Evaluation of Vulnerability and Stationary Source Pollution in Houston

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Introduction

Houston's energy, chemical, and industrial facilities contribute to elevated air pollution levels in the region, including volatile organic compounds (VOCs), particulate matter (PM), and a variety of toxic air pollutants. Much of Houston's industrial activity occurs in the area around the Port of Houston and the Houston Ship Channel, which carries Port traffic from the Gulf of Mexico to and from Houston Port terminals. In areas with numerous pollution sources emitting different types of pollution, the accumulation of risks is of greater concern than the risks posed by each individual pollution source.

Elevated air pollution is of concern when it poses a health risk, particularly in areas where residents are exposed to several sources of pollution, which makes characterizing and mitigating health risks more challenging. In many regions air pollution burdens have been found to disproportionately affect disadvantaged residents, such as people of color and low-income households. This type of environmental injustice is exacerbated when these populations face vulnerability to pollution exposures.

Sustainable Systems Research (SSR) has been asked to characterize the potential for environmental justice concerns associated with stationary source emissions in the Houston area. We first discuss key concepts from cumulative risk assessment and cumulative impacts literature and their intersection with environmental justice concerns. We then evaluate stationary source pollution emissions and demographic vulnerability across the Houston region and the degree to which they converge, posing potential environmental justice concerns. We highlight results in five communities located along the Houston Ship Channel: Manchester, Magnolia Park, Pasadena, Baytown, and Deer Park. We also discuss the potential for environmental justice concerns related to unauthorized air pollution emissions from stationary sources in the Houston area.

Background: Cumulative Risks, Cumulative Impacts, and Environmental Justice

The incremental risks of an activity are of greater concern when the overall risk of many activities in an area is significant. The US EPA's 2003 Framework for Cumulative Risk Assessment defines cumulative risks as "the combined risks from aggregate exposures to multiple agents or stressors."[1] According to the 2003 Framework, cumulative risks can result from exposure to multiple pollutants from multiple sources and may occur over a long period of time. While traditional risk assessment focuses on exposure to one chemical (often from one source), cumulative risk assessments can be helpful in settings where the effects of multiple exposures and multiple sources can result in greater risks to human health or the environment. The evaluation of cumulative risks is not simply the addition of the risks from different chemicals or sources; it includes an assessment of how these

[1] EPA, 2003. "Framework for Cumulative Risk Assessment," May 2003, EPA/630/P-02/001F

stressors interact. Additionally, cumulative risk assessment emphasizes actual people that can be affected, rather than theoretical populations. It can also consider a wider array of stressors (including non-pollutant stressors such as a lack of health care or car crashes) and their interactive effects.

EPA's 2007 Cumulative Health Risk Assessment guidance indicates that one situation which might indicate a need for a health risk assessment is the existence of multiple pollution sources or chemical releases.[2] In order to conduct a cumulative risk assessment in that case, the first step would be to identify all the relevant (present and future) chemical releases and exposure pathways that can affect the population of concern. In particular, chemicals with high potential for health risks and similar effects are of interest. Once the sources and chemicals that will be assessed have been identified, the analysis follows exposure assessment steps of characterizing the sources, determining the spatial scope of analysis, evaluating the fate of emissions, determining who could be exposed, and quantifying their exposures.

Consideration of cumulative risks has become more common in a number of environmental evaluation settings. A handful of states and localities have begun to require cumulative risk assessments. For example, a 2008 Minnesota statute requires that cumulative effects be evaluated and considered before air permits are issued in the Phillips Communities in South Minneapolis.[3] Similarly, under a 2009 ordinance in Cincinnati, Ohio, facilities seeking a new or expanded permit are required to show that they will not have a "cumulative adverse impact" on the environment or the community's health.[4] Health Impact Assessments[5] (HIAs), which have been conducted in a variety of jurisdictions and situations, often include an evaluation of cumulative risks.

An important factor when evaluating cumulative risks is understanding the vulnerability of at-risk populations. EPA outlines four areas of vulnerability that should be assessed in cumulative risk assessments: differential exposure, susceptibility/sensitivity, differential preparedness, and differential ability to recover.[6] Children, the elderly, and people with existing health conditions are

[2] EPA, "Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document," August 2007, EPA/600/R-06/013F
[3] See EPA, "Cumulative Risk Webinar Series: What We Learned," July 2014, EPA/600/R-14/212.
[4] Rachel Morello-Frosch, Miriam Zuk, Michael Jerrett, Bhavna Shamasunder and Amy D. Kyle. Understanding The Cumulative Impacts Of Inequalities In Environmental Health: Implications For Policy. Health Affairs, 30, no.5 (2011):879-887.
[5] For more information about Health Impact Assessments, see http://www.cdc.gov/healthyplaces/hia.htm
[6] EPA, "Framework for Cumulative Risk Assessment," May 2003, EPA/630/P-02/001F; "Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document," August 2007, EPA/600/R-06/013F

particularly vulnerable to exposure to pollution[7, 8]. Additionally, low-income households and people of color can be more vulnerable to the effects of pollution exposure for a number of reasons, including greater rates of preexisting health conditions, greater exposure to a number of environmental hazards, greater social vulnerability (including stress), and limited access to health care.[9, 10]

"Cumulative impacts" are a related concept that is an important part of Environmental Impact Assessments (EIAs) of federal projects conducted under the National Environmental Policy Act (NEPA). Consideration of cumulative impacts in EIAs was first required in 1979. Consideration of a community's vulnerability is also an important part of evaluating cumulative impacts.[11]

Both the cumulative risk and cumulative impact literature point to the importance of understanding the overlap between heightened *exposure* to health risk as a result of multiple stressors and heightened *vulnerability* to that exposure. Populations and communities with this combination of factors can also be examined through the lens of environmental justice. The US EPA defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies."[12] Concerns about environmental justice have grown out of a number of studies that indicate that in many cases the burdens of environmental harms fall disproportionately onto people of color and low-income populations, while environmental benefits are often unavailable to those people.[13] While environmental justice concerns can stem from pollution of a single chemical or from a single type of pollution source (e.g. landfills), disadvantaged populations and communities often face the cumulative risks caused by numerous pollution sources and chemical exposures. Concepts that underpin cumulative risk assessment and cumulative impacts can broaden our understanding of environmental justice concerns in vulnerable populations and communities.

Data and Methods

In order to better understand the potential for environmental justice concerns related to stationary source pollution in the Houston region, this analysis focuses on three questions:

1. Are total stationary source air pollution burdens in the Houston region greater for vulnerable groups (including people living in poverty, limited-English speaking households, and people of color)?

[7] Morello-Frosch et al., Cumulative Impacts of Inequalities In Environmental Health, 2011.
[8] "Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment of Multiple Chemicals, Exposures and Effects: A Resource Document," August 2007, EPA/600/R-06/013F.
[9] Morello-Frosch et al., Cumulative Impacts of Inequalities In Environmental Health, 2011.
[10] EPA, Concepts, Methods, and Data Sources for Cumulative Health Risk Assessment, 2007.
[11] These factors are outlined in relation to NEPA document evaluation in EPA, "Consideration of Cumulative Impacts in EPA Review of NEPA Documents," May 1999, EPA 315-R-00-002.
[12] See http://www.epa.gov/environmentaljustice/.
[13] Morello-Frosch et al., Cumulative Impacts of Inequalities In Environmental Health, 2011.

2. How do total stationary source emissions burdens and vulnerability in several communities of interest near the Ship Channel compare to the rest of the region?
3. Do unauthorized emissions burdens pose unique concerns (in addition to any concerns that may arise in relation to authorized emissions)?

The focus of this analysis is on pollution *emissions*. This analysis is intended to identify areas where there is potential for elevated and disproportionate pollution emissions in order to identify areas that may be of heightened concern and merit additional scrutiny. This analysis should not be interpreted as an analysis of pollution *exposures* or *health risks*, which would require more in-depth measurements and/or modeling of pollution fate and transport, toxicity, and exposure pathways.

This assessment focuses on where pollution emissions overlap with vulnerable populations. Our approach is similar to the approaches used in screening tools such as US EPA's EJScreen[14] and CalEnviroScreen[15] which overlay environmental burdens and various measures of vulnerability, although it is simplified in its focus on emissions only (rather than concentrations or health risks). Stationary source emissions rates are a result of regulatory and economic decision-making processes (industrial siting decisions, the permitting process, operational or enforcement decisions, etc.), so examining emissions directly may provide insights into patterns that arise in the current decision-making environment.

Emissions Data

All air pollution point sources in Texas that emit or have the potential to emit quantities of criteria pollutants, VOCs, or hazardous air pollutants that exceed reporting requirements (as described in 30-TAC 110.10[16]) are required to report their emissions. Emissions of any pollutant may be reported as *annual emissions*, *emissions events (EE)*, or *scheduled maintenance, startup, and* shutdown *(SMSS)* emissions, depending on how they occur. The Texas Commission on Environmental Quality (TCEQ) tracks reported emissions of over 2000 pollutants and pollutant categories in a point source emissions inventory (PSEI) and provides detailed data upon request.[17] This analysis draws from the TCEQ PSEI data.

TCEQ describes annual emissions as follows:

> "Annual emissions include all of a site's actual annual emissions associated with authorized (routine) operations, maintenance, startup, and shutdown

[14] https://www.epa.gov/ejscreen

[15] https://oehha.ca.gov/calenviroscreen

[16] 30 Tex. Admin. Code §101.10 (2019) (TCEQ, Emissions Inventory Requirements), available at https://texreg.sos.state.tx.us/public/readtac%24ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=101&rl=10

[17] Information about the PSEI is available at https://www.tceq.texas.gov/airquality/point-source-ei/psei.html. A full list of contaminants is available at http://www.tceq.texas.gov/assets/public/implementation/air/ie/pseiforms/contams.xlsx.

activities. It does not include emissions that are defined in 30 TAC Section 101.1 as emissions events or unauthorized scheduled maintenance, startup, and shutdown activities."[18]

We refer to annual emissions as *authorized emissions* in this report.

EE[19] and SMSS emissions [20] are reported for any quantity of emissions that is unauthorized [21]. We refer to EE and SMSS emissions together as *unauthorized emissions* in this report.

Demographic Data

Demographic data are obtained from the US Census[22]. Measures of vulnerability were identified by community partners, and include people of color (POC), people

[18] TCEQ (2017) "TCEQ 2016 Emissions Inventory Guidelines", Publication RG-360/16, p 60, available at https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg360/rg360-16/rg-360.pdf

[19] According to 30 TAC § 101.1, an emissions event is

> "any upset event or unscheduled maintenance, startup, or shutdown activity, from a common cause that results in **unauthorized emissions [emphasis added]** of air contaminants from one or more emissions points at a regulated entity."

See 30 TAC § 101.1 for definitions of upset events and unplanned maintenance, startup, or shutdown activities. TCEQ also provides guidance on reporting emissions events as follows:

> "...Include the emissions in tons per year from all releases due to emissions events, regardless of whether those releases represent reportable or nonreportable quantities and regardless of whether an affirmative defense is claimed for those emissions…." (TCEQ, 2017, TCEQ 2016 Emissions Inventory Guidelines, page 64).

[20] TCEQ provides guidance on reporting SMSS emissions as follows:

> "Report the emissions in tons from all releases due to scheduled maintenance, startup, and shutdown activities that are **not** authorized by a new source review permit or permit by rule in the "SMSS" category, regardless of whether those releases represent reportable or nonreportable quantities and regardless of whether an affirmative defense is claimed for those emissions…" (TCEQ, 2017, TCEQ 2016 Emissions Inventory Guidelines, page 64-65).

30 TAC § 101.1 defines SMSS activity as follows:

> "For activities with **unauthorized emissions [emphasis added]** that are expected to exceed a reportable quantity (RQ), a scheduled maintenance, startup, or shutdown activity is an activity that the owner or operator of the regulated entity whether performing or otherwise affected by the activity, provides prior notice and a final report as required by §101.211 of this title (relating to Scheduled Maintenance, Startup, and Shutdown Reporting and Recordkeeping Requirements); the notice or final report includes the information required in §101.211 of this title; and the actual **unauthorized emissions [emphasis added]** from the activity do not exceed the emissions estimates submitted in the initial notification by more than an RQ. For activities with **unauthorized emissions [emphasis added]** that are not expected to, and do not, exceed an RQ, a scheduled maintenance, startup, or shutdown activity is one that is recorded as required by §101.211 of this title. Expected excess opacity events as described in §101.201(e) of this title (relating to Emissions Event Reporting and Recordkeeping Requirements) resulting from scheduled maintenance, startup, or shutdown activities are those that provide prior notice (if required), and are recorded and reported as required by §101.211 of this title."

[21] 30 TAC § 101.1 defines unauthorized emissions as

> "Emissions of any air contaminant except water, nitrogen, ethane, noble gases, hydrogen, and oxygen that exceed any air emission limitation in a permit, rule, or order of the commission or as authorized by Texas Health and Safety Code, §382.0518(g)."

[22] https://www.census.gov/

living in poverty (POV), and limited-English households (LEH). The 2010 decennial census provides people of color data (including all Hispanic and/or non-white residents). The population living at or below the poverty level and the number of limited-English households (in which no one age 14 and over speaks English "very well" or speaks English only) are obtained from the 2016 five-year American Community Survey (ACS) data. The total population estimate is also from the 2016 five-year ACS data. Decennial census data were obtained at the block, tract, and place level, and ACS data were obtained at the block-group, tract, and place level for use at different scales of analysis, as described further below. We also present a vulnerability index, calculated as the average of the percent people of color, percent living in poverty, and percent limited-English.

Analysis Areas

This analysis examines emissions, demographic vulnerability, and the potential for environmental justice concerns across the Houston region. In addition, community partners have expressed interest in characterizing vulnerability and emissions in several communities adjacent to the Houston Ship Channel.

In this analysis we evaluate data over two spatial scales as shown in Figure 1:

1. **Eight-County Houston Region:** We evaluate emissions and demographic vulnerability at the Census tract level across the eight-county Houston region. The eight-county area provides a second site for examining larger scale trends, as well as a point of reference to which we can compare the communities of interest. The eight-county area includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties. These eight counties are in ozone nonattainment and therefore have more consistent (more stringent) emissions reporting requirements for the TCEQ's PSEI than other counties in the region. This area encompasses the communities of interest.
2. **Communities of Interest:** We also evaluate emissions and demographic vulnerability at the community level for neighborhoods and cities in the region. Community partners have expressed interest in characterizing vulnerability and emissions in several communities that are in the vicinity of the Houston Ship Channel, including the Harrisburg / Manchester and Magnolia Park neighborhoods as well as the cities of Pasadena, Baytown, and Deer Park.

Pollutants

SSR was asked to evaluate emissions of 29 air pollutants in the region that were identified by community partners based on their potential to pose a risk to human health. These include 16 EPA prioritized polycyclic aromatic hydrocarbons (PAHs) and 12 other pollutants identified as of concern based on a recent Union of

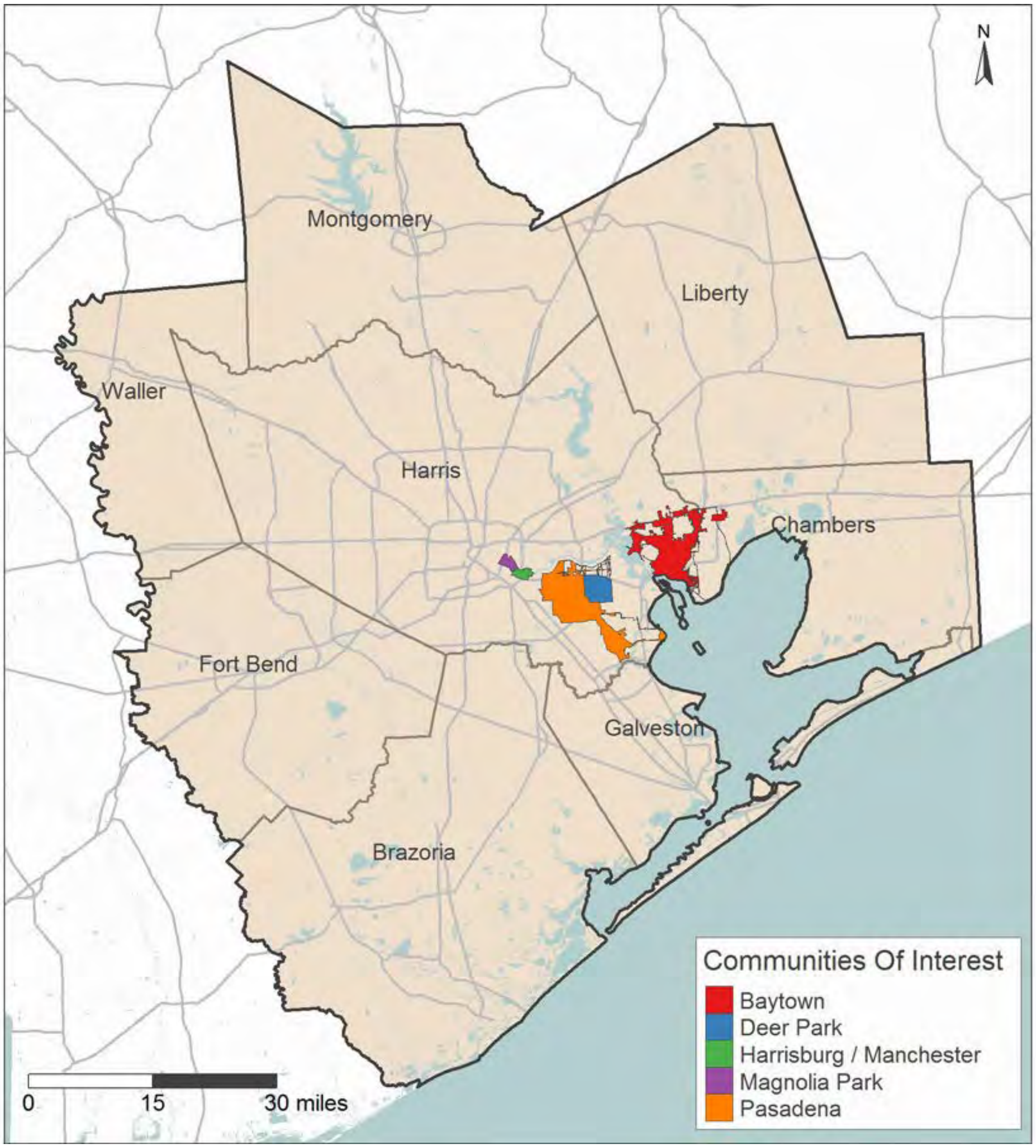


Figure 1: Map of the Eight-County Houston, Texas Region and Communities of Interest

Concerned Scientists / Texas Environmental Justice Advocacy Services Report[23]. One additional pollutant (hydrogen sulfide) was also identified by community partners. Of this list of 29 pollutants, our evaluation includes the 19 pollutants for which PSEI data are available. In order to characterize overall trends, we combine these 19 pollutants into a pollution index. Additionally, we evaluate emissions of three broader categories of pollutants that overlap with several pollutants of concern. Pollutants that are included in this analysis are listed in Table 1.

[23] See Union of Concerned Scientists, "Double Jeopardy in Houston: Acute and Chronic Chemical Exposures Pose Disproportionate Risks for Marginalized Communities," October 2016, https://www.ucsusa.org/resources/double-jeopardy-houston. Pollutants of concern were identified based on the risks indicated in US EPA's Risk-Screening Environmental Indicators (RSEI) and National Air Toxics Assessment (NATA) datasets.

Time periods

We evaluate total emissions over three time periods: the most recently available year (2016), the most recent five-year period (2012 to 2016), and the most recent ten-year period (2007 to 2016). Evaluating all three time periods provides insight into the consistency of emissions over time.

Data analysis

In order to understand the potential for disproportionate emissions burdens in vulnerable populations and communities, this analysis focuses on whether there are patterns of emissions in the region. Thus, this report focuses on broad pollution categories (PM2.5, PM10, VOCs, and an index of the remaining 19 pollutants of concern). The distribution of emissions of any single pollutant may also be of concern, so additional information on each of the 19 pollutant is provided in the Appendices.

We first evaluate each pollutant's emissions density (annual quantity emitted divided by land area) at the census tract level across the eight-county region and for each of the three time periods. We present total emissions (which are the sum of authorized emissions and unauthorized emissions). We then estimate the emissions density as the total emissions per year divided by the tract's land area. Examining emissions density allows us to compare emissions rates across tracts of varying sizes.

We then calculate an index of the 19 pollutants of concern (these are the pollutants listed in the PAH and other pollutants of concern sections of Table 1). The index is a sum of the scaled burden of each of these pollutants.[24] The purpose of the index is to identify areas where emission densities of multiple pollutants of interest are relatively high in order to highlight potential patterns in elevated emissions densities for the 19 pollutants. The index does not capture all pollutants, nor does it indicate pollution concentrations (which depend on the fate and transport of pollutants), pollution exposures, or the magnitude of health risks[25].

[24] We first use a min-max normalization approach to scale the tract-level emissions density of each of the 19 pollutants from 0 to 1. For each pollutant the minimum tract-level emissions density (zero in all cases) is set to 0 and the maximum tract-level emissions density is set equal to 1, with intermediate values scaled by dividing by the maximum tract-level emissions density. These scaled values are estimated for each pollutant and then summed across the 19 pollutants to arrive at the pollution index value for each tract.

[25] The focus of this index is on the density of emissions in each tract rather than the health risk. Because the pollutants of concern were selected based on concerns communities of interest, we also include pollution categories, which reflect a broader number of pollutants. This index does not weight the potential health impacts of each pollutant individually so it does not reflect the magnitude of health risks. A more complex analysis that accounts for the fate and transport of pollution, its toxicological properties, exposures, and population vulnerability would be required to turn emissions data into health risks.

Table 1: Air Pollutants of Interest[26]

Pollutants of interest in study area	Available in TCEQ PSEI data?
Broad pollution categories	
Particulate matter <2.5 μm diameter (PM2.5)	✓
Particulate matter <10 μm diameter (PM10)	✓
Volatile organic compounds (VOCs)	✓
Polycyclic aromatic hydrocarbons (PAHs)	
Naphthalene	✓
Acenaphthene	
Acenaphthylene	✓
Anthracene	✓
Benz[*a*]anthracene	
Benzo[*a*]pyrene	✓
Benzo[*b*]fluoranthene	
Benzo[*ghi*]perylene	
Benzo[*k*]fluoranthene	
Chrysene	
Dibenz[*a,h*]anthracene	
Fluoranthene	✓
Fluorene	
Indeno[1,2,3-*cd*]pyrene	
Phenanthrene	✓
Pyrene	✓
Other pollutants of concern	
Chromium and chromium compounds	✓
1,3-Butadiene	✓
Acetaldehyde	✓
Acrolein	✓
Benzene	✓
Carbon Tetrachloride	✓
Chlorine	✓
Diaminotoluene (mixed isomers)	✓
Diesel Particulate Matter	
Formaldehyde	✓
Hydrogen Chloride	✓
Hydrogen Cyanide	✓
Hydrogen Sulfide	✓

[26] Pollutants that are available in TCEQ PSEI data (https://www.tceq.texas.gov/airquality/point-source-ei/psei.html) are evaluated in this memo. The PAHs and other pollutants of concern are combined in a 19-pollutant index in this report, with detailed results presented in the Appendices.

Once we have tract-level emissions densities for the pollutants and the 19-pollutant index value, we combine these with tract-level measures of vulnerability obtained from the US Census. For each of the three vulnerable populations (people living in poverty, people of color, and limited-English households), we compare emissions densities to the corresponding advantaged populations (people living above poverty, non-Hispanic white people, and English proficient households). We evaluate the emissions density burdens for each population using three metrics:

1. **Average emissions density for the entire population.** This is the average emissions density experienced by the population living in each tract. This is a measure of the average emissions burden on each population.
2. **Percent living near emissions.** This is the share of the population that lives in a tract with an emissions density greater than zero. This is a measure of how widespread the emissions are.
3. **Average emissions density for those living near emissions.** This is the average tract-level emissions density experienced by all individuals of the population that live in a tract with an emissions density greater than zero. This is a measure of how severe the emissions are for those living near them.

We also present maps of the region showing the percent of the population that is vulnerable and emissions densities.

We then evaluate the quantity of emissions that are unauthorized (emissions events and unauthorized scheduled maintenance, startup, and shutdown emissions) for each analysis area and time period for one example pollution category (VOCs). As with total emissions, unauthorized emissions are estimated as an emissions density (tons per year per square mile).

