantification of Odors and Odorants from Swine Operations in North Carolina. Agricultural and Forest Meteorology 108:213-240.

Schiffman SS, Sattely Miller EA, Suggs MS, Graham BG. 1995. The Effect of Environmental Odors Emanating from Commercial Swine Operations on the Mood of Nearby Residents. Brain Research Bulletin 17:369-375.

Schinasi L, Horton RA, Guidry VT, Wing S, Marshall SW, Morland KB. 2011. Air Pollution, Lung Function, and Physical Symptoms in Communities Near Concentrated Swine Feeding Operations. Epidemiology 22:208-215.

Schulz J, Friese A, Klees S, Tenhagen BA, Fetsch A, Rosler U, et al. 2012. Longitudinal Study of the Contamination of Air and of Soil Surfaces in the Vicinity of Pig Barns by Livestock-Associated Methicillin-Resistant Staphylococcus Aureus. Applied and Environmental Microbiology 78:5666-5671.

Silbergeld EK, Graham J, Price LB. 2008. Industrial Ffood Animal Production, Antimicrobial Resistance, and Human Health. Annual Review of Public Health 29:151-169.

Tajik M, Muhammad N, Lowman A, Thu K, Wing S, Grant G. 2008. Impact of Odor from Industrial Hog Operations on Daily Living Activities. New Solututions 18:193-205.

Thu K, Donham K, Ziegenhorn R, Reynolds S, Thorne P, Subramanian P, et al. 1997. A Control Study of the Physical and Mental Health of Residents Living near a Large-Scale Swine Operation. Journal of Agricultural Safety and Health 3:13-26.

Thu K. 2001. Agriculture, the Environment, and Sources of State Ideology and Power. Culture and Agriculture 23:1-7.

Thu K. 2003. Industrial Agriculture, Democracy, and the Future. In: Beyond Factory Farming: Corporate Hog Barns and the Threat to Public Health, the Evironment, and Rural Communities, (Ervin A, Holtslander C, Qualman D, Sawa R, eds). Saskatoon, Saskatchewan:Canadian Centre for Policy Alternatives.

van de Giessen AW, van Santen-Verheuvel MG, Hengeveld PD, Bosch T, Broens EM, Reusken CB. 2009. Occurrence of Methicillin-Resistant Staphylococcus Aureus in Rats Living on Pig Farms. Preventive Veterinary Medicine 91:270-273.

Wing S, Cole D, Grant G. 2000. Environmental Injustice in North Carolina's Hog Industry. Environ. Health Perspect. 108:225-231.

Wing S, Wolf S. 2000. Intensive Livestock Operations, Health, and Quality of Life among Eastern North Carolina Residents. Environ. Health Perspect. 108:233-238.

Wing S. 2002. Social Responsibility and Research Ethics in Community-Driven Studies of Industrialized Hog Production. Environ. Health Perspect. 110:437–444.

Wing S, Freedman S, Band L. 2002. The Potential Impact of Flooding on Confined Animal Feeding Operations in Eastern North Carolina. Environ. Health Perspect. 110:387-391.

Wing S, Horton RA, Marshall SW, Thu K, Tajik M, Schinasi L, et al. 2008. Air Pollution and Odor in Communities Near Industrial Swine Operations. Environ. Health Perspect. 116:1362-1368.

Wing S, Horton RA, Rose KM. 2013. Air Pollution from Industrial Swine Operations and Blood Pressure of Neighboring Residents. Environ. Health Perspect. 121:92-96.