Finally, we examine emissions and vulnerability for communities in the region. We first map emissions and vulnerability at the tract level in the Ship Channel area, highlighting the communities of interest. We then quantify vulnerability and emissions densities at the city and neighborhood scales.[27] Emissions estimates are evaluated as total emissions per year per square mile, as above. Demographic estimates at the city level are obtained directly from the US Census. For the neighborhood-level analysis, demographic data are obtained at the smallest scale available and assigned to the corresponding neighborhood.[28] As part of the

[27] We use 2016 US Census "Place" boundaries to identify city boundaries and City of Houston "Super Neighborhood" boundaries (from https://cohgis-mycity.opendata.arcgis.com/) to identify neighborhoods in the City of Houston, which is the largest city in the region.

[28] Decennial census data is available at the block level while ACS data are available at the block-group level. The block level POC/non-POC population is assigned to the neighborhood in which the block centroid falls. The total number of POC/non-POC is then summed for all blocks in the neighborhood to arrive at the neighborhood-level populations. The block-group level POV/non-POV and LEH/non-LEH populations are assigned to each block they encompass in proportion to the share of the block-group's population that the block comprised in the 2010 decennial Census. These populations are then assigned to neighborhoods based on the block centroid.

community-scale analysis, we also evaluate the vulnerability and emissions densities for three reference areas: the eight-county region, Harris County, and the City of Houston. The eight-county region and Harris County vulnerability estimates are obtained by aggregating tract-level populations to those areas, while the City of Houston estimates are obtained directly from the US Census.

Results

We focus our evaluation of emissions on comparisons of the relative magnitudes of emissions experienced by different populations and communities. This analysis does not represent an evaluation of health risks. The health risks experienced by different groups is a function of the magnitude of emissions in their area (which is presented here), in combination with several other factors that were not evaluated here, including each pollutant's fate and transport, toxicity, the location of potentially exposed populations, and the vulnerability of the population.

Regionwide

We first compare the emissions burdens of vulnerable populations (versus their advantaged counterparts) across the eight-county region.

What is the average emissions burden?

Table 2 shows the average emissions density experienced by each population living in the eight-county Houston region. The "% Difference" columns indicate the percent difference between each vulnerable population (e.g. people of color, or POC) relative to its advantaged counterpart (e.g. non-POC, or non-Hispanic white residents). A percent difference equal to zero indicates that on average the two populations live in areas with the same emissions density. These columns are highlighted to indicate the level of disparity. Bright red highlighting indicates greater levels of disparity for vulnerable populations, white highlighting indicates equal burdens, and bright green highlighting indicates emissions burdens that disproportionately fall on advantaged populations. Note that the values in Table 2 all reflect disparate burdens for vulnerable populations, so they are highlighted in varying degrees of red.

For example, on average, limited-English households live in tracts with 0.81 tons of 2016 PM2.5 emissions per year per square mile, whereas households with some English proficiency live in tracts with 0.4 tons of 2016 PM2.5 emissions per year per square mile. Thus, limited-English households have 101% greater 2016 PM2.5 emissions densities. In other words, on average, limited-English households live in tracts with 2016 PM2.5 emissions densities that are about twice as high as English proficient households.

Looking at the percent difference across demographic groups (which indicates the disparity in average emissions), we see that on average, people of color, people living in poverty, and limited-English households live in tracts with higher emissions densities than their more advantaged counterparts. This finding is consistent across all four pollution categories examined (VOCs, PM10, PM2.5 and the 19-pollutant index) and across all three time periods. Disparities are greatest for VOCs, PM10, and PM2.5 for all vulnerable population definitions. Disparities are also greater for people of color and limited-English households than for households living in poverty. Disparities for PM2.5 and PM10 decrease slightly in more recent time periods for people of color and people living in poverty. Results for each of the 19 pollutants of concern are more mixed, as shown in Appendix A.

Looking at the average emissions burden for each population, we see that emissions for PM2.5, PM10, and VOCs are relatively consistent or modestly decreasing across the three time periods. The 19-pollutant index shows modest reductions in the 2012 to 2016 period and then modest increases in 2016. These trends are similar for vulnerable populations and their more advantaged counterparts.

How widespread are emissions?

Table 3 shows the share of each population living in tracts with emissions that are greater than zero in the eight-county Houston region. As above, the "% Difference" columns indicate the percent difference between each vulnerable population relative to its advantaged counterpart. These columns are again highlighted to indicate the level of disparity, where bright red indicates greater levels of disparity for vulnerable populations and bright green indicates emissions burdens that disproportionately fall on advantaged populations.

For example, on average, 11% of limited-English households live in tracts with 2016 PM2.5 emissions, whereas 12% of households with some English proficiency live in tracts with 2016 PM2.5 emissions. Thus, limited-English households are 8% less likely to live in tracts with 2016 PM2.5 emissions than English-proficient households.

Looking at the percent difference across demographic groups (which indicates the disparity in average emissions), we see that on average people of color, people living in poverty, and limited-English households are less likely to live in tracts with emissions than their more advantaged counterparts, although the differences are modest. This finding is consistent across all four pollution categories examined (VOCs, PM10, PM2.5 and the 19-pollutant index) and across all three time periods. In more recent analysis years (2012 to 2016 and 2016), the modest differences between populations in poverty and limited-English households and their more advantaged counterparts shrink slightly. Results for each of the 19 pollutants of concern are again mixed, as shown in Appendix A.

Looking at the share of each population that lives in a tract with emissions, we see that the scopes of emissions for the three broad pollution categories (PM2.5, PM10, and VOCs) and the 19-pollutant index are modestly decreasing across the three time periods. These trends are similar for vulnerable populations and their more advantaged counterparts.

How severe are emissions for those living near them?

Above we observed that vulnerable populations experience greater emissions densities (on average) than their more advantaged counterparts, although they are also modestly less likely to live in tracts with emissions. These seemingly conflicting accounts of disparity are reconciled when we examine the severity of emissions burdens that vulnerable populations bear when they live in tracts with emissions.

Table 4 shows the severity of the emissions burdens for residents of tracts with emissions. As above, the "% Difference" columns indicate the percent difference between each vulnerable population relative to its advantaged counterpart. These columns are again highlighted to indicate the level of disparity, where bright red indicates greater levels of disparity for vulnerable populations and bright green indicates emissions burdens that disproportionately fall on advantaged populations.

For example, looking at limited-English households living in tracts with 2016 PM2.5 emissions that are greater than zero, we see that these households live in tracts with an average of 7.1 tons of 2016 PM2.5 emissions per year per square mile, versus 3.3 tons of 2016 PM2.5 emissions per year per square mile for English-proficient households. Thus, limited-English households that live in tracts with 2016 PM2.5 emissions have 119% greater 2016 PM2.5 emissions densities.

Looking at the severity of emissions burdens (the average emissions densities experienced by people living in tracts with emissions), we see that people of color, people living in poverty, and limited-English households living in tracts with emissions experience higher average emissions densities when compared with their more advantaged counterparts. This finding is consistent across all four pollution categories examined (VOCs, PM10, PM2.5 and the 19-pollutant index) and across all three time periods. Disparities are generally greater for VOCs, PM10, and PM2.5 for all vulnerable population definitions. Disparities are also greater for people of color and limited-English households than for households living in poverty. Disparities for PM2.5 and PM10 decrease slightly in more recent time periods for all three vulnerable populations. Results for each of the 19 pollutants of concern are again mixed, as shown in Appendix A.

Looking at the severity of emissions for each population we see that emissions for PM2.5, PM10, and VOCs are increasing across the three time periods, particularly for the 19-pollutant index. These trends are similar for vulnerable populations and their more advantaged counterparts.

Table 2: Average Emissions Burden for Residents of the Eight County Houston Region

		Average Burden: Average Emissions Density (tons / year / sq mile estimated at the census tract level)								
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
PM2.5	2007 - 2016	0.670	0.331	103%	0.683	0.455	50%	0.845	0.424	99%
	2012 - 2016	0.651	0.322	102%	0.656	0.446	47%	0.828	0.410	102%
	2016	0.625	0.328	90%	0.634	0.436	45%	0.811	0.403	101%
PM10	2007 - 2016	1.02	0.458	122%	1.06	0.665	60%	1.33	0.621	114%
	2012 - 2016	0.953	0.419	127%	0.986	0.617	60%	1.27	0.572	121%
	2016	0.808	0.404	100%	0.831	0.548	52%	1.06	0.512	107%
Total VOCs	2007 - 2016	3.07	1.38	122%	3.07	2.09	47%	3.46	1.91	81%
	2012 - 2016	2.87	1.26	128%	2.83	1.94	46%	3.21	1.76	82%
	2016	2.48	1.17	113%	2.56	1.68	52%	2.90	1.55	87%
19-pollutant index	2007 - 2016	0.0232	0.0198	17%	0.0270	0.0193	40%	0.0278	0.0188	48%
	2012 - 2016	0.0218	0.0170	28%	0.0240	0.0179	34%	0.0274	0.0166	64%
	2016	0.0262	0.0240	9%	0.0279	0.0237	17%	0.0317	0.0222	43%

Table 3: Scope of Emissions in the Eight County Houston Region

Pollutant	Year range	People of Color (POC)	Non POC	% Difference (POC - NonPOC) / NonPOC	People Living in Poverty (POV)	Non POV	% Difference (POV - NonPOV) / NonPOV	Limited English Household (LEH)	Non LEH	% Difference (LEH - NonLEH) / NonLEH
Emissions Scope: Share of Population Living in Tracts with Emissions (%)										
PM2.5	2007 - 2016	17.2	18.9	-9%	17.5	18.2	-4%	15	18	-17%
	2012 - 2016	14.8	16.7	-11%	15.2	15.7	-3%	13	15	-14%
	2016	12.6	13.2	-5%	13.1	12.9	2%	11	12	-8%
PM10	2007 - 2016	17.6	19.3	-9%	17.7	18.7	-5%	15	18	-17%
	2012 - 2016	15.4	17.1	-10%	15.6	16.3	-4%	13	16	-15%
	2016	12.8	13.5	-5%	13.4	13.1	2%	12	13	-9%
Total VOCs	2007 - 2016	19.4	21.1	-8%	19.9	20.4	-2%	17	20	-13%
	2012 - 2016	16.8	18.7	-10%	17.5	17.7	-1%	15	17	-12%
	2016	14.7	15.4	-5%	15.4	14.9	3%	13	14	-6%
19-pollutant index	2007 - 2016	14.5	17.6	-18%	14.9	16.4	-9%	12	16	-23%
	2012 - 2016	12.1	15.4	-22%	12.6	13.6	-8%	10	13	-24%
	2016	9.1	11.9	-23%	9.8	10.5	-7%	8	10	-22%

Table 4: Severity of Emissions Burdens for Residents Living in Tracts with Emissions in the Eight County Houston Region

Emissions Severity: Average Emissions Density for People Living in Tract with Emissions (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
PM2.5	2007 - 2016	3.89	1.75	123%	3.89	2.49	56%	5.75	2.40	140%
	2012 - 2016	4.40	1.93	128%	4.32	2.84	52%	6.39	2.71	136%
	2016	4.95	2.48	100%	4.83	3.38	43%	7.15	3.26	119%
PM10	2007 - 2016	5.78	2.37	144%	6.00	3.56	69%	8.88	3.43	159%
	2012 - 2016	6.17	2.45	152%	6.31	3.79	67%	9.51	3.66	160%
	2016	6.31	2.99	111%	6.22	4.18	49%	9.18	4.05	127%
Total VOCs	2007 - 2016	15.9	6.57	141%	15.4	10.3	50%	20.3	9.7	109%
	2012 - 2016	17.0	6.72	153%	16.2	11.0	48%	21.6	10.4	108%
	2016	16.9	7.57	124%	16.6	11.3	47%	21.6	10.8	100%
19-pollutant index	2007 - 2016	0.160	0.113	42%	0.181	0.118	53%	0.229	0.119	93%
	2012 - 2016	0.181	0.111	63%	0.190	0.131	45%	0.272	0.126	116%
	2016	0.286	0.202	42%	0.284	0.226	26%	0.396	0.217	83%

Mapping Vulnerability and Emissions Burdens

To get a better understanding of demographic vulnerability and emissions burdens across the region, we also present maps of tract-level vulnerability and emissions densities. We present 2007 to 2016 emissions burdens in this section. Maps of emissions burdens in the 2012 to 2016 and 2016 time periods show similar spatial patterns and are included in Appendix B. Maps of each of the 19 pollutants of concern are included in Appendix C.

Figure 2 shows demographic vulnerability across the eight-county Houston region. The share of the population that is in poverty and of color is generally greater in more centrally-located tracts than in outlying areas, with the exception of parts of the west central area. The share of households that are limited-English is greater in the north central and parts of the east and southwest central areas. Accordingly, the vulnerability index (which is an average of the three vulnerability shares) is greater in more centrally-located tracts (with the exception of parts of the west central area).

Emissions densities for the three broad categories of pollutants and the 19-pollutant index are generally greatest in tracts in the vicinity of the Ship Channel (Figure 3). This is consistent across most pollutants and study years (Appendices B and C).

Overlaying emissions densities and the vulnerability index (Figure 4) reveals that the confluence of pollution and vulnerability occurs along the Ship Channel, particularly in centrally-located tracts. This is consistent across the three broad pollution categories and the 19-pollutant index.

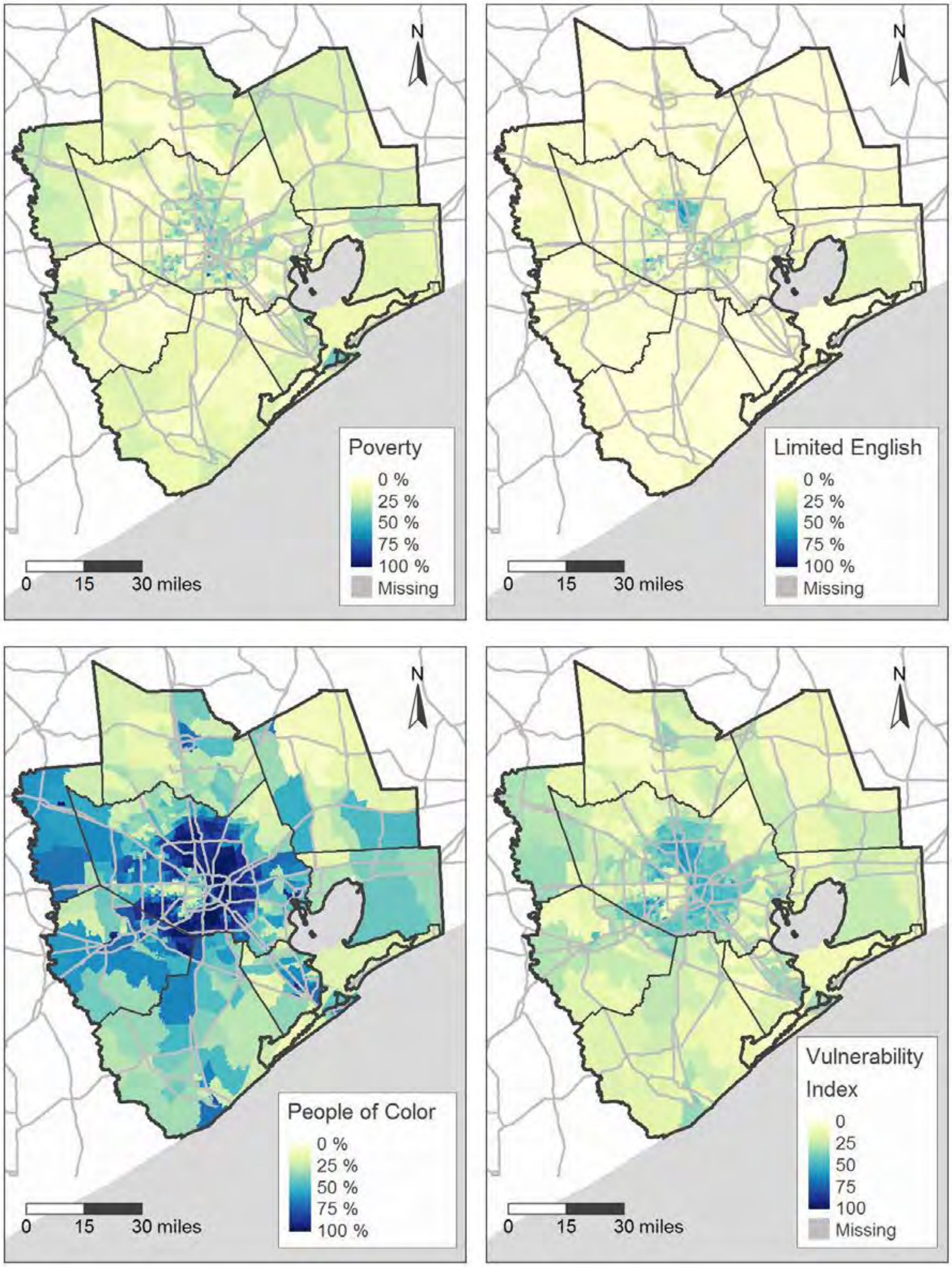


Figure 2: Vulnerability in the Eight-County Houston Region[29]

[29] The Vulnerability Index is an average of % Poverty, % Limited English, and % People of Color.

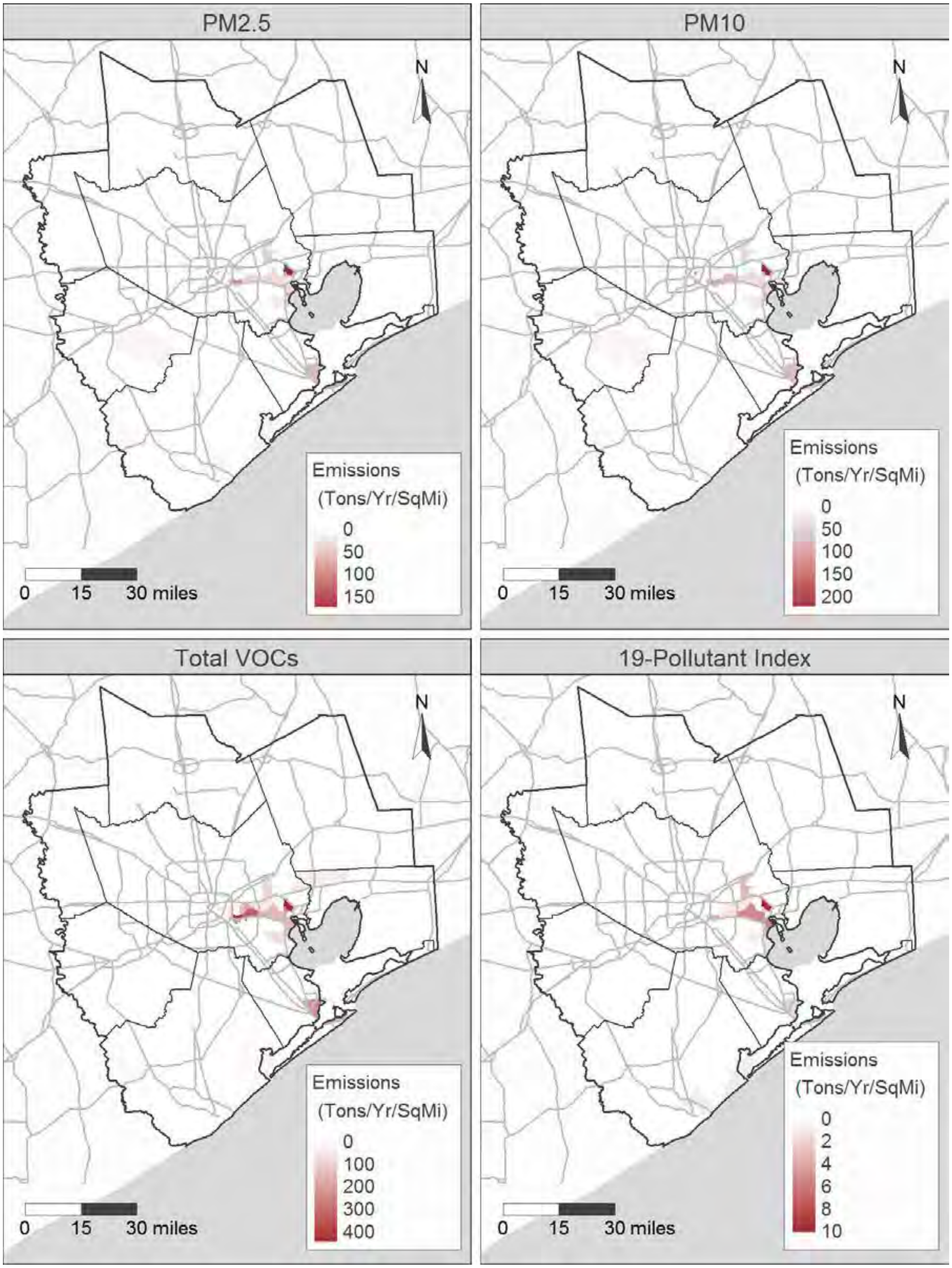


Figure 3: 2007 to 2016 Emissions in the Eight-County Houston Region

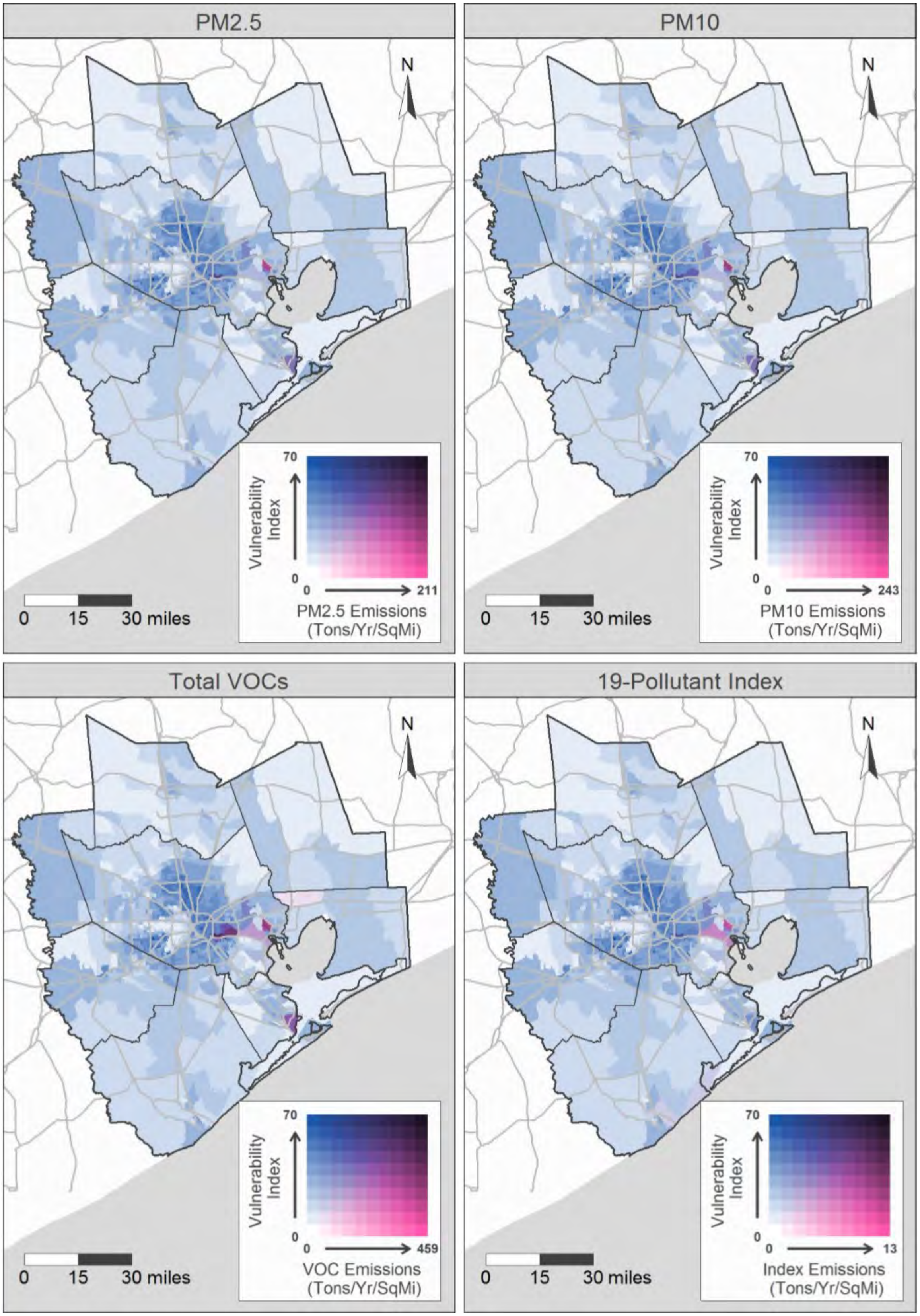


Figure 4: 2007 to 2016 Emissions and Vulnerability in the Eight-County Houston Region

Unauthorized Emissions

The analysis above focuses on total emissions, which include both authorized and unauthorized emissions. Because the unauthorized emissions are not permitted in advance, it is also of interest to examine unauthorized emissions alone. Note that these emissions may be more likely to be uncontrolled, so may occur over short periods of time, potentially leading to spikes in pollution concentrations which have the potential to contribute to acute and chronic health risks.

Table 5 shows the average emissions burden (average emissions density), the scope of emissions (share of population living in tracts with emissions greater than zero), and the severity of emissions for those that are exposed (average emissions density for those that live in tracts with emissions greater than zero). As in Tables 2 to 4, columns are highlighted to indicate the level of disparity, where bright red indicates greater levels of disparity for disadvantaged populations and bright green indicates emissions burdens that disproportionately fall on advantaged populations.

Table 5 shows that vulnerable populations experience greater emissions densities (on average) than their more advantaged counterparts, although they are also modestly less likely to live in tracts with emissions. This is due to the greater severity of emissions burdens that vulnerable populations bear when they live in tracts with emissions. These findings are consistent with emissions of total VOCs (shown in Tables 2 to 4). The average burden and severity of emissions of unauthorized VOCs are approximately an order of magnitude smaller than for total VOCs. At the same time, the shares of the populations living in tracts with unauthorized VOC emissions are approximately half to two-thirds of the shares living in tracts with emissions of total VOCs. Disparities in the severity of emissions experienced by people living in poverty are more modest for unauthorized VOC emissions than for total VOC emissions. Disparities in the average emissions burden and the severity of emissions experienced by people of color and limited-English households are greater for unauthorized emissions in the 2007 to 2016 time period, but these disparities appear to trend downward in the more recent time periods evaluated.

Looking at the magnitude of the average emissions burden and the scope and severity of emissions, we see that emissions burdens and the scope of emissions decrease in more recent time periods when compared with the 2007 to 2016 time period for all populations. The severity of emissions increases slightly for people of color and people living in poverty and decreases for limited-English households, while it increases for all three of the corresponding advantaged populations.

Figure 5 shows the location of unauthorized VOC emissions across the region. These emissions are most prevalent in the area around the Ship Channel, similar to the four pollution categories shown in Figure 3.

Table 5: Unauthorized VOCs in the Eight County Houston Region: Average Burden, Scope, and Severity

Pollutant	Year range	People of Color (POC)	Non POC	% Difference (POC - NonPOC) / NonPOC	People Living in Poverty (POV)	Non POV	% Difference (POV - NonPOV) / NonPOV	Limited English Household (LEH)	Non LEH	% Difference (LEH - NonLEH) / NonLEH
Average Burden: Average Emissions Density (tons / year / sq mile estimated at the census tract level)										
VOCs (unauthorized emissions only)	2007 - 2016	0.192	0.0719	167%	0.170	0.132	29%	0.250	0.103	143%
	2012 - 2016	0.135	0.0587	130%	0.115	0.094	22%	0.175	0.078	126%
	2016	0.106	0.0539	97%	0.103	0.079	30%	0.098	0.071	38%
Emissions Scope: Share of Population Living in Tracts with Emissions (%)										
VOCs (unauthorized emissions only)	2007 - 2016	9.07	11.6	-22%	10.2	9.86	3%	7.82	9.77	-20%
	2012 - 2016	6.90	8.93	-23%	7.90	7.68	3%	5.92	7.60	-22%
	2016	4.97	6.06	-18%	5.73	5.33	8%	4.50	5.27	-15%
Emissions Severity: Average Emissions Density for People Living in Tract with Emissions (tons / year / sq mile estimated at the census tract level)										
VOCs (unauthorized emissions only)	2007 - 2016	2.11	0.621	241%	1.67	1.34	25%	3.19	1.05	203%
	2012 - 2016	1.96	0.658	198%	1.45	1.22	19%	2.96	1.02	190%
	2016	2.14	0.890	140%	1.80	1.49	21%	2.19	1.35	62%

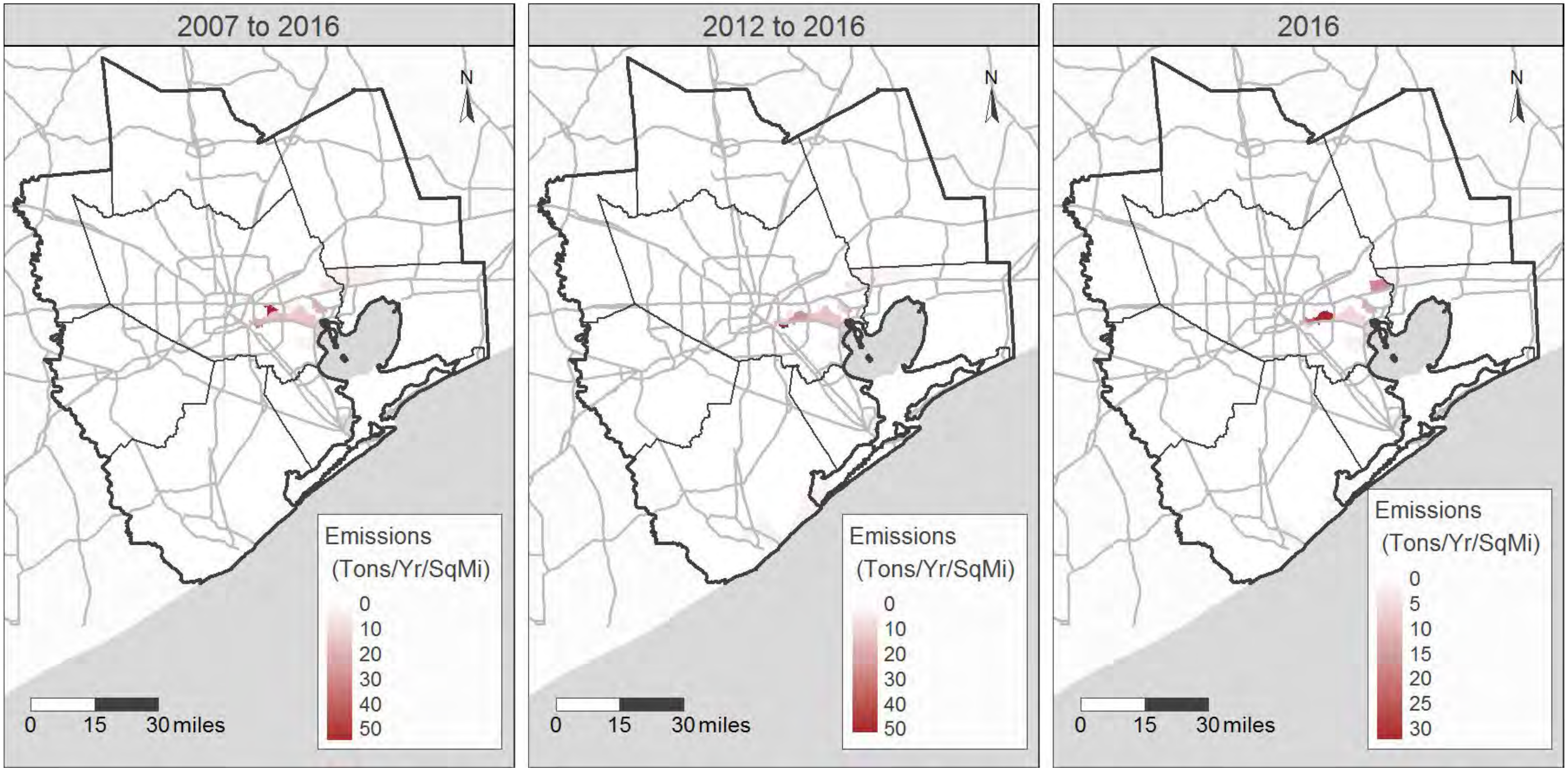


Figure 5: Unauthorized VOC Emissions in the Eight-County Houston Region

The Ship Channel and Communities of Interest

In light of the interest in several Ship Channel communities expressed by community partners and the findings of the previous sections, in this section we examine vulnerability and emissions burdens in the Ship Channel area.

We first zoom in on the vulnerability and emissions maps. Figure 6 shows demographics in the Ship Channel Area, with the communities of interest highlighted. Magnolia Park, Harrisburg / Manchester, and the northwest part of Pasadena exhibit greater vulnerability than outlying areas, particularly in terms of the share of people of color. At the same time, areas along the Ship Channel (including Harrisburg / Manchester, the northern edges of Pasadena and Deer Park, and the southwest of Baytown) exhibit greater total emissions burdens in the 2007 to 2016 period than most other areas (Figure 7). These findings are consistent in the other time periods examined (see Appendix D) and for unauthorized emissions (Figure 8). Additional maps of each of emissions of the 19 pollutants are included in Appendix E. The confluence of vulnerability and emissions burdens is greatest in the Harrisburg / Manchester community and along the northern edges of Pasadena and Deer Park (Figure 9). The differences observed are substantial. For example, the vulnerability measures in Harrisburg / Manchester range from 1.6 to 3.1 times the values for the eight-county region, while the pollution measures shown range from 28 to 61 times the values for the eight-county region for the period from 2007 to 2016.

We then summarize vulnerability and the 2007 to 2016 emissions by community in order to quantify the patterns shown in the maps described above. We also present comparable information for three reference areas: the eight-county Houston area, Harris County, and the City of Houston (Figure 10).[30] Looking at Figure 10a, we see that when compared with the reference areas, Harrisburg / Manchester and Magnolia Park exhibit greater vulnerability, Deer Park exhibits less vulnerability, and Baytown and Pasadena are approximately on par with the reference areas. Figure 10b shows that when compared with the reference areas, Harrisburg / Manchester exhibits far greater emissions density, Baytown, Deer Park, and Magnolia exhibit smaller emissions densities, and Pasadena exhibits emissions densities that are approximately on par with the reference areas. These findings are consistent in the two other time periods evaluated (Appendix F). Detailed tables are provided in Appendix G.

[30] The 19-pollutant index is not included in this part of the analysis because it is not comparable across analysis scales.