Figure 1
North Carolina study area, 2014

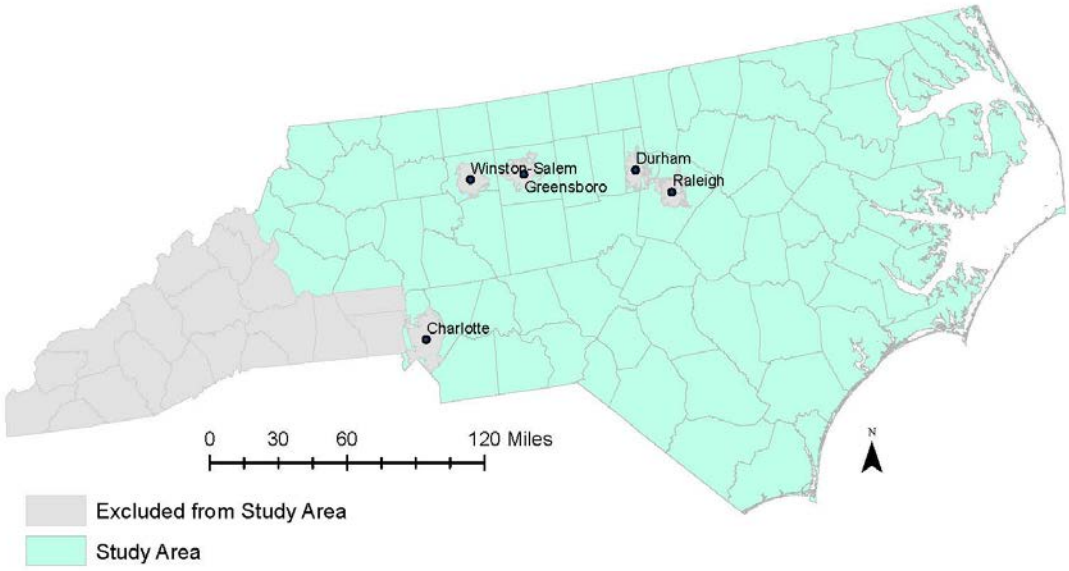

Figure 2
Percent of population living within 3 miles of an IHO
in relation to percent people of color, NC, 2014

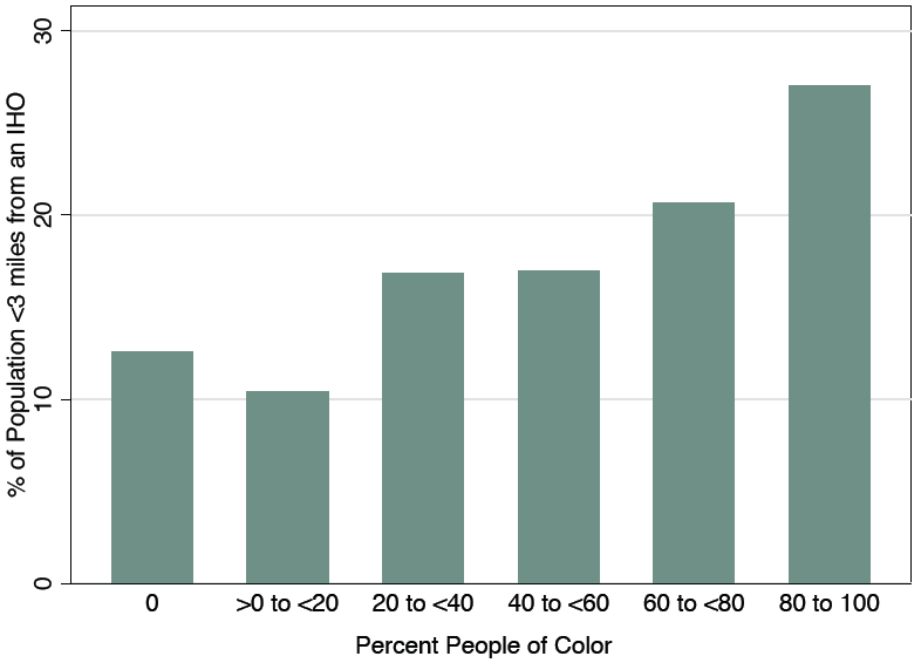

Figure 3
Racial and ethnic composition of census blocks and the locations of NC IHOs operating under the General Permit, 2014