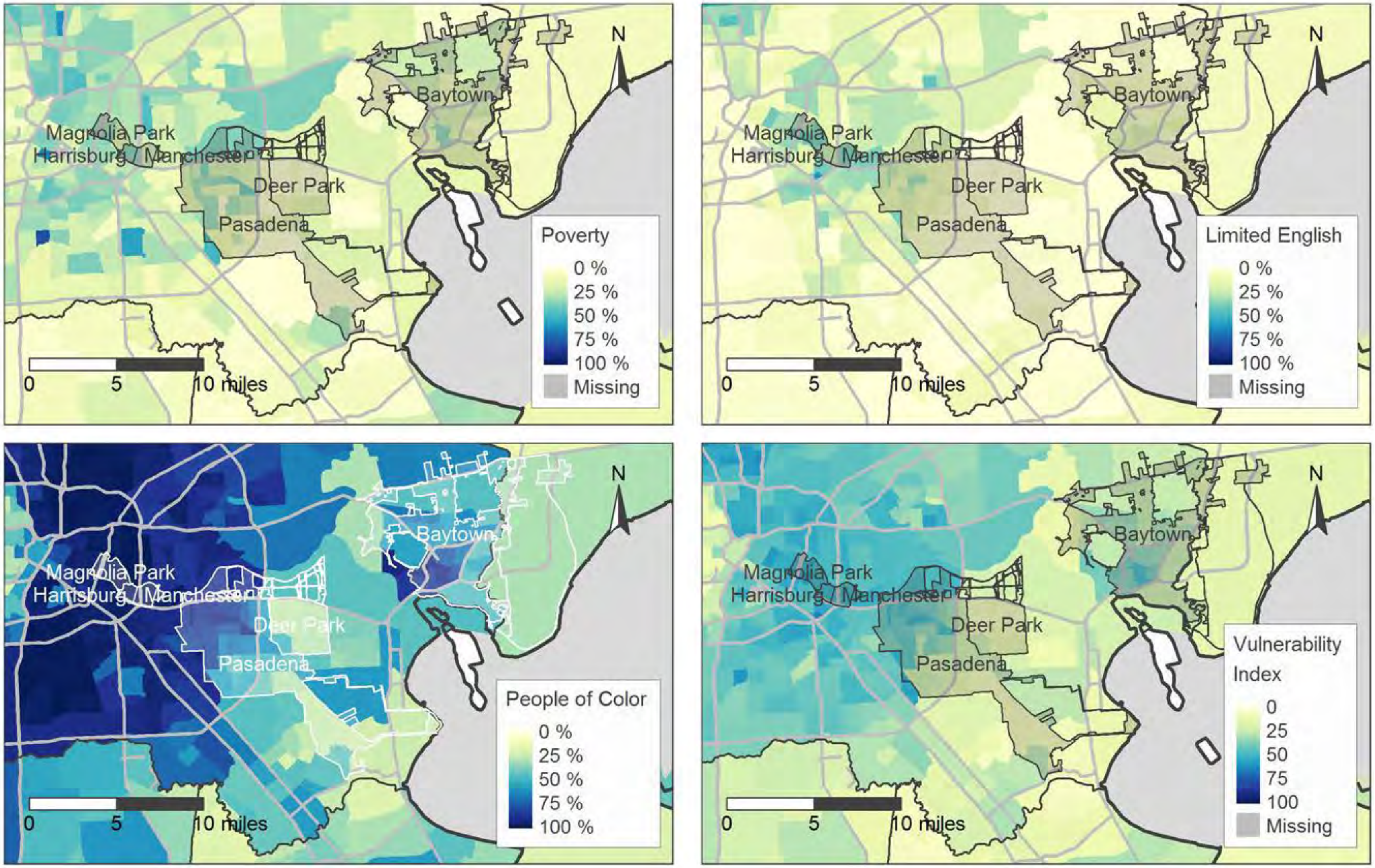


Figure 6: Vulnerability in the Ship Channel Area

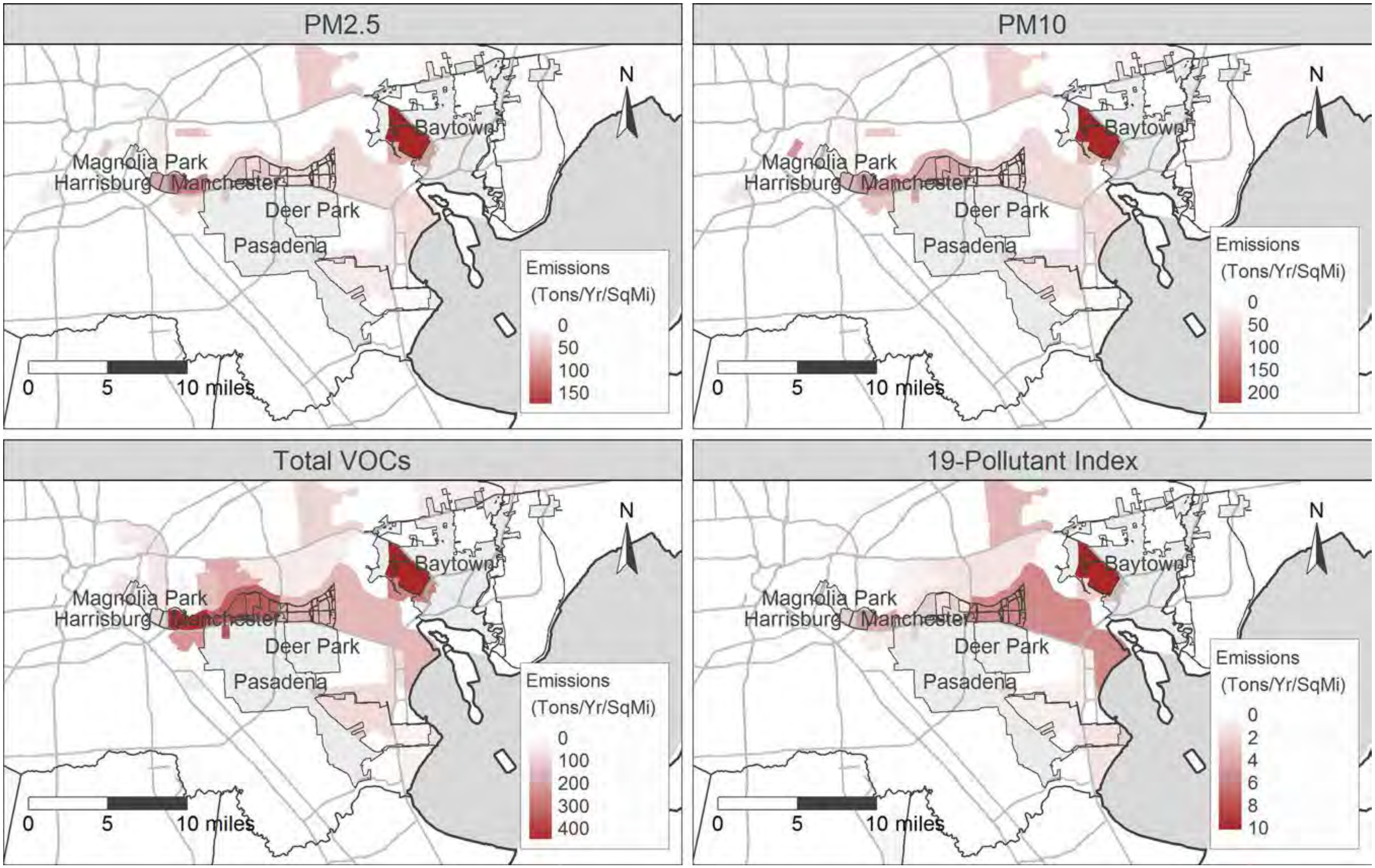


Figure 7: 2007 to 2016 Emissions in the Ship Channel Area

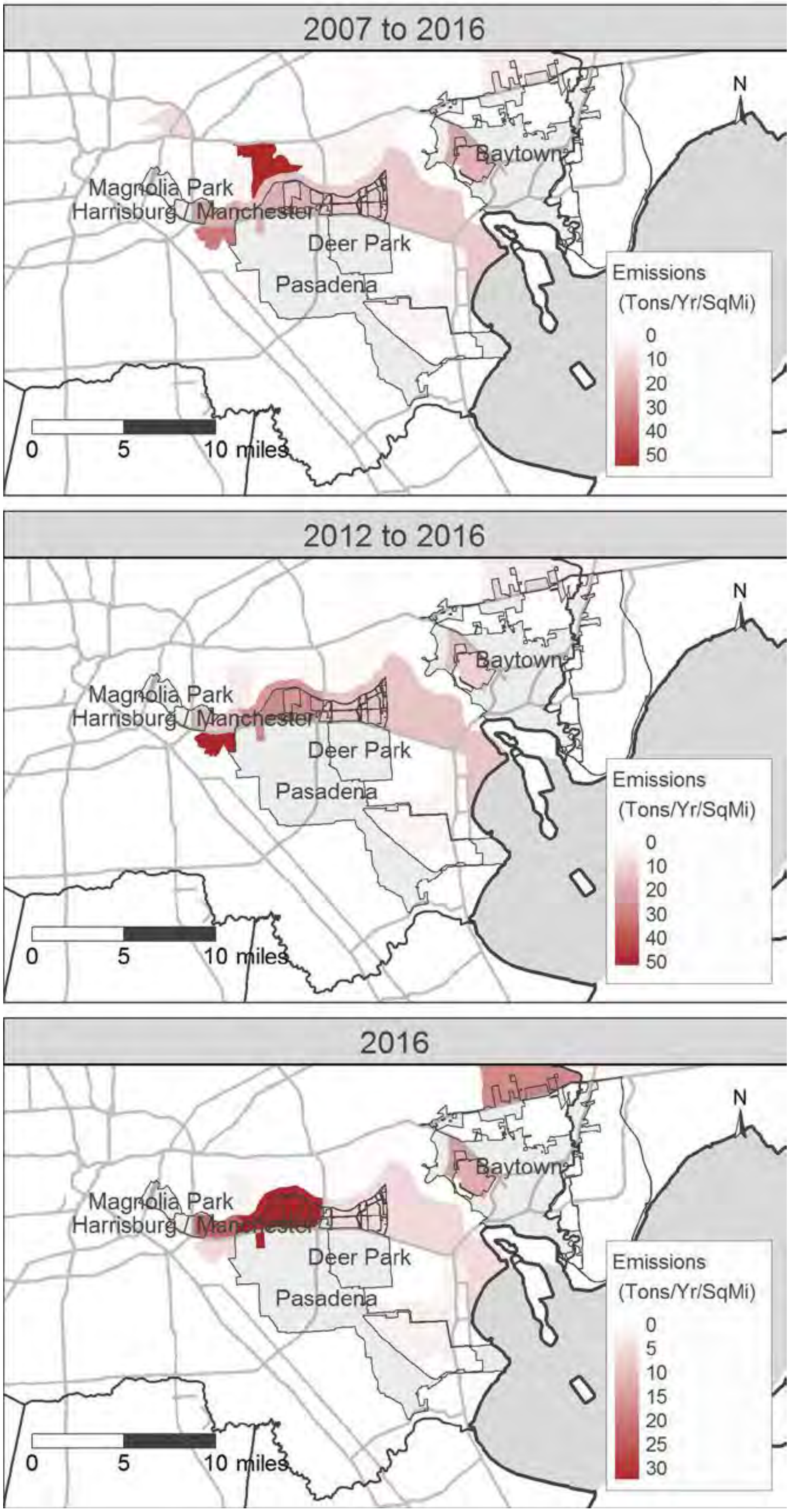


Figure 8: Unauthorized VOC Emissions in the Ship Channel Area

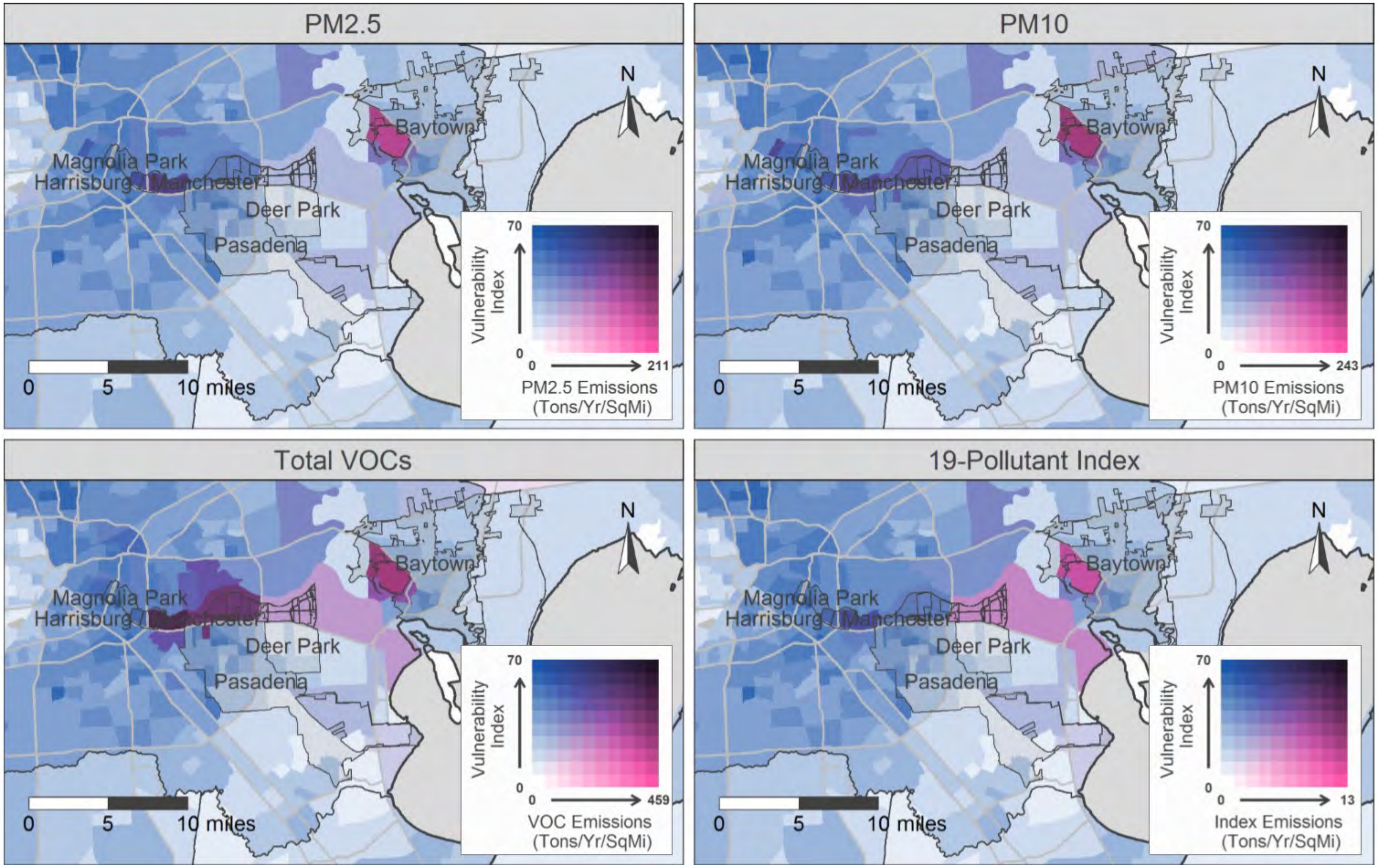


Figure 9: 2007 to 2016 Emissions and Vulnerability in the Ship Channel Area

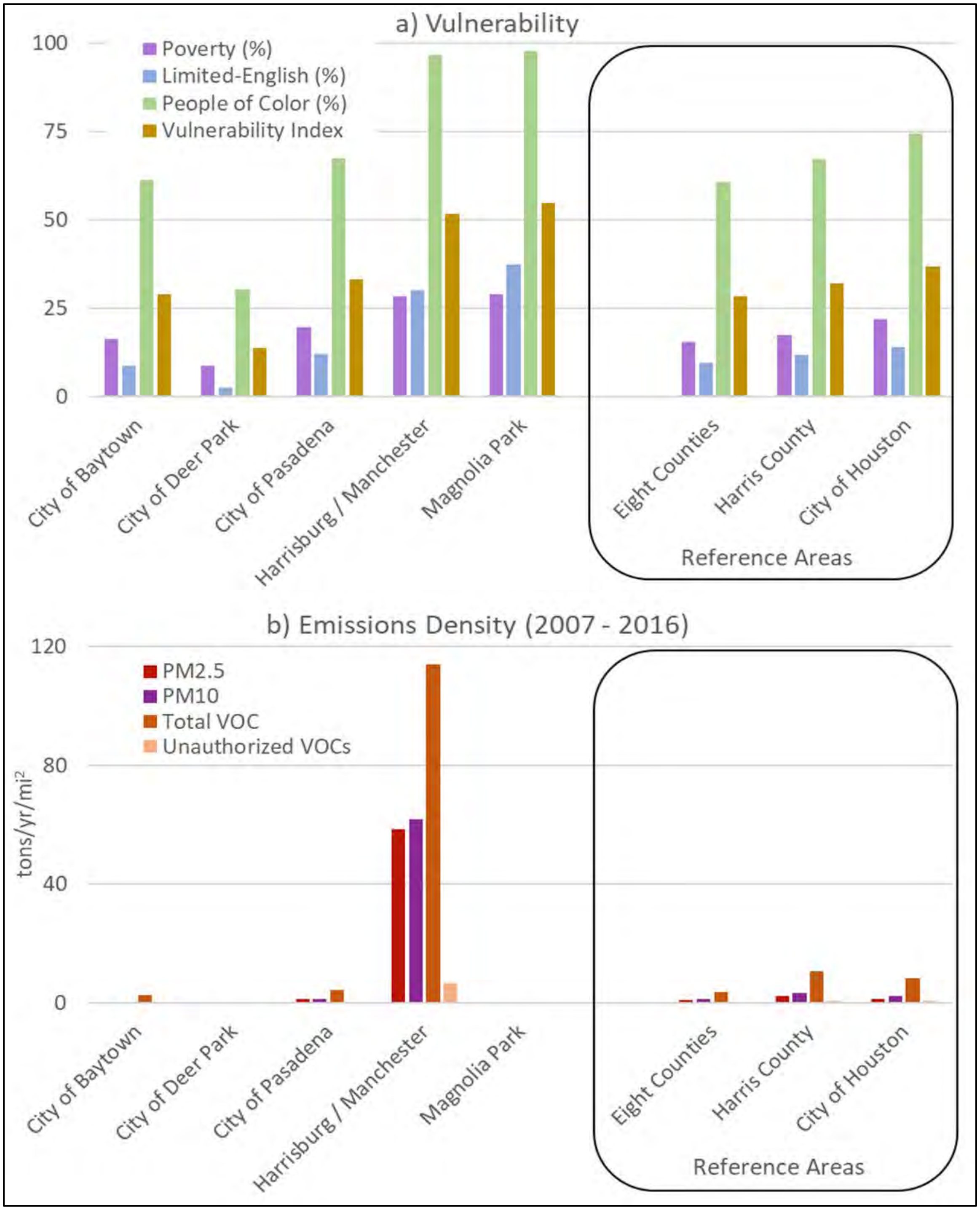


Figure 10: Vulnerability and Emissions in Communities of Interest

Discussion

This analysis evaluates vulnerability and stationary source emissions in the Houston region. Emissions burdens are estimated at the census-tract level, represented as the quantity of pollution emitted per land area. Vulnerability is also evaluated at the tract level, and is estimated based on the share of households that are living in poverty, the share of limited-English households, and the share of the population that are people of color.

The regional-level analysis indicates that the share of vulnerable populations living in tracts where pollution is emitted is modestly smaller than that of more advantaged populations. However, vulnerable populations living in tracts where emissions occur are in proximity to greater densities of pollution emissions than more advantaged populations living in tracts where emissions occur. The overall effect of these two patterns is that the overall average emissions burdens of vulnerable populations are greater than those of more advantaged populations. These findings are consistent for most pollution categories and time periods examined. Disparities are greater for people of color and limited-English households than for people living in poverty.

The regional-scale analysis also points to greater densities of emissions in the Ship Channel area. A closer examination of tracts and communities in that area confirms that many areas along the Ship Channel exhibit greater levels of vulnerability and emissions burdens than the rest of the region. This is particularly true in the Harrisburg / Manchester community.

By examining the density of emissions of different pollutants and pollutant categories experienced by different communities and populations live, we are able to bring attention to areas where emissions burdens and vulnerability intersect. Where and when stationary sources emit different types of pollution is of interest both because of the potential for health risks and because it may provide insight into the regulatory and decision-making context. The authorized emissions included here undergo a permitting process while the unauthorized emissions are reported but are not permitted. In other words, emissions density is closely linked to regulatory and economic decisions.

Limitations

This study focuses on average emissions burdens for different populations and communities. As with any study, this analysis is limited in scope. We evaluated emissions densities but did not evaluate pollution fate and transport in the environment (including chemical reactions that might change the chemical composition of pollutants and the movement of pollutants), residents' exposures to pollution, residents' vulnerability to pollution exposure, or the health risks associated with pollution exposure. Note that this analysis does not account for movement of pollution from adjacent tracts, and it did not include statistical tests of the differences in pollution burdens experienced by different populations and communities.

Comparisons between time periods point to slight to moderate temporal trends for some pollution categories, but the periods of analysis used in this report were not designed to characterize trends over time. Further study would be required to identify trends of increasing or decreasing pollution levels in different populations or communities. Additional avenues for future study include characterizing pollution magnitudes or time trends from different sizes or types of sources, or characterizing the populations that live in areas at these extremes—e.g. those with pollution levels that far exceed the regional average. Additional analysis could also include modeling the fate and transport of pollution in the environment, the population's exposure and vulnerability to pollution, and the health risks borne in different communities and populations.

Conclusions

In this memo we have evaluated demographic vulnerability and point source emissions in the Houston region. This analysis focuses on pollution emissions densities and their relationship with vulnerability in order to identify areas with potential for disparities that may merit additional scrutiny. This analysis should not be interpreted as an analysis of pollution *exposures* or *health risks*, which would require more in-depth measurements and/or modeling of pollution fate and transport, toxicity, vulnerability, and exposure.

Key findings include:

Pollution burdens are disproportionately shouldered by vulnerable populations (people of color, people living in poverty, and limited-English households).

- Vulnerable populations experience greater emissions densities (on average) than their more advantaged counterparts, although they are also modestly less likely to live in tracts with emissions. These seemingly conflicting accounts of disparity are explained by the greater severity of emissions burdens that vulnerable populations bear when they live in tracts with emissions.
- Disparities are substantial, with average burdens for vulnerable populations ranging from 9% to 127% greater than their advantaged counterparts.

Vulnerability and emissions densities vary greatly across the region.

- More centrally-located areas are home to residents with greater vulnerability than are outlying areas, with the exception of the west central part of the region.
- Areas with greater emissions burdens are largely located in the vicinity of the Ship Channel.
- The confluence of pollution and vulnerability occurs along the Ship Channel, particularly in areas that are closer to the center of the region.

- Variation is substantial. For example, the vulnerability measures in Harrisburg / Manchester range from 1.6 to 3.1 times the values for the eight-county region, while the pollution measures range from 28 to 61 times the values for the eight-county region for the period from 2007 to 2016.

Unauthorized emissions of VOCs exhibit similar trends to other pollution categories.

- Vulnerable populations experience greater emissions densities (on average) than their more advantaged counterparts, although they are also modestly less likely to live in tracts with emissions. This is due to the greater severity of emissions burdens that vulnerable populations bear when they live in tracts with emissions.
- Unauthorized emissions of VOCs are largely located in the vicinity of the Ship Channel.

Disparities are consistent across the pollution categories and time periods evaluated.

- Findings of population- and community-level disparities are consistent across the four pollution categories (PM2.5, PM10, total VOCs, and a 19-pollutant index) and the three time periods evaluated (2007 to 2016, 2012 to 2016, and 2016).

Appendices

Contents

Appendix A: Regionwide Analysis of 19 Pollutants of Concern by Population

Average Burden: Average Emissions Density (1 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Acenaphthylene	2007 - 2016	1.0E-05	1.9E-05	-47%	1.4E-05	1.2E-05	14%	1.3E-06	1.6E-05	-92%
	2012 - 2016	2.3E-07	4.8E-07	-53%	1.8E-07	2.8E-07	-37%	2.9E-07	2.8E-07	4%
	2016	2.7E-07	4.3E-07	-38%	1.3E-07	2.8E-07	-54%	3.5E-07	2.6E-07	31%
Acetaldehyde	2007 - 2016	4.1E-03	3.5E-03	17%	5.5E-03	3.4E-03	60%	5.5E-03	3.3E-03	66%
	2012 - 2016	4.3E-03	3.7E-03	16%	6.0E-03	3.7E-03	63%	6.7E-03	3.5E-03	94%
	2016	6.1E-03	5.2E-03	17%	9.1E-03	5.2E-03	74%	1.1E-02	4.7E-03	137%
Acrolein	2007 - 2016	4.0E-04	5.9E-04	-32%	2.7E-04	5.5E-04	-52%	3.5E-04	4.9E-04	-27%
	2012 - 2016	3.6E-04	5.6E-04	-36%	2.8E-04	5.9E-04	-53%	3.6E-04	5.1E-04	-29%
	2016	3.5E-04	5.3E-04	-33%	2.3E-04	6.5E-04	-64%	3.5E-04	5.4E-04	-34%
Anthracene	2007 - 2016	2.8E-05	2.8E-05	2%	4.4E-05	2.3E-05	86%	5.3E-05	2.2E-05	136%
	2012 - 2016	5.1E-06	5.0E-06	1%	6.7E-06	4.3E-06	56%	7.8E-06	4.2E-06	84%
	2016	3.8E-06	3.6E-06	6%	5.6E-06	3.1E-06	81%	7.7E-06	2.8E-06	176%
Benzene	2007 - 2016	3.0E-02	1.9E-02	57%	3.3E-02	2.2E-02	51%	3.6E-02	2.0E-02	78%
	2012 - 2016	2.4E-02	1.7E-02	48%	2.7E-02	1.9E-02	45%	2.8E-02	1.7E-02	65%
	2016	2.3E-02	1.6E-02	45%	2.4E-02	1.8E-02	29%	2.5E-02	1.7E-02	47%
Benzo[a]pyrene	2007 - 2016	3.7E-07	7.4E-08	406%	2.5E-07	2.0E-07	26%	6.2E-07	1.3E-07	362%
	2012 - 2016	1.1E-07	8.7E-08	30%	4.9E-08	8.2E-08	-40%	1.7E-07	6.8E-08	141%
	2016	9.8E-08	8.3E-08	18%	3.9E-08	7.4E-08	-46%	1.4E-07	6.3E-08	124%
1,3-Butadiene	2007 - 2016	3.0E-02	1.3E-02	129%	2.5E-02	2.1E-02	21%	4.9E-02	1.6E-02	212%
	2012 - 2016	2.7E-02	1.3E-02	114%	2.3E-02	1.9E-02	19%	4.4E-02	1.4E-02	206%
	2016	2.1E-02	1.1E-02	92%	1.9E-02	1.5E-02	21%	3.4E-02	1.2E-02	186%
Carbon tetrachloride	2007 - 2016	5.8E-05	7.0E-05	-17%	1.2E-04	4.7E-05	157%	7.1E-05	5.7E-05	24%
	2012 - 2016	5.1E-05	5.5E-05	-8%	1.0E-04	3.9E-05	167%	6.3E-05	4.5E-05	39%
	2016	1.7E-05	4.8E-05	-64%	3.7E-05	2.7E-05	38%	1.4E-05	3.4E-05	-59%
Chlorine	2007 - 2016	1.6E-03	9.1E-04	79%	2.5E-03	1.1E-03	134%	2.1E-03	1.1E-03	98%
	2012 - 2016	1.3E-03	7.2E-04	83%	2.1E-03	8.2E-04	150%	1.7E-03	8.7E-04	92%
	2016	1.3E-03	7.1E-04	78%	2.0E-03	7.9E-04	146%	1.5E-03	8.6E-04	78%

Average Burden: Average Emissions Density (2 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Chromium and compounds	2007 - 2016	4.5E-05	4.8E-05	-6%	3.4E-05	4.4E-05	-24%	5.0E-05	4.2E-05	18%
	2012 - 2016	3.1E-05	3.2E-05	-4%	1.2E-05	2.6E-05	-53%	3.7E-05	2.4E-05	53%
	2016	4.1E-05	4.6E-05	-10%	1.5E-05	3.5E-05	-57%	5.0E-05	3.3E-05	54%
Diaminotoluene (mixed isomers)	2007 - 2016	2.4E-07	1.1E-06	-78%	6.0E-07	6.1E-07	-2%	1.1E-07	6.6E-07	-83%
	2012 - 2016	4.7E-08	2.7E-08	75%	6.2E-08	3.3E-08	87%	6.2E-08	3.2E-08	96%
	2016	1.5E-09	5.6E-09	-73%	1.8E-09	3.5E-09	-48%	2.6E-09	3.2E-09	-18%
Fluoranthene	2007 - 2016	7.6E-07	1.4E-06	-45%	9.2E-07	8.6E-07	7%	1.9E-07	1.1E-06	-83%
	2012 - 2016	1.4E-07	1.7E-07	-17%	3.8E-08	1.3E-07	-70%	1.9E-07	1.1E-07	61%
	2016	1.5E-07	1.7E-07	-13%	5.0E-08	1.2E-07	-59%	1.8E-07	1.2E-07	57%
Formaldehyde	2007 - 2016	8.4E-03	1.1E-02	-23%	7.4E-03	9.8E-03	-25%	6.6E-03	9.5E-03	-31%
	2012 - 2016	7.4E-03	9.5E-03	-22%	7.0E-03	8.7E-03	-19%	6.1E-03	8.3E-03	-26%
	2016	6.3E-03	8.4E-03	-25%	5.9E-03	8.5E-03	-31%	6.1E-03	7.8E-03	-21%
Hydrogen chloride	2007 - 2016	1.1E-02	4.0E-03	183%	9.6E-03	7.0E-03	38%	6.8E-03	7.0E-03	-2%
	2012 - 2016	1.1E-02	3.6E-03	199%	9.3E-03	6.3E-03	47%	6.6E-03	6.4E-03	3%
	2016	4.8E-03	3.1E-03	54%	4.9E-03	3.5E-03	40%	3.1E-03	3.7E-03	-18%
Hydrogen cyanide gas	2007 - 2016	1.5E-02	3.5E-03	318%	1.1E-02	7.9E-03	43%	2.2E-02	6.1E-03	263%
	2012 - 2016	2.9E-02	6.3E-03	357%	2.2E-02	1.5E-02	43%	4.4E-02	1.2E-02	278%
	2016	3.5E-02	8.1E-03	336%	2.7E-02	1.9E-02	46%	5.3E-02	1.5E-02	259%
Hydrogen sulfide	2007 - 2016	7.4E-03	4.2E-03	77%	6.4E-03	4.8E-03	35%	7.6E-03	4.7E-03	64%
	2012 - 2016	7.3E-03	3.9E-03	87%	6.3E-03	4.7E-03	35%	7.5E-03	4.5E-03	65%
	2016	7.6E-03	3.4E-03	123%	6.6E-03	4.7E-03	41%	8.2E-03	4.5E-03	82%
Naphthalene	2007 - 2016	4.2E-03	2.2E-03	87%	4.7E-03	2.8E-03	69%	5.6E-03	2.6E-03	117%
	2012 - 2016	4.0E-03	2.4E-03	68%	4.4E-03	2.7E-03	64%	5.4E-03	2.5E-03	111%
	2016	2.6E-03	1.9E-03	38%	3.2E-03	1.9E-03	70%	3.9E-03	1.8E-03	117%
Phenanthrene	2007 - 2016	1.5E-04	1.7E-04	-11%	6.2E-05	1.3E-04	-53%	2.0E-04	1.2E-04	68%
	2012 - 2016	2.8E-04	3.3E-04	-14%	9.8E-05	2.4E-04	-60%	3.7E-04	2.2E-04	69%
	2016	2.6E-04	3.0E-04	-14%	9.3E-05	2.3E-04	-59%	3.5E-04	2.0E-04	72%

Pollutant	Year range	People of Color (POC)	Non POC	% Difference (POC - NonPOC) / NonPOC	People Living in Poverty (POV)	Non POV	% Difference (POV - NonPOV) / NonPOV	Limited English Household (LEH)	Non LEH	% Difference (LEH - NonLEH) / NonLEH
Average Burden: Average Emissions Density (3 of 3) (tons / year / sq mile estimated at the census tract level)										
Pyrene	2007 - 2016	2.1E-06	3.9E-06	-45%	2.7E-06	2.5E-06	10%	4.0E-07	3.2E-06	-87%
	2012 - 2016	2.4E-07	2.9E-07	-18%	5.9E-08	2.1E-07	-72%	3.1E-07	1.9E-07	62%
	2016	2.2E-07	2.7E-07	-18%	5.7E-08	1.9E-07	-70%	2.8E-07	1.8E-07	62%

Emissions Scope: Share of Population Living in Tracts with Emissions (%) (1 of 3)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Acenaphthylene	2007 - 2016	0.07	0.17	-58%	0.10	0.10	-2%	0.04	0.12	-62%
	2012 - 2016	0.03	0.09	-67%	0.04	0.05	-18%	0.04	0.05	-24%
	2016	0.03	0.09	-67%	0.04	0.05	-18%	0.04	0.05	-24%
Acetaldehyde	2007 - 2016	4.36	5.76	-24%	4.58	5.42	-16%	3.71	5.14	-28%
	2012 - 2016	3.83	4.81	-20%	3.78	4.87	-23%	3.17	4.51	-30%
	2016	2.57	2.81	-9%	2.60	3.13	-17%	2.33	2.90	-20%
Acrolein	2007 - 2016	3.39	4.83	-30%	3.47	4.60	-25%	2.79	4.28	-35%
	2012 - 2016	3.05	4.26	-28%	2.99	4.17	-28%	2.45	3.87	-37%
	2016	2.34	2.64	-11%	2.23	2.95	-25%	2.16	2.70	-20%
Anthracene	2007 - 2016	0.62	0.67	-8%	0.63	0.59	6%	0.56	0.59	-6%
	2012 - 2016	0.56	0.66	-16%	0.59	0.56	6%	0.53	0.56	-6%
	2016	0.31	0.40	-23%	0.42	0.29	45%	0.48	0.29	63%
Benzene	2007 - 2016	11.46	14.08	-19%	11.43	13.30	-14%	9.08	12.80	-29%
	2012 - 2016	9.09	11.95	-24%	9.23	10.65	-13%	7.09	10.31	-31%
	2016	6.76	9.09	-26%	7.13	8.14	-12%	5.85	7.87	-26%
Benzo[a]pyrene	2007 - 2016	0.07	0.08	-14%	0.07	0.06	18%	0.09	0.07	39%
	2012 - 2016	0.06	0.02	242%	0.04	0.03	12%	0.09	0.02	307%
	2016	0.06	0.02	242%	0.04	0.03	12%	0.09	0.02	307%
1,3-Butadiene	2007 - 2016	2.59	3.02	-14%	2.70	2.76	-2%	2.34	2.78	-16%
	2012 - 2016	2.05	2.44	-16%	2.09	2.22	-6%	1.90	2.23	-15%
	2016	1.76	1.84	-5%	1.83	1.71	7%	1.78	1.75	2%
Carbon tetrachloride	2007 - 2016	0.61	1.52	-60%	0.99	0.96	3%	0.75	1.05	-28%
	2012 - 2016	0.42	1.07	-60%	0.62	0.69	-10%	0.51	0.71	-28%
	2016	0.35	0.95	-63%	0.54	0.60	-9%	0.47	0.61	-22%
Chlorine	2007 - 2016	1.24	1.60	-23%	1.55	1.32	17%	1.62	1.34	21%
	2012 - 2016	1.12	1.47	-24%	1.36	1.22	11%	1.48	1.18	25%
	2016	0.83	1.37	-39%	1.25	1.00	26%	1.16	0.99	17%

Emissions Scope: Share of Population Living in Tracts with Emissions (%) (2 of 3)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Chromium and compounds	2007 - 2016	1.61	1.07	51%	1.50	1.35	11%	1.38	1.24	11%
	2012 - 2016	0.79	0.67	18%	0.72	0.77	-6%	0.54	0.73	-26%
	2016	0.57	0.54	5%	0.55	0.60	-8%	0.38	0.56	-32%
Diaminotoluene (mixed isomers)	2007 - 2016	0.22	0.72	-70%	0.34	0.44	-23%	0.29	0.44	-34%
	2012 - 2016	0.17	0.48	-65%	0.21	0.31	-33%	0.27	0.29	-5%
	2016	0.13	0.47	-73%	0.15	0.30	-48%	0.22	0.27	-18%
Fluoranthene	2007 - 2016	0.11	0.13	-12%	0.12	0.09	25%	0.07	0.12	-42%
	2012 - 2016	0.07	0.05	42%	0.06	0.05	36%	0.06	0.05	22%
	2016	0.07	0.05	42%	0.06	0.05	36%	0.06	0.05	22%
Formaldehyde	2007 - 2016	9.57	13.30	-28%	9.88	11.51	-14%	7.67	11.14	-31%
	2012 - 2016	8.52	12.12	-30%	8.65	10.51	-18%	6.62	10.13	-35%
	2016	5.75	8.66	-34%	5.99	7.49	-20%	4.79	7.22	-34%
Hydrogen chloride	2007 - 2016	2.89	3.32	-13%	3.07	2.98	3%	2.27	2.98	-24%
	2012 - 2016	2.26	2.53	-11%	2.59	2.22	17%	1.80	2.26	-21%
	2016	1.76	2.16	-18%	2.19	1.81	21%	1.37	1.86	-26%
Hydrogen cyanide gas	2007 - 2016	0.60	0.56	8%	0.69	0.51	36%	0.56	0.55	2%
	2012 - 2016	0.57	0.48	19%	0.69	0.46	50%	0.53	0.49	7%
	2016	0.33	0.41	-20%	0.43	0.30	46%	0.30	0.33	-8%
Hydrogen sulfide	2007 - 2016	3.46	4.48	-23%	3.96	3.69	7%	3.00	3.76	-20%
	2012 - 2016	3.22	4.15	-22%	3.52	3.46	2%	2.48	3.49	-29%
	2016	2.27	3.06	-26%	2.48	2.46	1%	1.85	2.48	-25%
Naphthalene	2007 - 2016	6.29	5.59	13%	6.67	5.70	17%	6.41	5.64	14%
	2012 - 2016	5.31	4.63	15%	5.50	4.76	16%	5.41	4.65	16%
	2016	3.92	3.52	11%	3.97	3.61	10%	4.05	3.51	16%
Phenanthrene	2007 - 2016	0.74	0.74	1%	0.81	0.67	21%	0.79	0.65	22%
	2012 - 2016	0.66	0.49	36%	0.69	0.54	28%	0.68	0.51	35%
	2016	0.60	0.48	26%	0.65	0.51	29%	0.65	0.48	37%

Emissions Scope: Share of Population Living in Tracts with Emissions (%) (3 of 3)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Pyrene	2007 - 2016	0.29	0.19	51%	0.19	0.23	-19%	0.13	0.26	-48%
	2012 - 2016	0.07	0.05	42%	0.06	0.05	36%	0.06	0.05	22%
	2016	0.07	0.05	42%	0.06	0.05	36%	0.06	0.05	22%

Emissions Severity: Average Emissions Density for People Living in Tract with Emissions (1 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Acenaphthylene	2007 - 2016	1.4E-02	1.1E-02	26%	1.4E-02	1.2E-02	16%	3.0E-03	1.4E-02	-78%
	2012 - 2016	7.3E-04	5.1E-04	44%	4.3E-04	5.6E-04	-24%	7.3E-04	5.3E-04	37%
	2016	8.6E-04	4.6E-04	88%	3.1E-04	5.5E-04	-44%	8.6E-04	5.0E-04	72%
Acetaldehyde	2007 - 2016	9.3E-02	6.1E-02	54%	1.2E-01	6.3E-02	89%	1.5E-01	6.5E-02	129%
	2012 - 2016	1.1E-01	7.7E-02	45%	1.6E-01	7.6E-02	110%	2.1E-01	7.7E-02	175%
	2016	2.4E-01	1.9E-01	29%	3.5E-01	1.7E-01	110%	4.8E-01	1.6E-01	195%
Acrolein	2007 - 2016	1.2E-02	1.2E-02	-3%	7.6E-03	1.2E-02	-36%	1.3E-02	1.1E-02	11%
	2012 - 2016	1.2E-02	1.3E-02	-11%	9.4E-03	1.4E-02	-34%	1.5E-02	1.3E-02	13%
	2016	1.5E-02	2.0E-02	-24%	1.0E-02	2.2E-02	-53%	1.6E-02	2.0E-02	-18%
Anthracene	2007 - 2016	4.6E-03	4.1E-03	11%	6.9E-03	4.0E-03	75%	9.5E-03	3.8E-03	150%
	2012 - 2016	9.2E-04	7.6E-04	20%	1.1E-03	7.6E-04	48%	1.5E-03	7.5E-04	95%
	2016	1.3E-03	9.2E-04	36%	1.4E-03	1.1E-03	25%	1.6E-03	9.6E-04	69%
Benzene	2007 - 2016	2.6E-01	1.3E-01	93%	2.9E-01	1.6E-01	76%	4.0E-01	1.6E-01	150%
	2012 - 2016	2.7E-01	1.4E-01	95%	2.9E-01	1.7E-01	67%	4.0E-01	1.7E-01	140%
	2016	3.4E-01	1.7E-01	96%	3.3E-01	2.2E-01	48%	4.2E-01	2.1E-01	98%
Benzo[a]pyrene	2007 - 2016	5.4E-04	9.3E-05	487%	3.4E-04	3.2E-04	6%	6.6E-04	2.0E-04	232%
	2012 - 2016	2.0E-04	5.3E-04	-62%	1.4E-04	2.6E-04	-46%	1.8E-04	3.1E-04	-41%
	2016	1.8E-04	5.1E-04	-66%	1.1E-04	2.3E-04	-52%	1.5E-04	2.8E-04	-45%
1,3-Butadiene	2007 - 2016	1.2E+00	4.3E-01	167%	9.3E-01	7.5E-01	24%	2.1E+00	5.6E-01	270%
	2012 - 2016	1.3E+00	5.1E-01	156%	1.1E+00	8.6E-01	27%	2.3E+00	6.5E-01	260%
	2016	1.2E+00	5.9E-01	101%	1.0E+00	9.0E-01	13%	1.9E+00	6.8E-01	181%
Carbon tetrachloride	2007 - 2016	9.6E-03	4.6E-03	107%	1.2E-02	4.9E-03	150%	9.4E-03	5.5E-03	73%
	2012 - 2016	1.2E-02	5.1E-03	133%	1.7E-02	5.6E-03	197%	1.2E-02	6.4E-03	93%
	2016	5.0E-03	5.1E-03	-2%	6.9E-03	4.5E-03	52%	3.0E-03	5.6E-03	-47%
Chlorine	2007 - 2016	1.3E-01	5.7E-02	131%	1.6E-01	8.0E-02	99%	1.3E-01	8.1E-02	63%
	2012 - 2016	1.2E-01	4.9E-02	141%	1.5E-01	6.7E-02	125%	1.1E-01	7.4E-02	53%
	2016	1.5E-01	5.2E-02	193%	1.6E-01	8.0E-02	96%	1.3E-01	8.7E-02	52%

Emissions Severity: Average Emissions Density for People Living in Tract with Emissions (2 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Chromium and compounds	2007 - 2016	2.8E-03	4.5E-03	-38%	2.2E-03	3.3E-03	-32%	3.6E-03	3.4E-03	6%
	2012 - 2016	3.9E-03	4.7E-03	-18%	1.7E-03	3.4E-03	-50%	6.8E-03	3.3E-03	107%
	2016	7.3E-03	8.5E-03	-14%	2.8E-03	5.9E-03	-53%	1.3E-02	5.8E-03	125%
Diaminotoluene (mixed isomers)	2007 - 2016	1.1E-04	1.5E-04	-27%	1.8E-04	1.4E-04	27%	3.8E-05	1.5E-04	-75%
	2012 - 2016	2.8E-05	5.6E-06	398%	3.0E-05	1.1E-05	182%	2.3E-05	1.1E-05	106%
	2016	1.2E-06	1.2E-06	0%	1.2E-06	1.2E-06	0%	1.2E-06	1.2E-06	0%
Fluoranthene	2007 - 2016	6.7E-04	1.1E-03	-37%	7.8E-04	9.1E-04	-14%	2.8E-04	9.4E-04	-71%
	2012 - 2016	2.1E-04	3.5E-04	-42%	6.1E-05	2.7E-04	-78%	2.9E-04	2.2E-04	32%
	2016	2.1E-04	3.4E-04	-39%	8.1E-05	2.7E-04	-70%	2.9E-04	2.2E-04	28%
Formaldehyde	2007 - 2016	8.8E-02	8.2E-02	7%	7.5E-02	8.5E-02	-12%	8.6E-02	8.5E-02	0%
	2012 - 2016	8.7E-02	7.9E-02	11%	8.1E-02	8.2E-02	-2%	9.3E-02	8.2E-02	13%
	2016	1.1E-01	9.7E-02	13%	9.8E-02	1.1E-01	-14%	1.3E-01	1.1E-01	19%
Hydrogen chloride	2007 - 2016	3.9E-01	1.2E-01	224%	3.1E-01	2.3E-01	33%	3.0E-01	2.3E-01	28%
	2012 - 2016	4.7E-01	1.4E-01	235%	3.6E-01	2.8E-01	26%	3.7E-01	2.8E-01	30%
	2016	2.7E-01	1.4E-01	88%	2.2E-01	1.9E-01	16%	2.2E-01	2.0E-01	11%
Hydrogen cyanide gas	2007 - 2016	2.4E+00	6.3E-01	286%	1.6E+00	1.5E+00	5%	4.0E+00	1.1E+00	255%
	2012 - 2016	5.0E+00	1.3E+00	285%	3.2E+00	3.3E+00	-4%	8.3E+00	2.4E+00	253%
	2016	1.1E+01	2.0E+00	442%	6.3E+00	6.3E+00	0%	1.7E+01	4.4E+00	291%
Hydrogen sulfide	2007 - 2016	2.1E-01	9.3E-02	129%	1.6E-01	1.3E-01	26%	2.5E-01	1.2E-01	105%
	2012 - 2016	2.3E-01	9.4E-02	142%	1.8E-01	1.3E-01	33%	3.0E-01	1.3E-01	132%
	2016	3.4E-01	1.1E-01	200%	2.7E-01	1.9E-01	40%	4.4E-01	1.8E-01	145%
Naphthalene	2007 - 2016	6.7E-02	4.0E-02	66%	7.1E-02	4.9E-02	44%	8.7E-02	4.5E-02	91%
	2012 - 2016	7.5E-02	5.1E-02	46%	8.0E-02	5.7E-02	41%	9.9E-02	5.5E-02	81%
	2016	6.7E-02	5.4E-02	24%	8.1E-02	5.2E-02	55%	9.7E-02	5.2E-02	88%
Phenanthrene	2007 - 2016	2.1E-02	2.4E-02	-12%	7.7E-03	2.0E-02	-61%	2.5E-02	1.9E-02	37%
	2012 - 2016	4.2E-02	6.6E-02	-36%	1.4E-02	4.5E-02	-69%	5.4E-02	4.3E-02	25%
	2016	4.3E-02	6.3E-02	-31%	1.4E-02	4.4E-02	-68%	5.4E-02	4.3E-02	25%

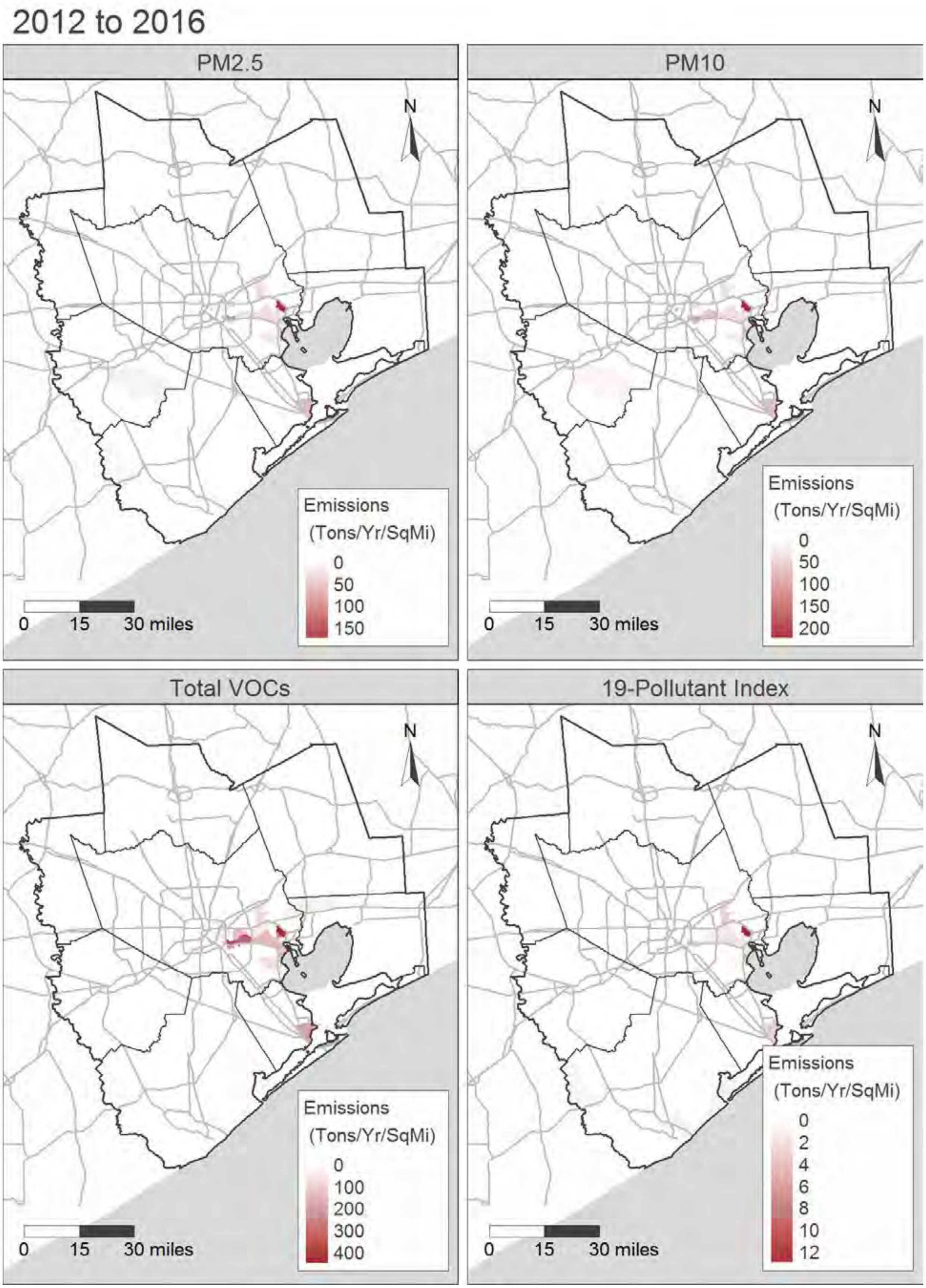
Emissions Severity: Average Emissions Density for People Living in Tract with Emissions (3 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Pyrene	2007 - 2016	7.4E-04	2.0E-03	-64%	1.4E-03	1.1E-03	36%	3.0E-04	1.2E-03	-76%
	2012 - 2016	3.4E-04	5.9E-04	-43%	9.4E-05	4.5E-04	-79%	4.9E-04	3.6E-04	33%
	2016	3.1E-04	5.4E-04	-42%	9.2E-05	4.2E-04	-78%	4.5E-04	3.4E-04	33%

Average Emissions Density for People Living in Tract with Emissions (1 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Acenaphthylene	2007 - 2016	1.4E-02	1.1E-02	26%	1.4E-02	1.2E-02	16%	3.0E-03	1.4E-02	-78%
	2012 - 2016	7.3E-04	5.1E-04	44%	4.3E-04	5.6E-04	-24%	7.3E-04	5.3E-04	37%
	2016	8.6E-04	4.6E-04	88%	3.1E-04	5.5E-04	-44%	8.6E-04	5.0E-04	72%
Acetaldehyde	2007 - 2016	9.3E-02	6.1E-02	54%	1.2E-01	6.3E-02	89%	1.5E-01	6.5E-02	129%
	2012 - 2016	1.1E-01	7.7E-02	45%	1.6E-01	7.6E-02	110%	2.1E-01	7.7E-02	175%
	2016	2.4E-01	1.9E-01	29%	3.5E-01	1.7E-01	110%	4.8E-01	1.6E-01	195%
Acrolein	2007 - 2016	1.2E-02	1.2E-02	-3%	7.6E-03	1.2E-02	-36%	1.3E-02	1.1E-02	11%
	2012 - 2016	1.2E-02	1.3E-02	-11%	9.4E-03	1.4E-02	-34%	1.5E-02	1.3E-02	13%
	2016	1.5E-02	2.0E-02	-24%	1.0E-02	2.2E-02	-53%	1.6E-02	2.0E-02	-18%
Anthracene	2007 - 2016	4.6E-03	4.1E-03	11%	6.9E-03	4.0E-03	75%	9.5E-03	3.8E-03	150%
	2012 - 2016	9.2E-04	7.6E-04	20%	1.1E-03	7.6E-04	48%	1.5E-03	7.5E-04	95%
	2016	1.3E-03	9.2E-04	36%	1.4E-03	1.1E-03	25%	1.6E-03	9.6E-04	69%
Benzene	2007 - 2016	2.6E-01	1.3E-01	93%	2.9E-01	1.6E-01	76%	4.0E-01	1.6E-01	150%
	2012 - 2016	2.7E-01	1.4E-01	95%	2.9E-01	1.7E-01	67%	4.0E-01	1.7E-01	140%
	2016	3.4E-01	1.7E-01	96%	3.3E-01	2.2E-01	48%	4.2E-01	2.1E-01	98%
Benzo[a]pyrene	2007 - 2016	5.4E-04	9.3E-05	487%	3.4E-04	3.2E-04	6%	6.6E-04	2.0E-04	232%
	2012 - 2016	2.0E-04	5.3E-04	-62%	1.4E-04	2.6E-04	-46%	1.8E-04	3.1E-04	-41%
	2016	1.8E-04	5.1E-04	-66%	1.1E-04	2.3E-04	-52%	1.5E-04	2.8E-04	-45%
1,3-Butadiene	2007 - 2016	1.2E+00	4.3E-01	167%	9.3E-01	7.5E-01	24%	2.1E+00	5.6E-01	270%
	2012 - 2016	1.3E+00	5.1E-01	156%	1.1E+00	8.6E-01	27%	2.3E+00	6.5E-01	260%
	2016	1.2E+00	5.9E-01	101%	1.0E+00	9.0E-01	13%	1.9E+00	6.8E-01	181%
Carbon tetrachloride	2007 - 2016	9.6E-03	4.6E-03	107%	1.2E-02	4.9E-03	150%	9.4E-03	5.5E-03	73%
	2012 - 2016	1.2E-02	5.1E-03	133%	1.7E-02	5.6E-03	197%	1.2E-02	6.4E-03	93%
	2016	5.0E-03	5.1E-03	-2%	6.9E-03	4.5E-03	52%	3.0E-03	5.6E-03	-47%
Chlorine	2007 - 2016	1.3E-01	5.7E-02	131%	1.6E-01	8.0E-02	99%	1.3E-01	8.1E-02	63%
	2012 - 2016	1.2E-01	4.9E-02	141%	1.5E-01	6.7E-02	125%	1.1E-01	7.4E-02	53%
	2016	1.5E-01	5.2E-02	193%	1.6E-01	8.0E-02	96%	1.3E-01	8.7E-02	52%

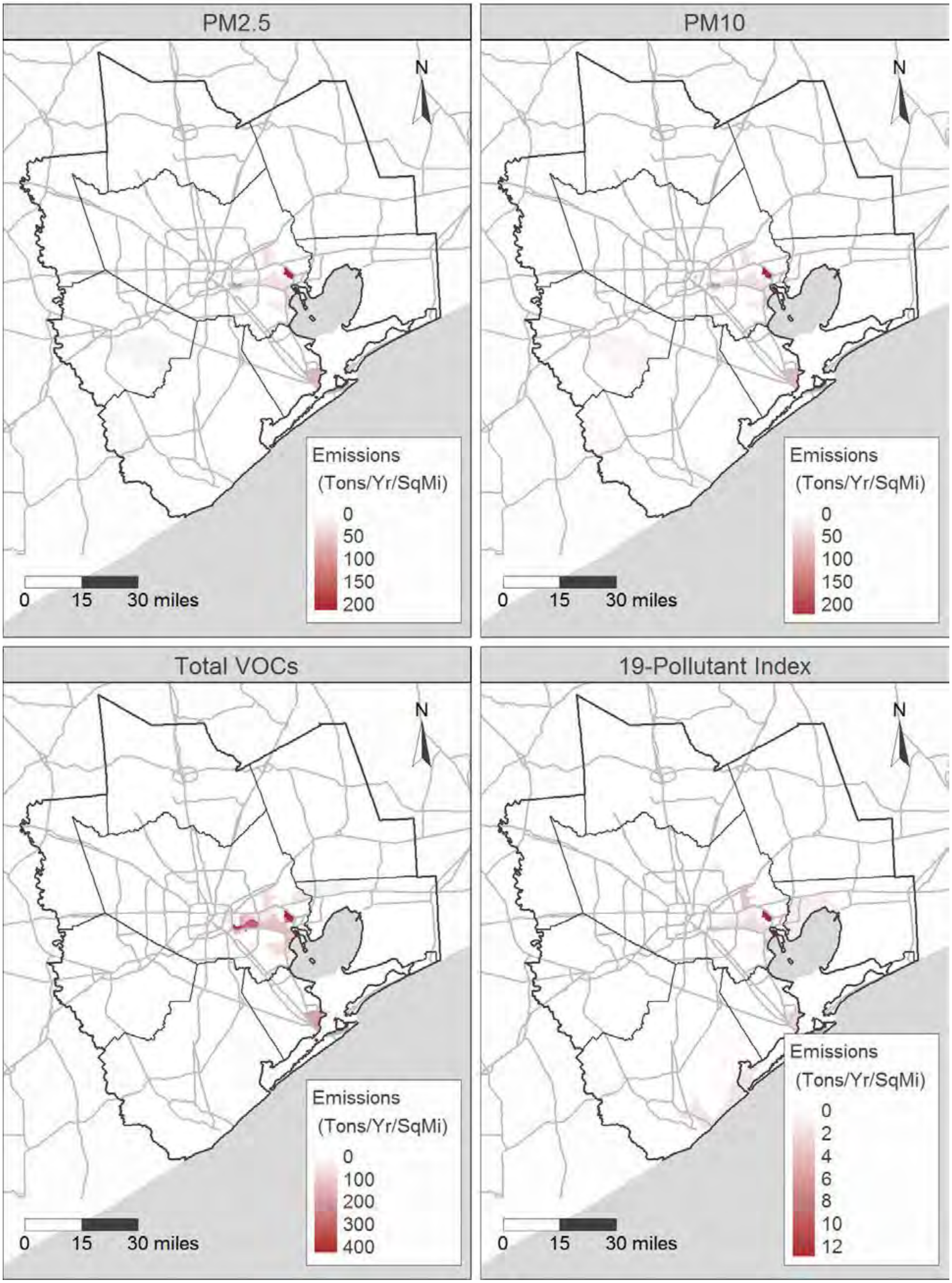
Average Emissions Density for People Living in Tract with Emissions (2 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Chromium and compounds	2007 - 2016	2.8E-03	4.5E-03	-38%	2.2E-03	3.3E-03	-32%	3.6E-03	3.4E-03	6%
	2012 - 2016	3.9E-03	4.7E-03	-18%	1.7E-03	3.4E-03	-50%	6.8E-03	3.3E-03	107%
	2016	7.3E-03	8.5E-03	-14%	2.8E-03	5.9E-03	-53%	1.3E-02	5.8E-03	125%
Diaminotoluene (mixed isomers)	2007 - 2016	1.1E-04	1.5E-04	-27%	1.8E-04	1.4E-04	27%	3.8E-05	1.5E-04	-75%
	2012 - 2016	2.8E-05	5.6E-06	398%	3.0E-05	1.1E-05	182%	2.3E-05	1.1E-05	106%
	2016	1.2E-06	1.2E-06	0%	1.2E-06	1.2E-06	0%	1.2E-06	1.2E-06	0%
Fluoranthene	2007 - 2016	6.7E-04	1.1E-03	-37%	7.8E-04	9.1E-04	-14%	2.8E-04	9.4E-04	-71%
	2012 - 2016	2.1E-04	3.5E-04	-42%	6.1E-05	2.7E-04	-78%	2.9E-04	2.2E-04	32%
	2016	2.1E-04	3.4E-04	-39%	8.1E-05	2.7E-04	-70%	2.9E-04	2.2E-04	28%
Formaldehyde	2007 - 2016	8.8E-02	8.2E-02	7%	7.5E-02	8.5E-02	-12%	8.6E-02	8.5E-02	0%
	2012 - 2016	8.7E-02	7.9E-02	11%	8.1E-02	8.2E-02	-2%	9.3E-02	8.2E-02	13%
	2016	1.1E-01	9.7E-02	13%	9.8E-02	1.1E-01	-14%	1.3E-01	1.1E-01	19%
Hydrogen chloride	2007 - 2016	3.9E-01	1.2E-01	224%	3.1E-01	2.3E-01	33%	3.0E-01	2.3E-01	28%
	2012 - 2016	4.7E-01	1.4E-01	235%	3.6E-01	2.8E-01	26%	3.7E-01	2.8E-01	30%
	2016	2.7E-01	1.4E-01	88%	2.2E-01	1.9E-01	16%	2.2E-01	2.0E-01	11%
Hydrogen cyanide gas	2007 - 2016	2.4E+00	6.3E-01	286%	1.6E+00	1.5E+00	5%	4.0E+00	1.1E+00	255%
	2012 - 2016	5.0E+00	1.3E+00	285%	3.2E+00	3.3E+00	-4%	8.3E+00	2.4E+00	253%
	2016	1.1E+01	2.0E+00	442%	6.3E+00	6.3E+00	0%	1.7E+01	4.4E+00	291%
Hydrogen sulfide	2007 - 2016	2.1E-01	9.3E-02	129%	1.6E-01	1.3E-01	26%	2.5E-01	1.2E-01	105%
	2012 - 2016	2.3E-01	9.4E-02	142%	1.8E-01	1.3E-01	33%	3.0E-01	1.3E-01	132%
	2016	3.4E-01	1.1E-01	200%	2.7E-01	1.9E-01	40%	4.4E-01	1.8E-01	145%
Naphthalene	2007 - 2016	6.7E-02	4.0E-02	66%	7.1E-02	4.9E-02	44%	8.7E-02	4.5E-02	91%
	2012 - 2016	7.5E-02	5.1E-02	46%	8.0E-02	5.7E-02	41%	9.9E-02	5.5E-02	81%
	2016	6.7E-02	5.4E-02	24%	8.1E-02	5.2E-02	55%	9.7E-02	5.2E-02	88%
Phenanthrene	2007 - 2016	2.1E-02	2.4E-02	-12%	7.7E-03	2.0E-02	-61%	2.5E-02	1.9E-02	37%
	2012 - 2016	4.2E-02	6.6E-02	-36%	1.4E-02	4.5E-02	-69%	5.4E-02	4.3E-02	25%
	2016	4.3E-02	6.3E-02	-31%	1.4E-02	4.4E-02	-68%	5.4E-02	4.3E-02	25%