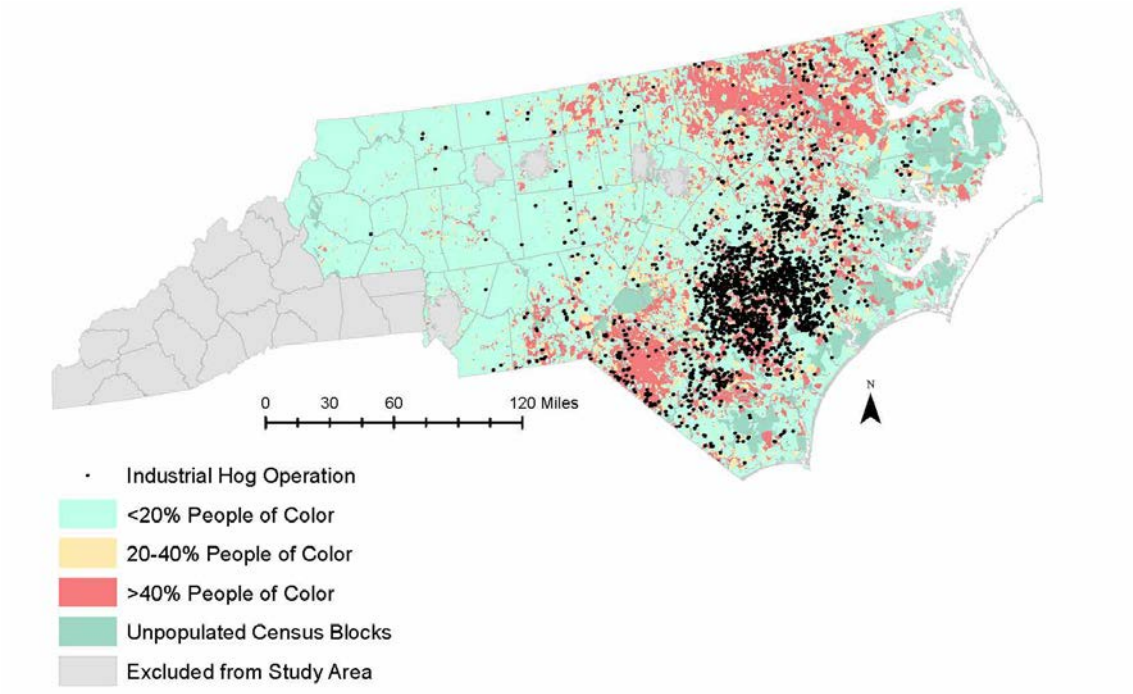

Table 1
Steady state live weight of IHOs
operating under the General Permit, NC, 2014

Permitted SSLW[1]	Number of IHOs	Percent of IHOs	Total SSLW[1]	Percent of total SSLW
20-	160	7.7	12,574	1.0
100-	447	21.6	76,626	5.9
250-	577	28.1	222,003	17.1
500-	529	25.4	383,918	29.6
1,000-10,200	342	17.2	603,354	46.5
Total	2055	100.0	1,298,474	100.0

[1]Thousands of pounds

Table 2
Racial and ethnic composition of NC census blocks within 3 miles
of an IHO and more than 3 Miles of an IHO, 2014

	≤3 miles from an IHO		>3 miles from an IHO		
Racial Category	Number	Percent	Number	Percent	Total[1]
Non-Hispanic white	602,380	13.1	4,003,455	86.9	4,605,835
POC[1]	383,522	19.9	1,548,276	80.1	1,931,798
Black	277,199	20.2	1,096,795	79.8	1,373,994
Hispanic	92,679	18.1	418,292	81.9	510,971
American Indian	40,621	28.5	101,872	71.5	142,493
Total[1]	985,902	15.1	5,551,731	84.9	6,537,633

[1]POC can be counted in more than one racial/ethnic category. The total population is equal to the number of non-Hispanic Whites plus the number of POC.

Table 3
Ratios of POC compared to non-Hispanic Whites living within 3 Miles
of an IHO operating under the General Permit, 2014

Racial/ethnic Category	Population	≤3 miles from an IHO Number	Percent	Ratio[2]	p-value[3]
Non-Hispanic white	4,605,835	602,380	13.1	1.00	--
POC[1]	1,931,798	383,522	19.9	1.52	<0.0001
Black	1,373,994	277,199	20.2	1.54	<0.0001
Hispanic	510,971	92,679	18.1	1.38	<0.0001
American Indian	142,493	40,621	28.5	2.18	<0.0001
Total[1]	6,537,633	985,902	15.1		

[1]People of color can be counted in more than one racial/ethnic category. The total population is equal to the number of non-Hispanic Whites plus the number of POC.
[2]Ratio of the percent of people of other racial/ethnic groups to percent of non-Hispanic Whites living within 3 miles of an IHO
[3]A difference in proportions of this magnitude or greater would be expected to occur less than one time in ten thousand if people of different racial/ethnic groups had been randomized to live within 3 miles of an IHO.