Average Emissions Density for People Living in Tract with Emissions (3 of 3) (tons / year / sq mile estimated at the census tract level)										
Pollutant	**Year range**	**People of Color (POC)**	**Non POC**	**% Difference (POC - NonPOC) / NonPOC**	**People Living in Poverty (POV)**	**Non POV**	**% Difference (POV - NonPOV) / NonPOV**	**Limited English Household (LEH)**	**Non LEH**	**% Difference (LEH - NonLEH) / NonLEH**
Pyrene	2007 - 2016	7.4E-04	2.0E-03	-64%	1.4E-03	1.1E-03	36%	3.0E-04	1.2E-03	-76%
	2012 - 2016	3.4E-04	5.9E-04	-43%	9.4E-05	4.5E-04	-79%	4.9E-04	3.6E-04	33%
	2016	3.1E-04	5.4E-04	-42%	9.2E-05	4.2E-04	-78%	4.5E-04	3.4E-04	33%

Appendix B: Additional Regionwide Maps of Four Pollution Categories

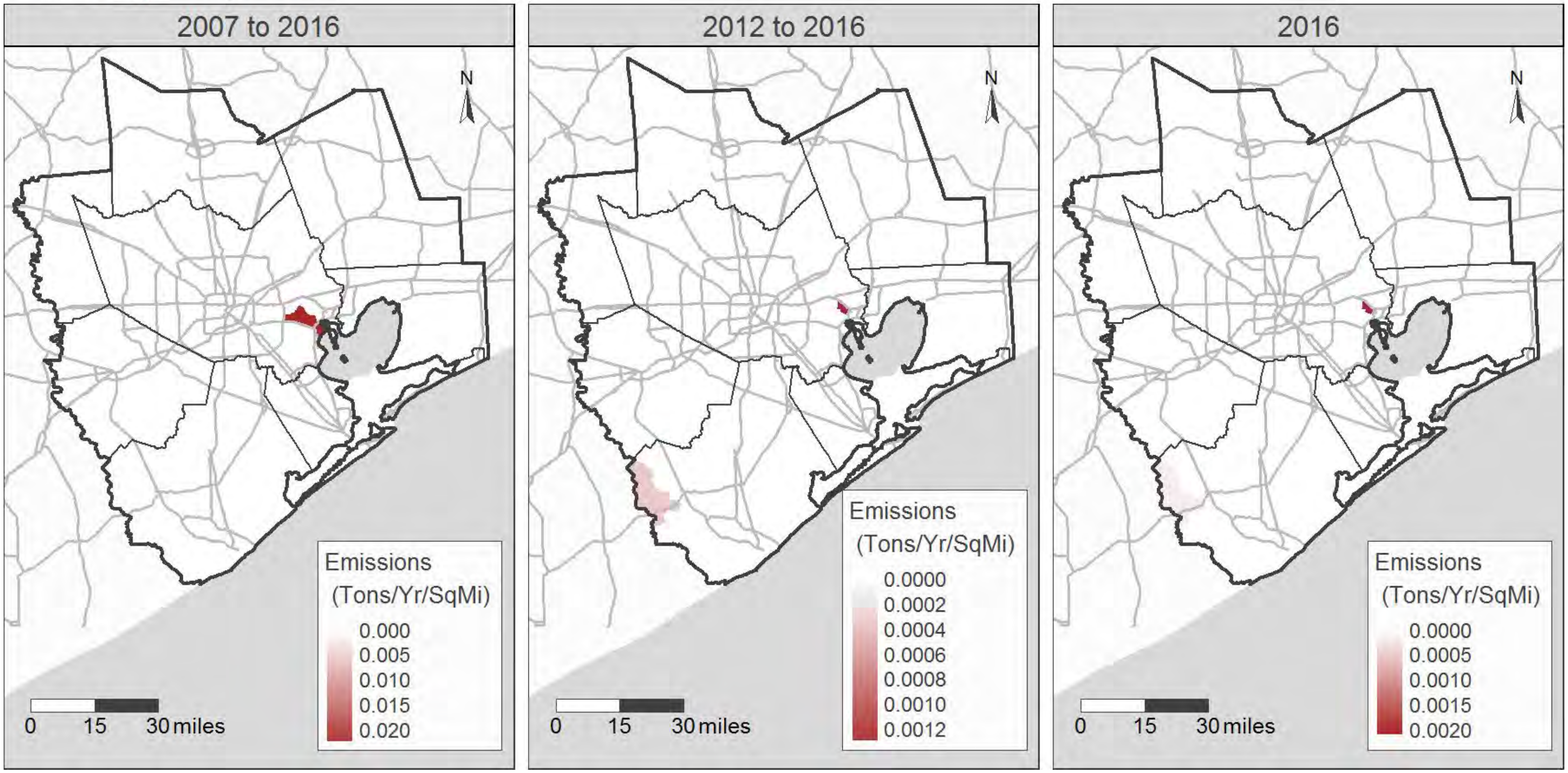

2012 to 2016
PM2.5
N
Emissions
(Tons/Yr/SqMi)
0
50
100
150
0
15
30 miles
PM10
N
Emissions
(Tons/Yr/SqMi)
0
50
100
150
200
0
15
30 miles
Total VOCs
N
Emissions
(Tons/Yr/SqMi)
0
100
200
300
400
0
15
30 miles
19-Pollutant Index
N
Emissions
(Tons/Yr/SqMi)
0
2
4
6
8
10
12
0
15
30 miles

2016

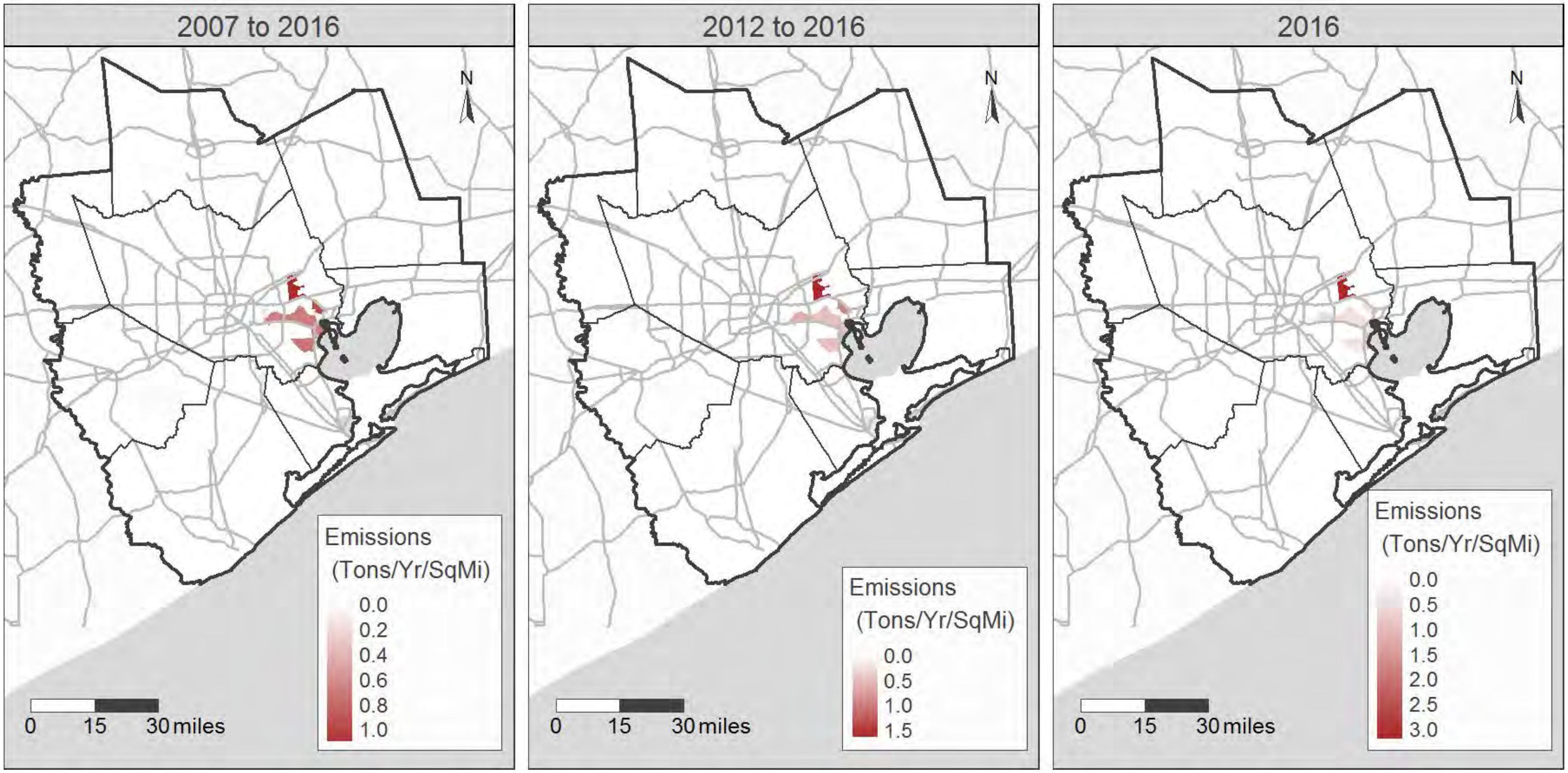

PM2.5
PM10
Total VOCs
19-Pollutant Index
N
Emissions
(Tons/Yr/SqMi)
0
50
100
150
200
0
100
200
300
400
0
2
4
6
8
10
12
0 15 30 miles

Appendix C: Regionwide Maps of 19 Pollutants of Concern

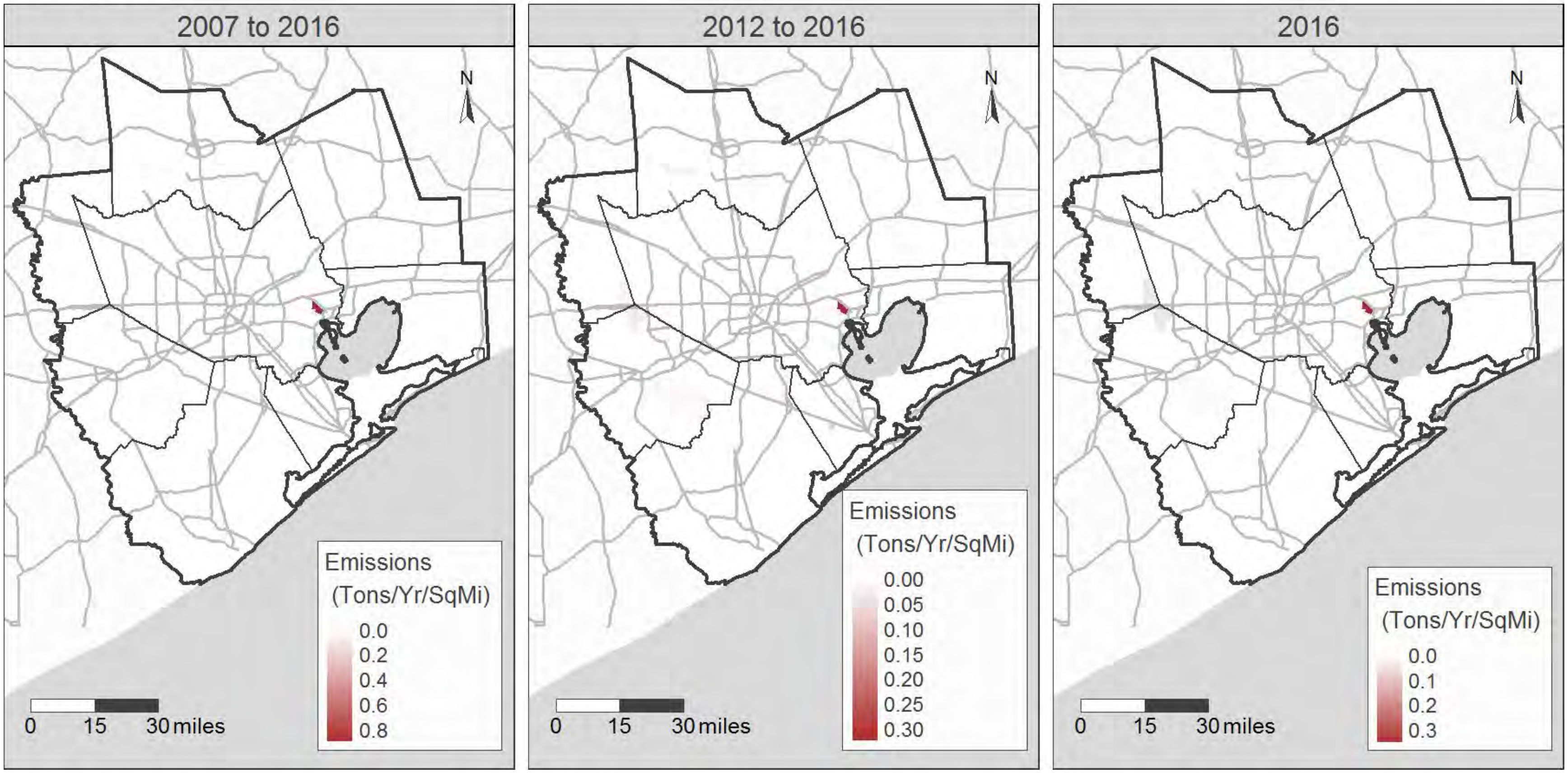
Acenaphthylene



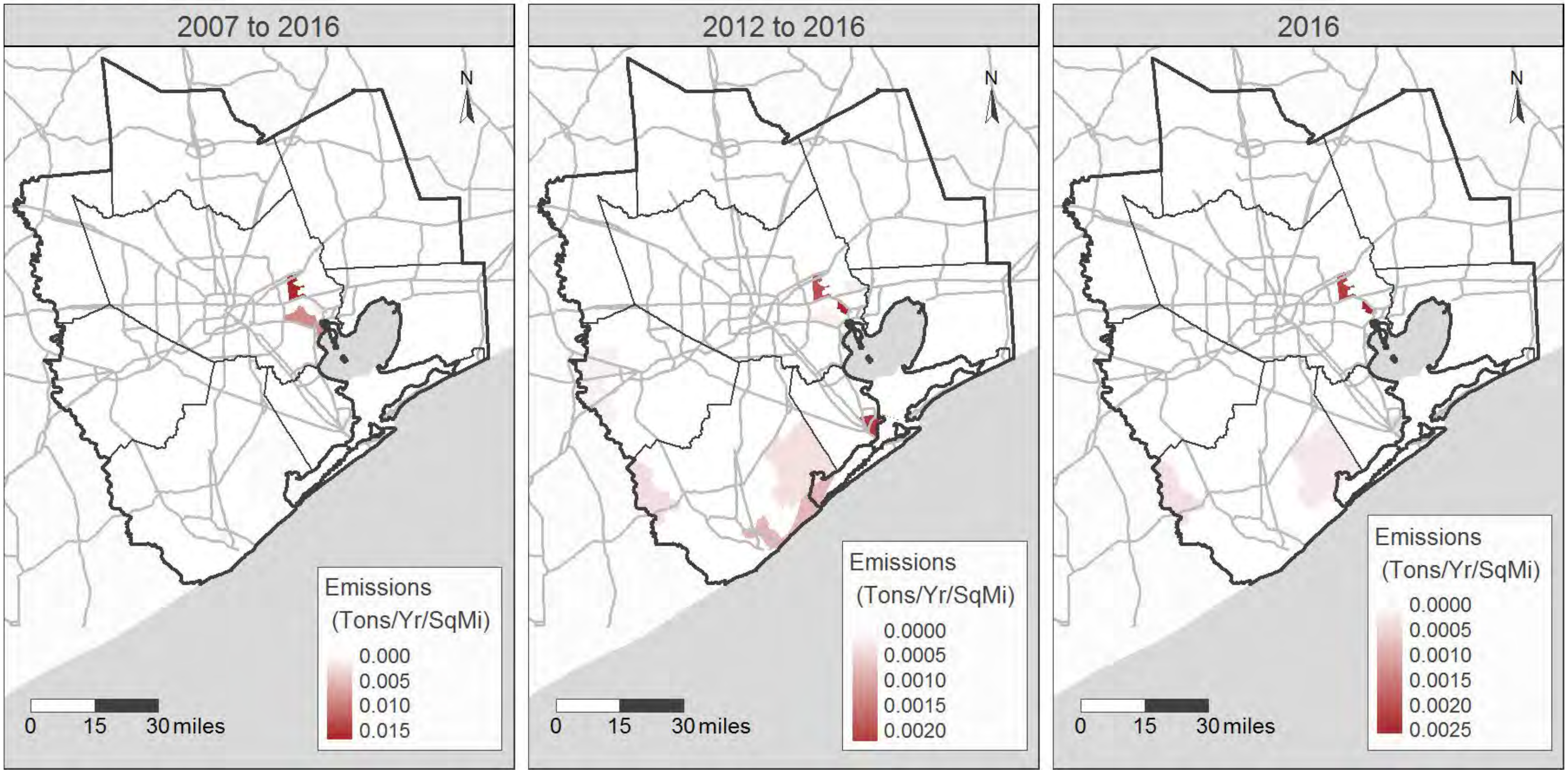
Acetaldehyde



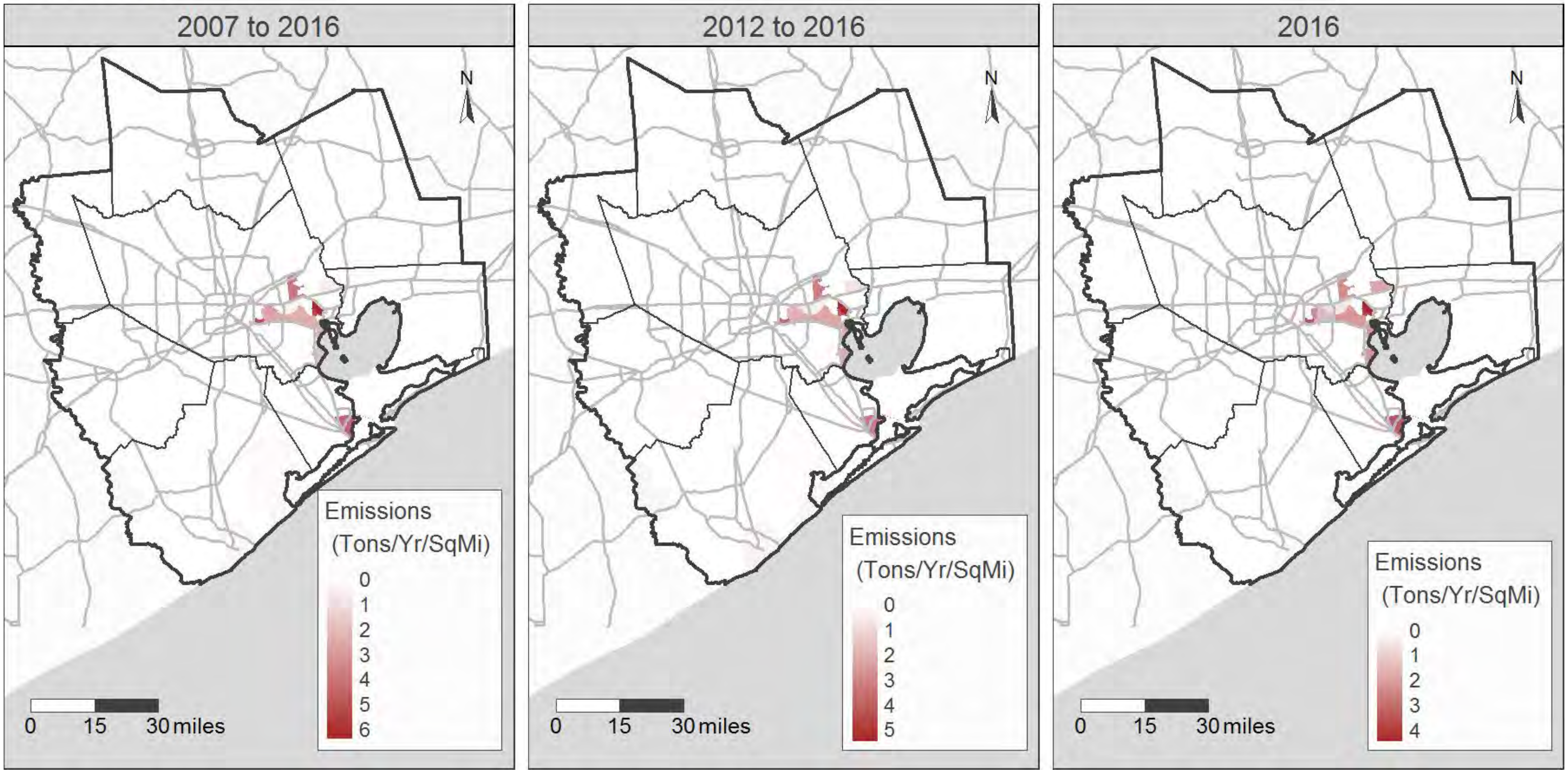
Acrolein


2007 to 2016
2012 to 2016
2016
N
Emissions
(Tons/Yr/SqMi)
0.0
0.2
0.4
0.6
0.8
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.0
0.1
0.2
0.3
0
15
30 miles

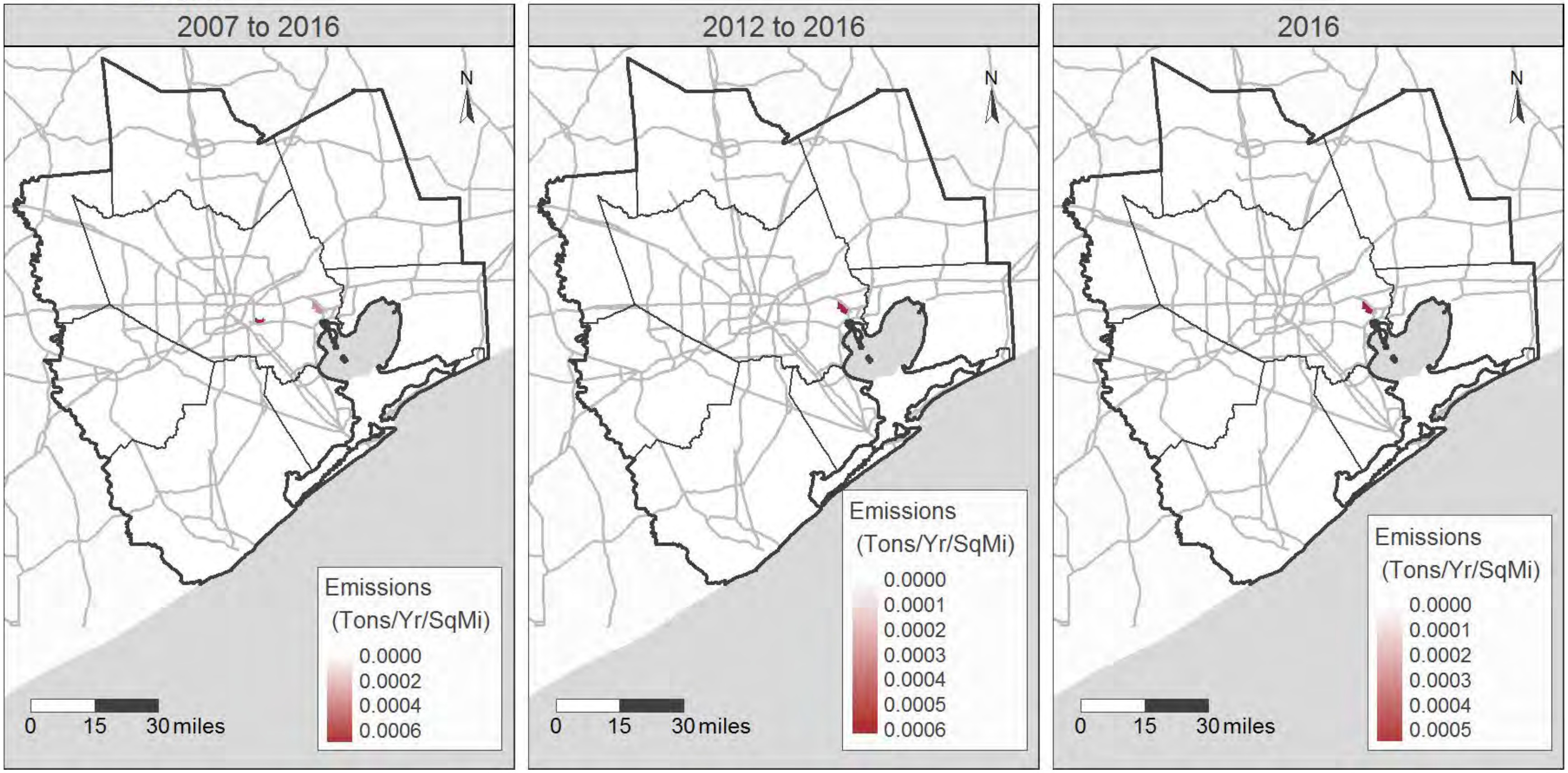
Anthracene


2007 to 2016
N
Emissions
(Tons/Yr/SqMi)
0.000
0.005
0.010
0.015
0
15
30 miles
2012 to 2016
N
Emissions
(Tons/Yr/SqMi)
0.0000
0.0005
0.0010
0.0015
0.0020
0
15
30 miles
2016
N
Emissions
(Tons/Yr/SqMi)
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0
15
30 miles

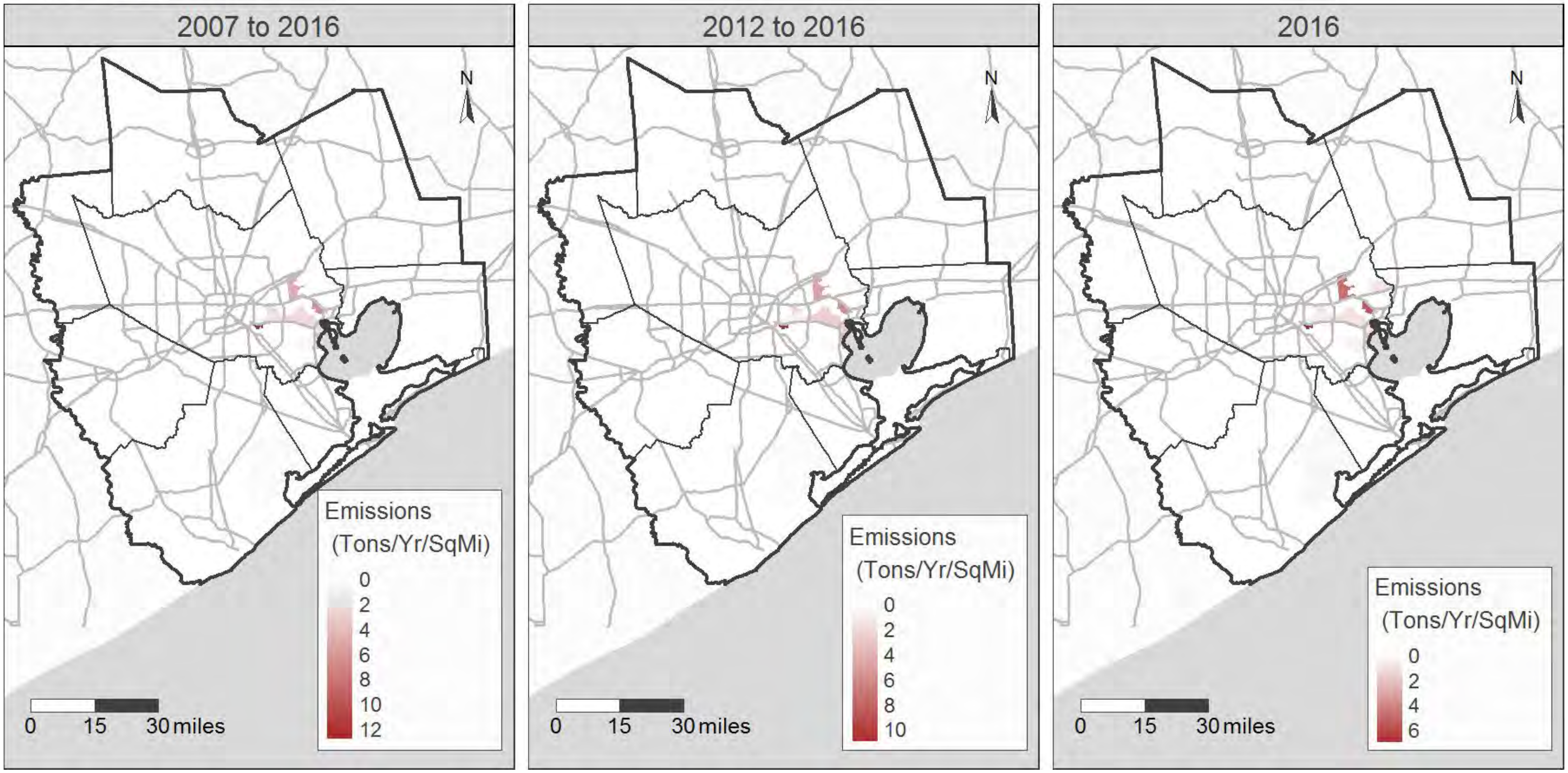
Benzene

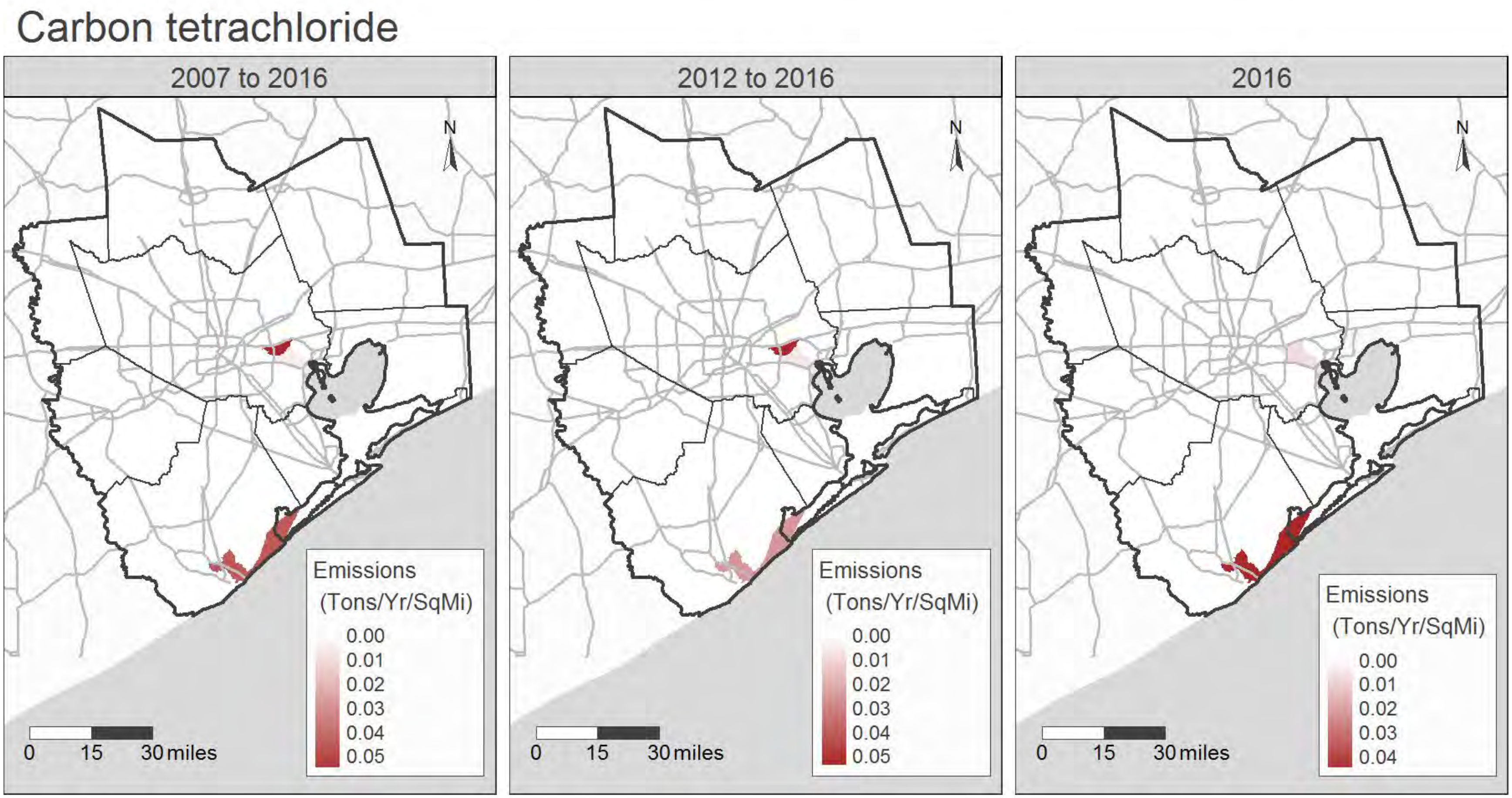

2007 to 2016
N
Emissions
(Tons/Yr/SqMi)
0
1
2
3
4
5
6
0 15 30 miles
2012 to 2016
N
Emissions
(Tons/Yr/SqMi)
0
1
2
3
4
5
0 15 30 miles
2016
N
Emissions
(Tons/Yr/SqMi)
0
1
2
3
4
0 15 30 miles

Benzo[a]pyrene



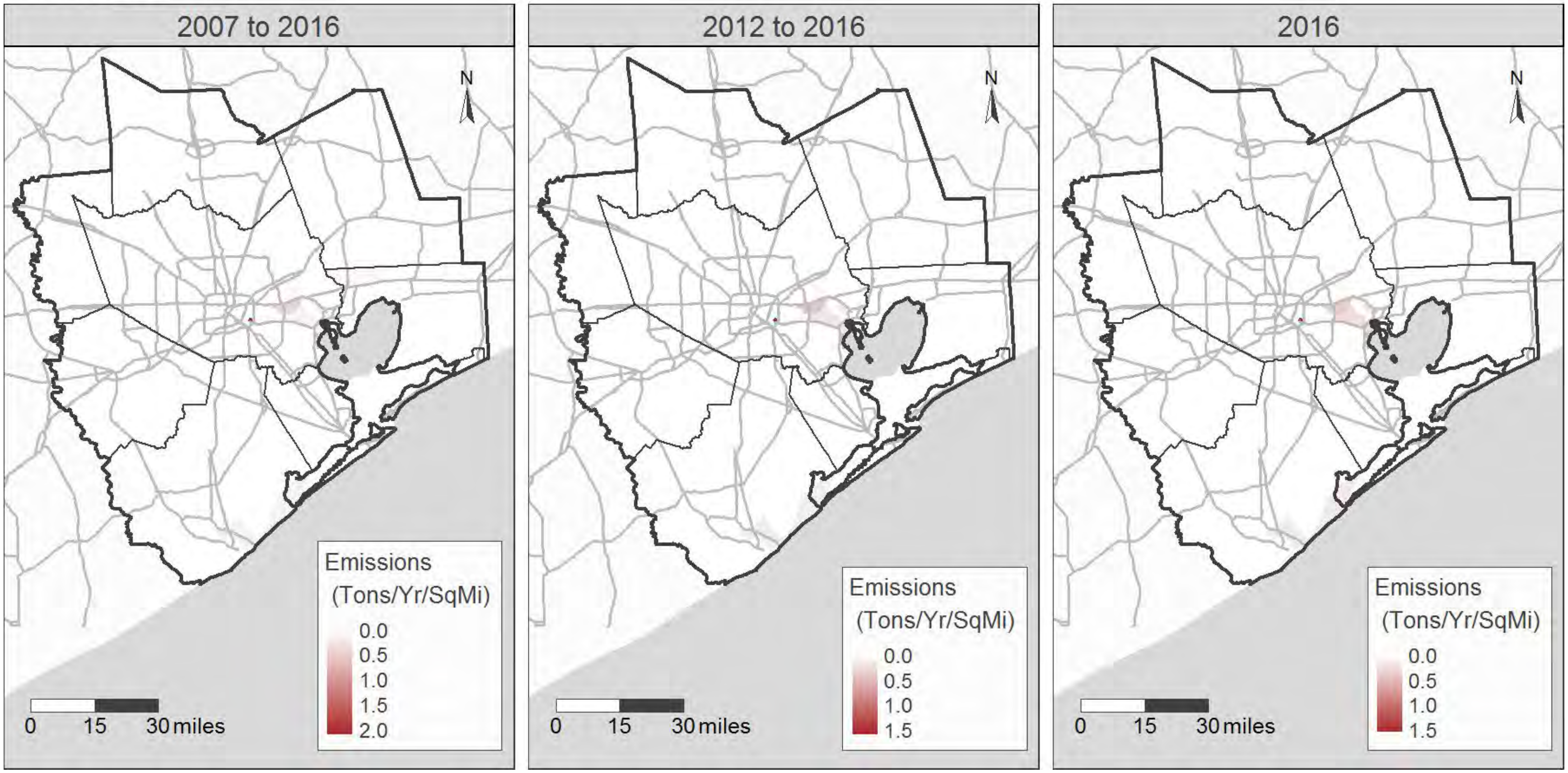
1,3-Butadiene



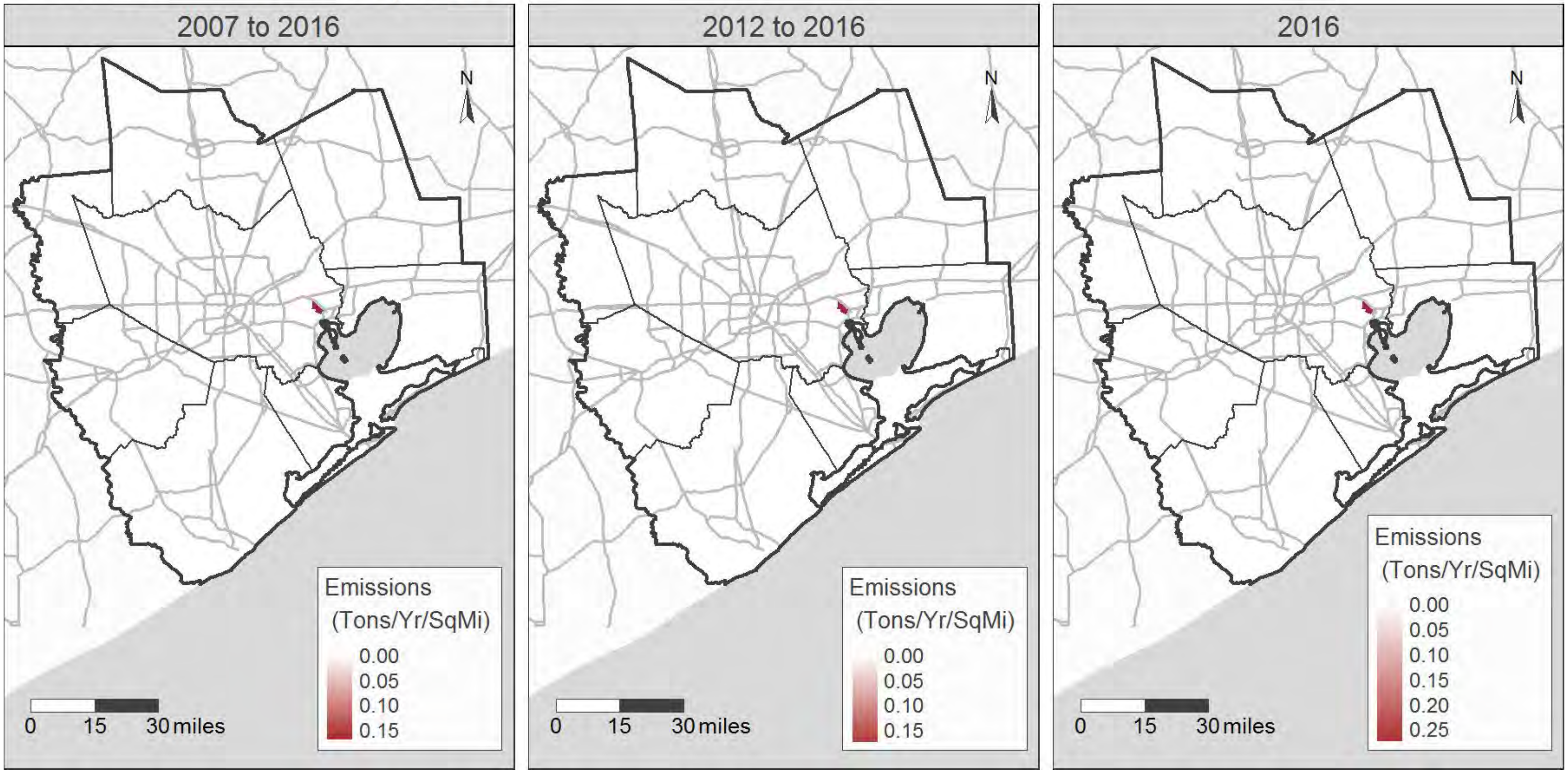


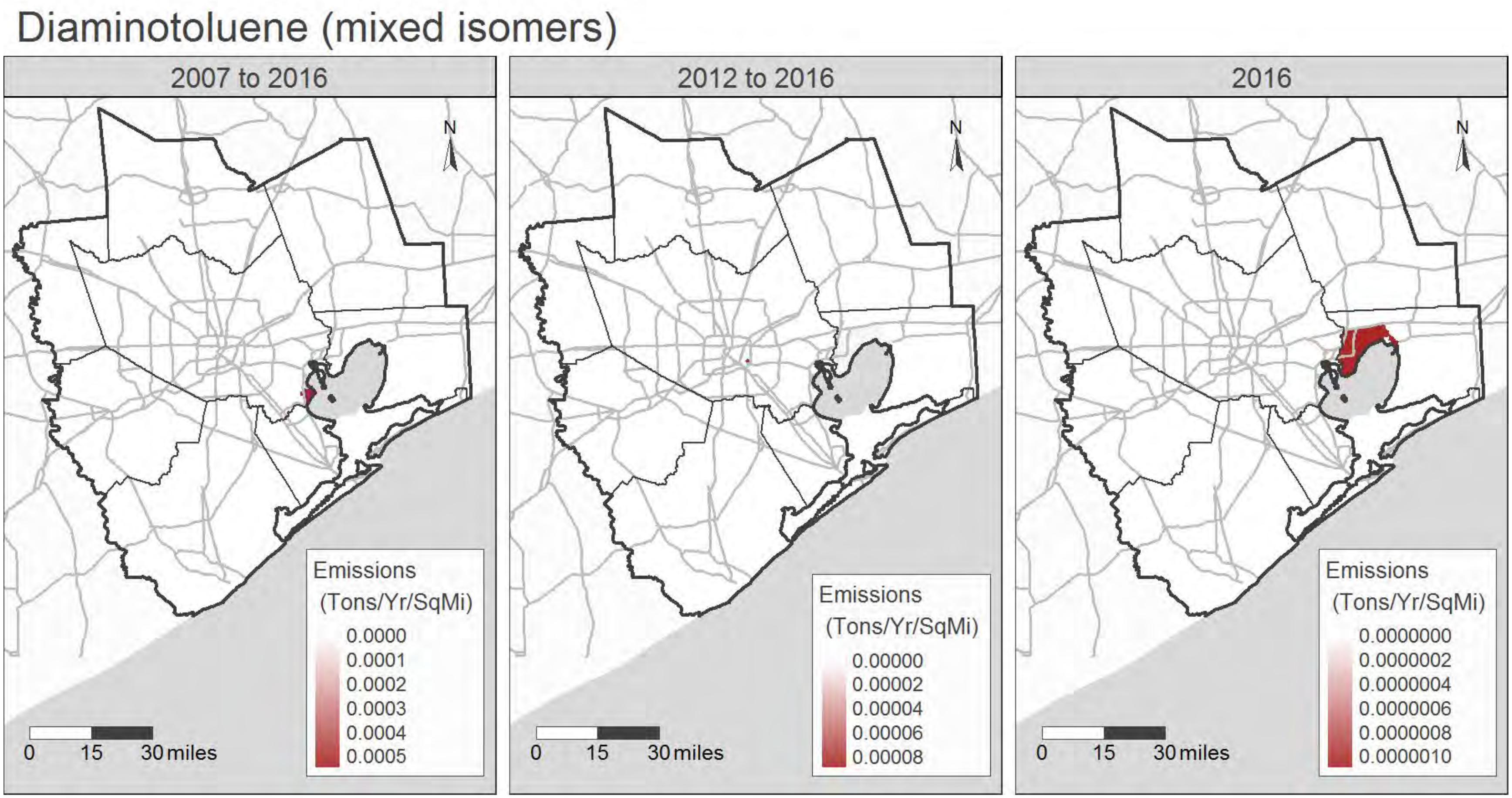
Carbon tetrachloride
2007 to 2016
2012 to 2016
2016
N
Emissions
(Tons/Yr/SqMi)
0.00
0.01
0.02
0.03
0.04
0.05
0 15 30 miles
Emissions
(Tons/Yr/SqMi)
0.00
0.01
0.02
0.03
0.04
0.05
0 15 30 miles
Emissions
(Tons/Yr/SqMi)
0.00
0.01
0.02
0.03
0.04
0 15 30 miles

Chlorine

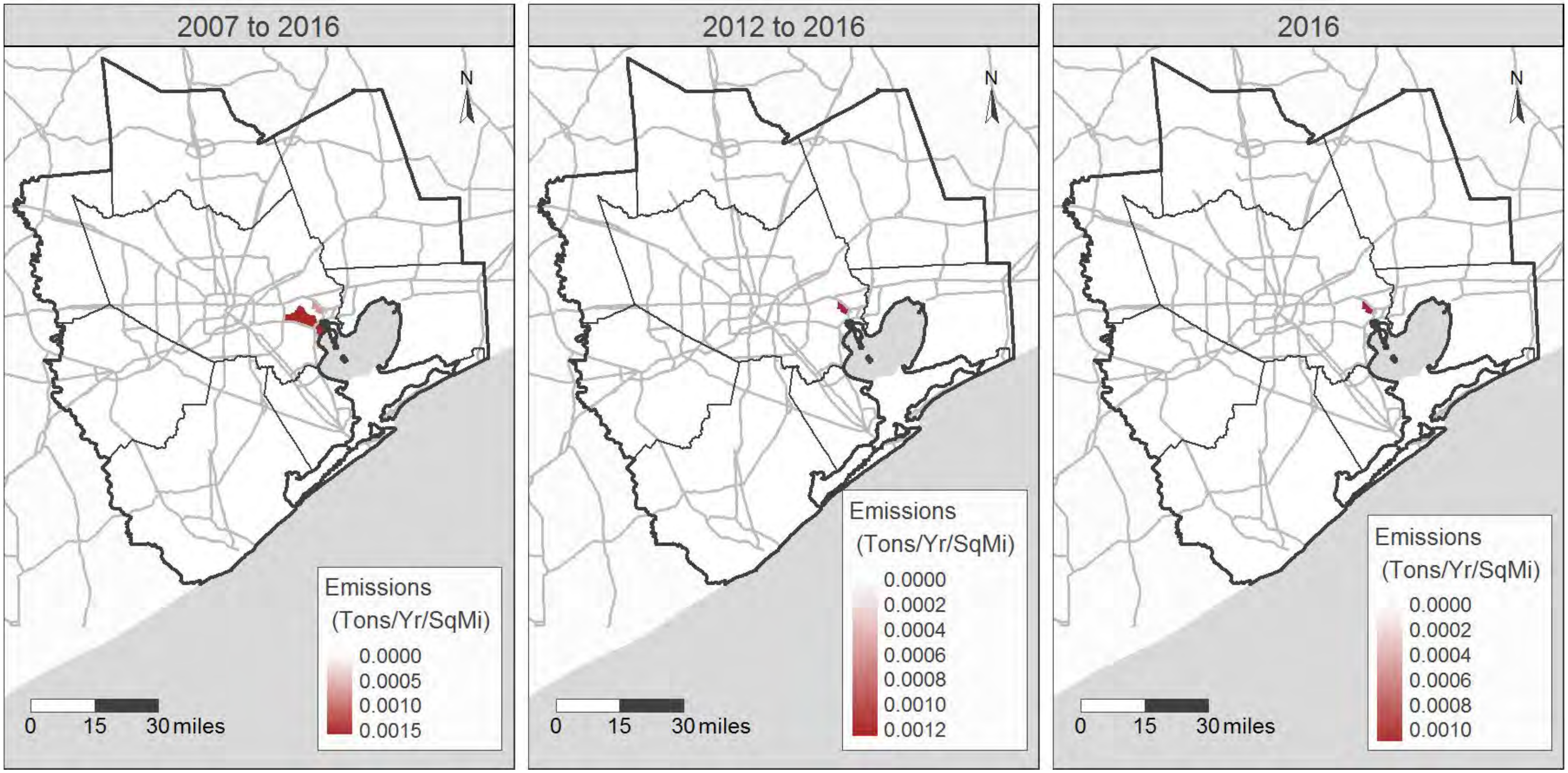

2007 to 2016
N
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
2.0
0
15
30 miles
2012 to 2016
N
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
0
15
30 miles
2016
N
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
0
15
30 miles