Table 4
Ratios comparing the percent of people residing within 3 miles of an IHO
in blocks with POC compared to blocks with no POC

Percent POC	Population	Unadjusted Prevalence Ratio	95% CI	Adjusted[1] Prevalence Ratio	95% CI
0	694,747	1.0	referent	1.00	referent
>0 to <20	2,577,015	0.83	0.82, 0.83	1.01	1.00,1.02
20 to <40	1,364,923	1.34	1.33, 1.45	1.95	1.93, 1.97
40 to <60	799,124	1.35	1.34, 1.36	2.15	2.13, 2.16
60 to <80	526,305	1.64	1.62, 1.65	2.53	2.50, 2.55
80 to 100	575,519	2.14	2.12, 2.16	3.30	3.27, 3.32

[1]Adjusted for rurality using a cubic polynomial of the natural log of population density

Table 5
Ratios comparing the percent of people residing within 3 miles of an IHO in blocks with Black residents compared to blocks with no Black residents

Percent Black	Population	Unadjusted Prevalence Ratio	95% CI	Adjusted[1] Prevalence Ratio	95% CI
0	1,308,061	1.00	referent	1.00	referent
>0 to <20	2,941,746	0.93	0.92, 0.94	1.20	1.19,1.21
20 to <40	1,043,277	1.44	1.43, 1.45	2.07	2.05, 2.08
40 to <60	536,198	1.52	1.51, 1.53	2.18	2.17, 2.20
60 to <80	336,232	1.57	1.56, 1.59	2.19	2.17, 2.21
80 to 100	372,119	2.01	1.99, 2.02	3.06	3.04, 3.09

[1]Adjusted for rurality using a cubic polynomial of the natural log of population density

Table 6
Percent difference in the percent of people residing within 3 miles of an IHO for a ten percent increase in the population of each racial/ethnic group

Racial/ethnic group	Unadjusted Percent	95% CI	Adjusted[1] Percent	95% CI
POC	10.7	10.6, 10.8	14.8	14.7, 14.9
Black	9.4	9.3, 9.4	13.0	12.9, 13.1
Hispanic	8.5	8.4, 8.6	16.3	16.1, 16.4
American Indian	16.2	16.0, 16.4	11.8	11.6, 12.0

[1]Adjusted for rurality using a cubic polynomial of the natural log of population density

Table 7
Difference in SSLW of hogs within 3 miles of residents of blocks with POC compared to blocks with no POC

Percent POC	Unadjusted SSLW[2]	95% CI	Adjusted[1] SSLW	95% CI
0	Referent	-	Referent	-
>0 to <20	-35	-73, 3	190	154, 227
20 to <40	177	136, 219	535	495, 575
40 to <60	308	262, 353	717	672, 762
60 to <80	510	459, 561	896	846, 946
80 to 100	453	403, 503	837	788, 885

[1]Adjusted for rurality using a cubic polynomial of the natural log of population density
[2]1,000s of pounds

Table 8
Difference in SSLW of hogs within 3 miles of residents of blocks with Black residents compared to blocks with no Black residents

Percent Black	Unadjusted SSLW[2]	95% CI	Adjusted[1] SSLW	95% CI
0	Referent	-	Referent	-
>0 to <20	-4	-33, 25	237	207, 265
20 to <40	190	153, 227	493	457, 530
40 to <60	327	281, 372	620	576, 665
60 to <80	275	221, 330	547	494, 599
80 to 100	165	113, 218	494	444, 545

[1]Adjusted for rurality using a cubic polynomial of the natural log of population density
[2]1,000s of pounds

Table 9
Difference in SSLW of hogs within 3 miles of residents of blocks for a ten percent increase in population of each racial group

Racial/ethnic group	Unadjusted SSLW[2]	95% CI	Adjusted[1] SSLW	95% CI
POC	67	63, 71	100	96, 104
Black	38	34, 42	64	60, 68
Hispanic	183	174, 192	242	234, 251
American Indian	124	111, 137	92	80, 105

[1]Adjusted for rurality using a cubic polynomial of the natural log of population density
[2]1,000s of pound