Chromium and compounds

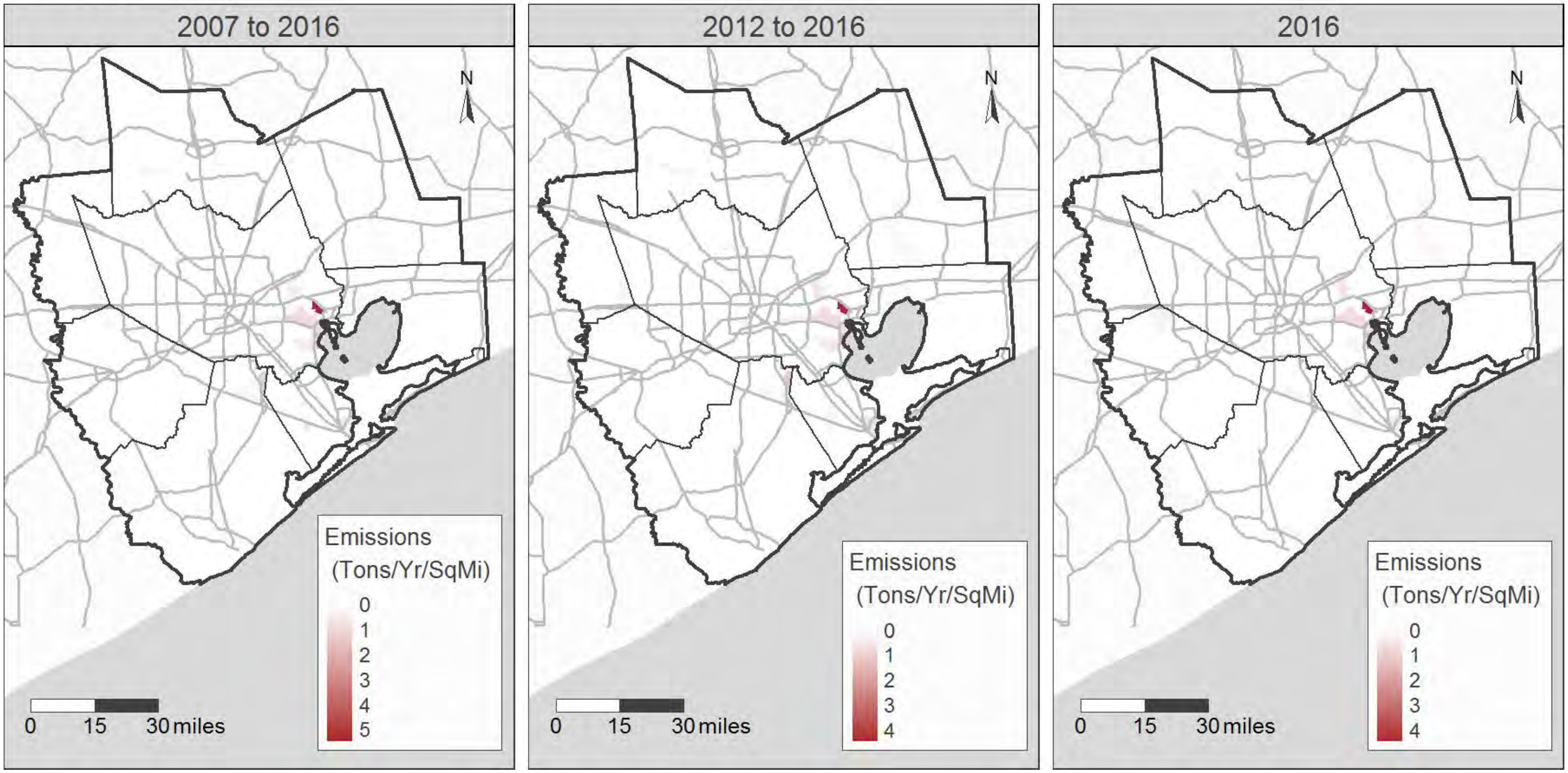


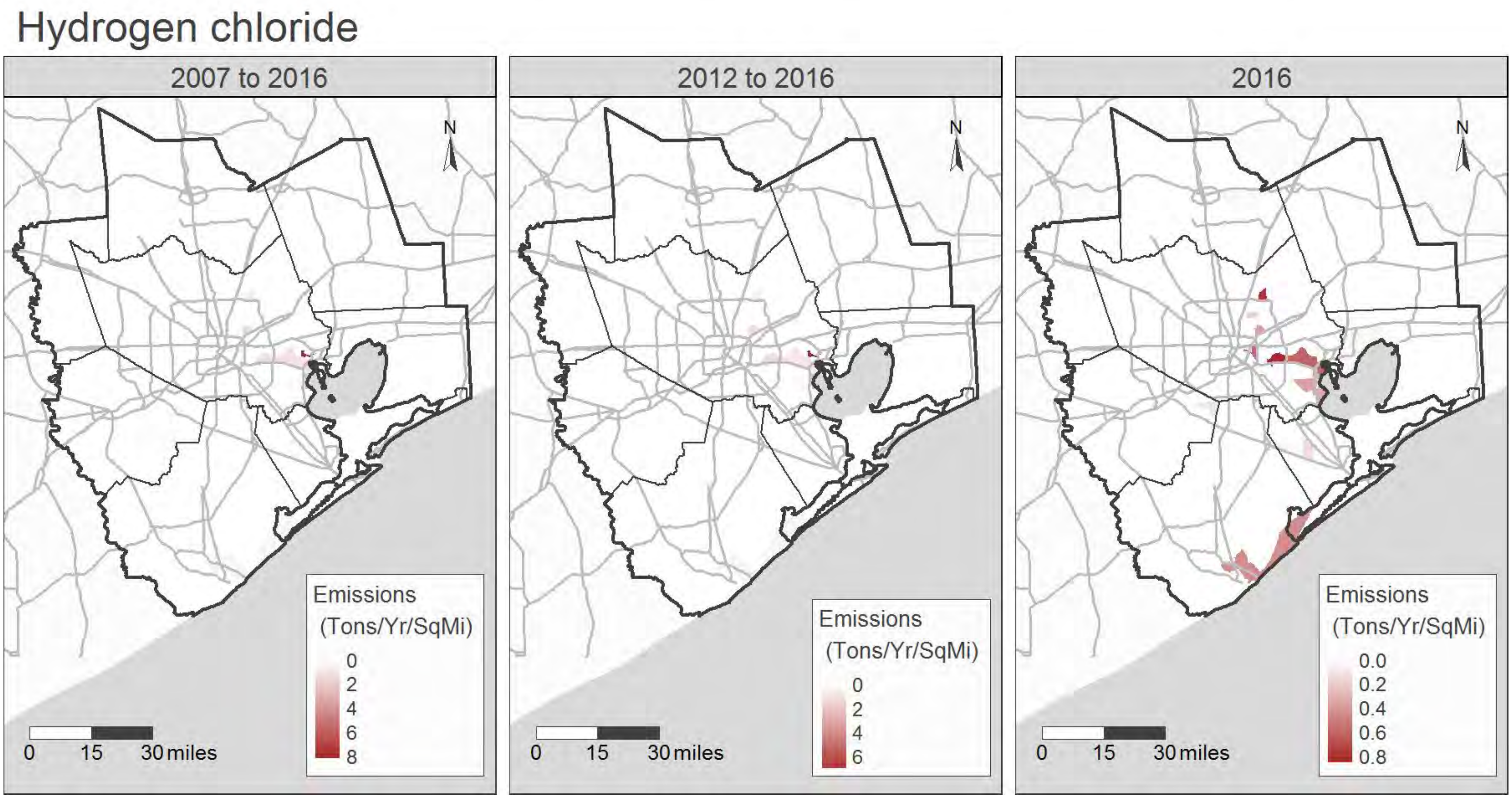

Diaminotoluene (mixed isomers)
2007 to 2016
N
Emissions
(Tons/Yr/SqMi)
0.0000
0.0001
0.0002
0.0003
0.0004
0.0005
0
15
30 miles
2012 to 2016
N
Emissions
(Tons/Yr/SqMi)
0.00000
0.00002
0.00004
0.00006
0.00008
0
15
30 miles
2016
N
Emissions
(Tons/Yr/SqMi)
0.0000000
0.0000002
0.0000004
0.0000006
0.0000008
0.0000010
0
15
30 miles

Fluoranthene

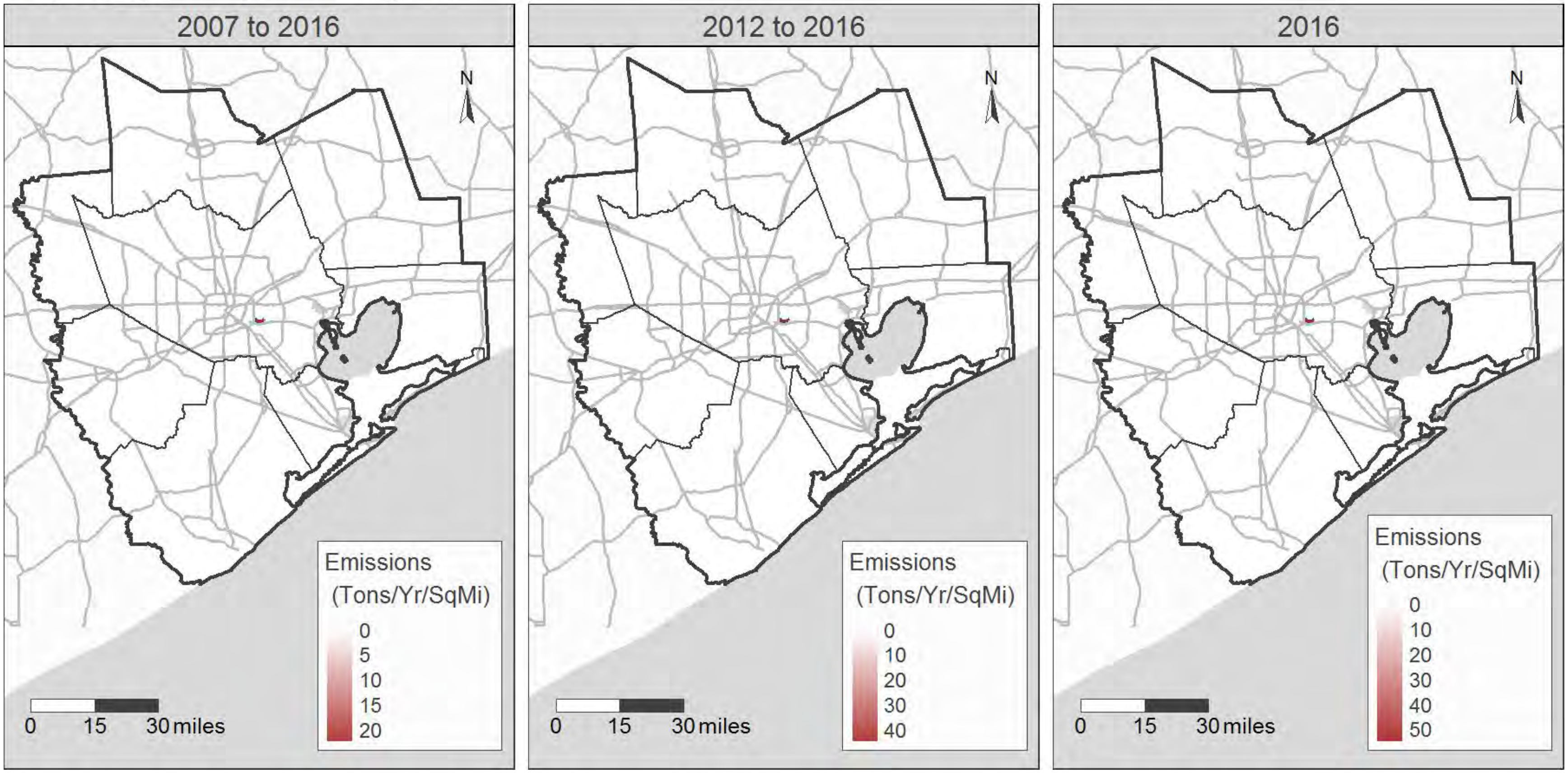


Formaldehyde

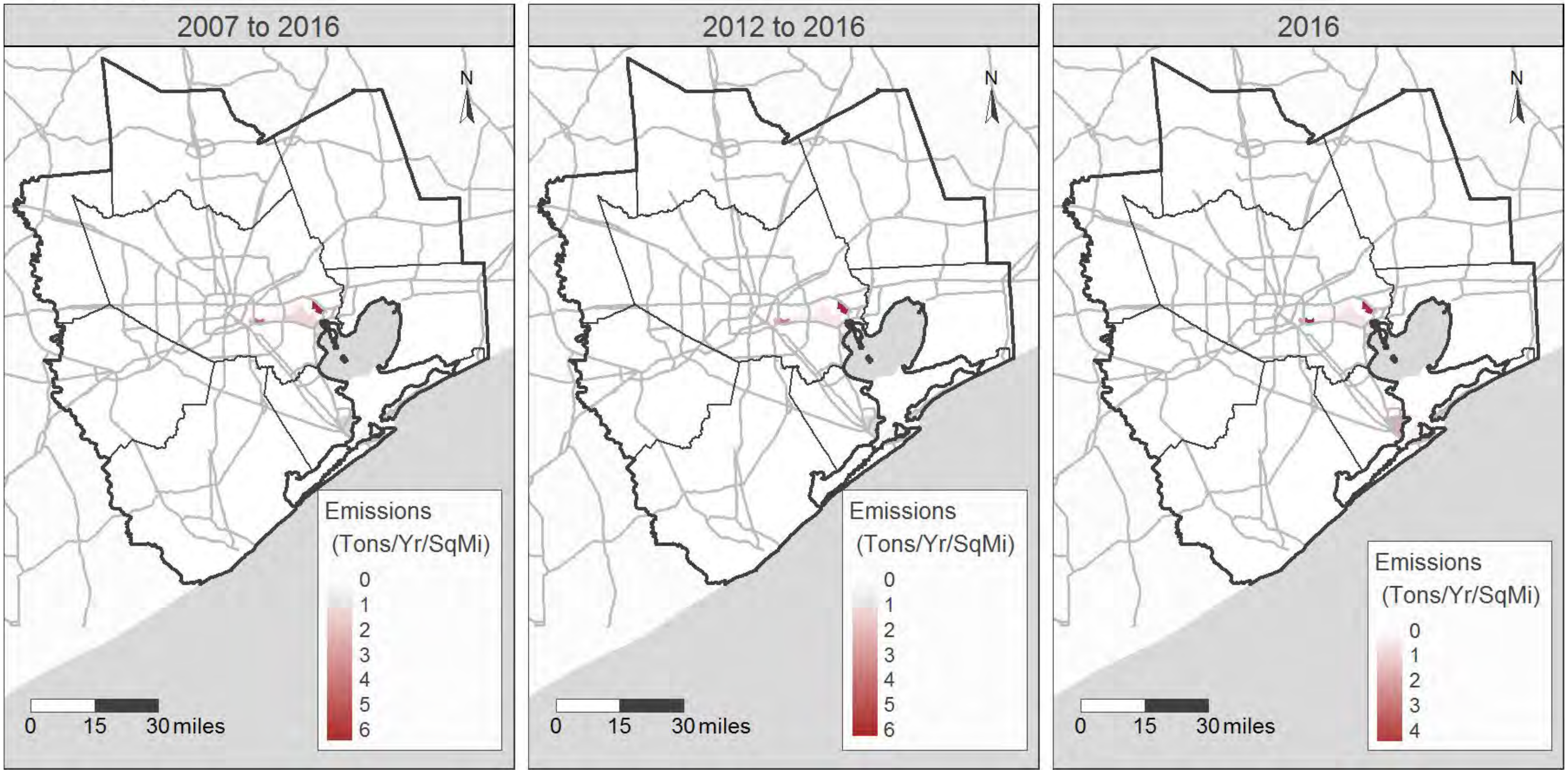


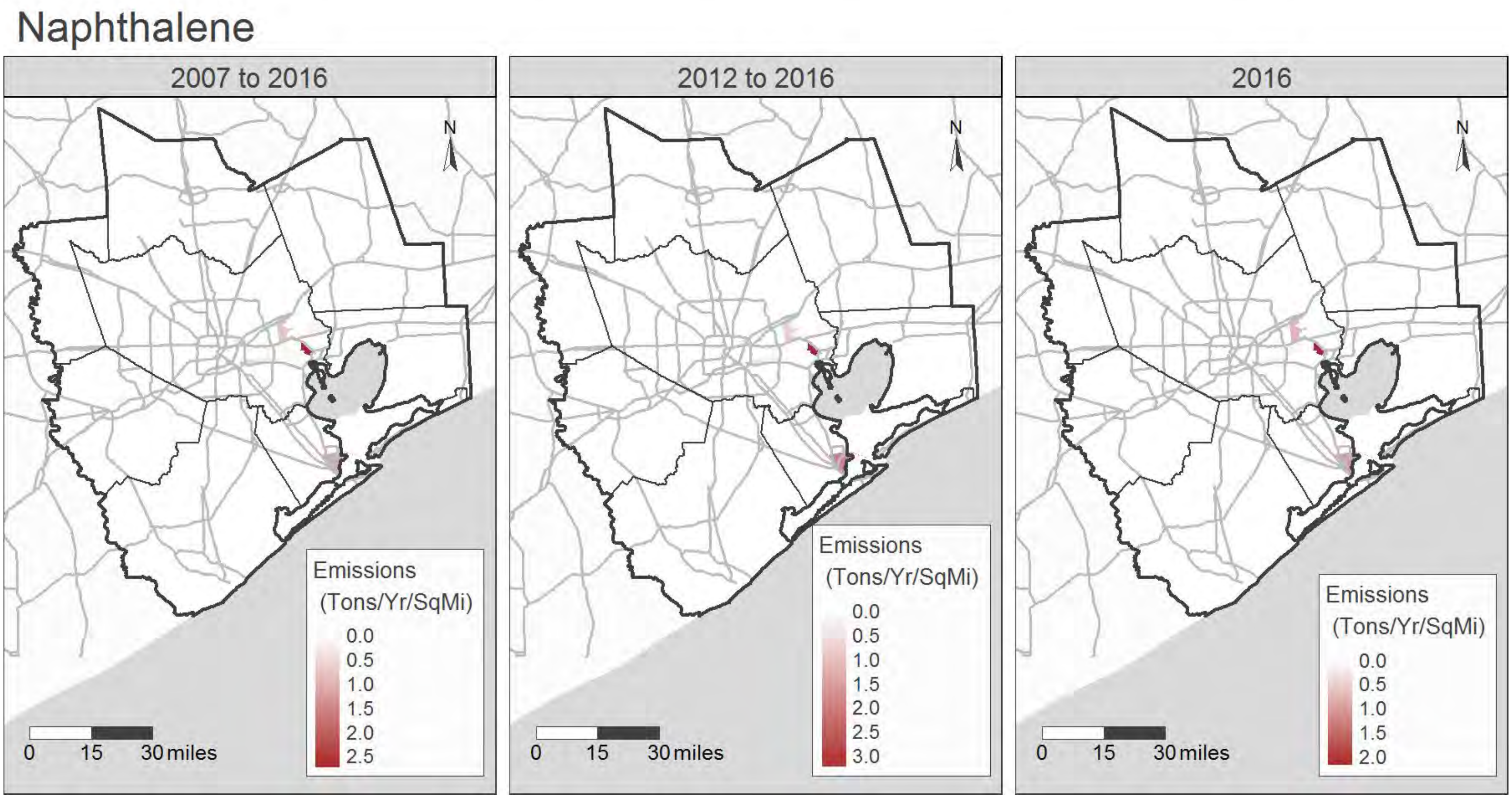

Hydrogen chloride
2007 to 2016
2012 to 2016
2016
N
N
N
Emissions
(Tons/Yr/SqMi)
0
2
4
6
8
0 15 30 miles
Emissions
(Tons/Yr/SqMi)
0
2
4
6
0 15 30 miles
Emissions
(Tons/Yr/SqMi)
0.0
0.2
0.4
0.6
0.8
0 15 30 miles

Hydrogen cyanide gas

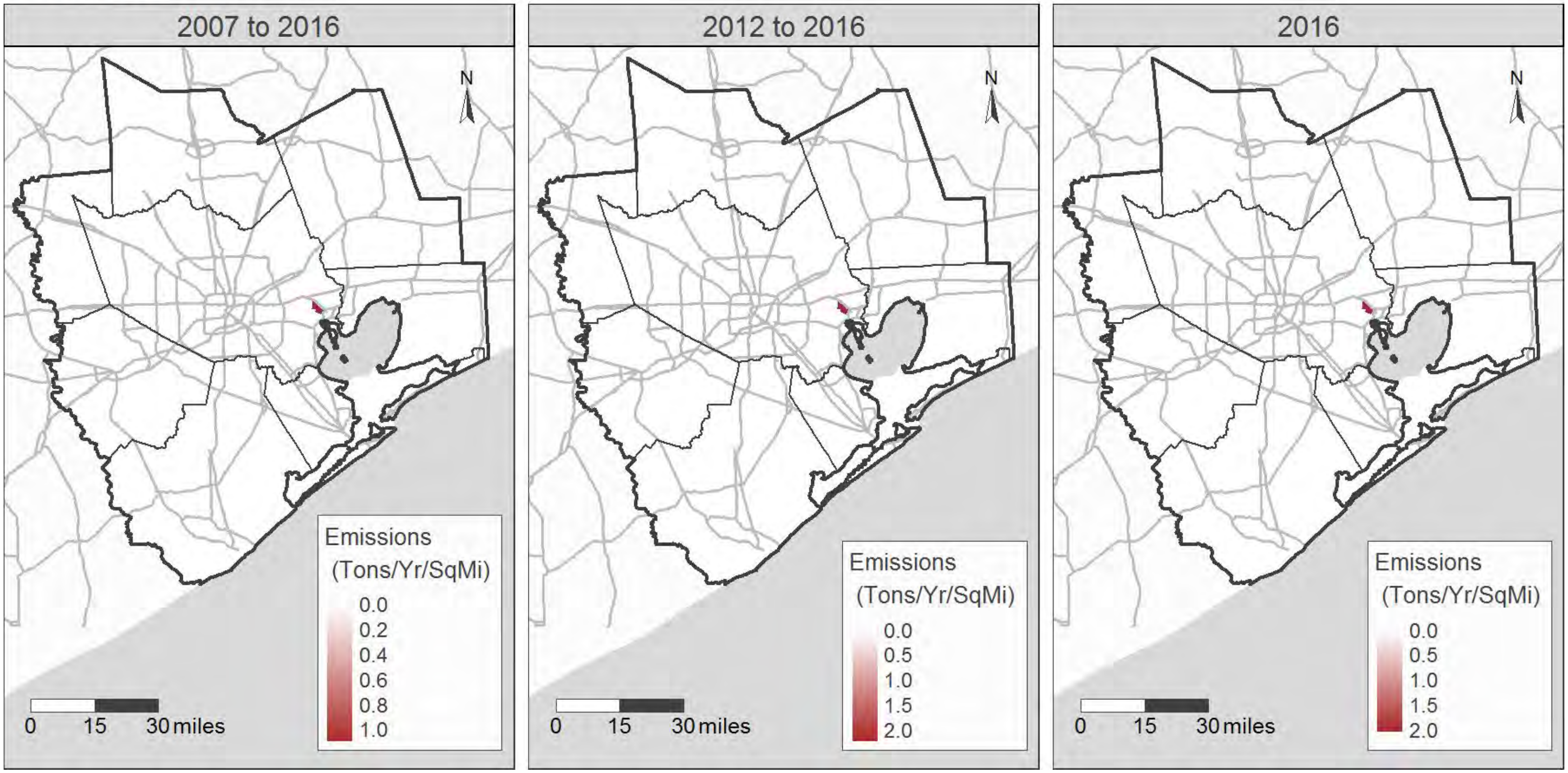


Hydrogen sulfide

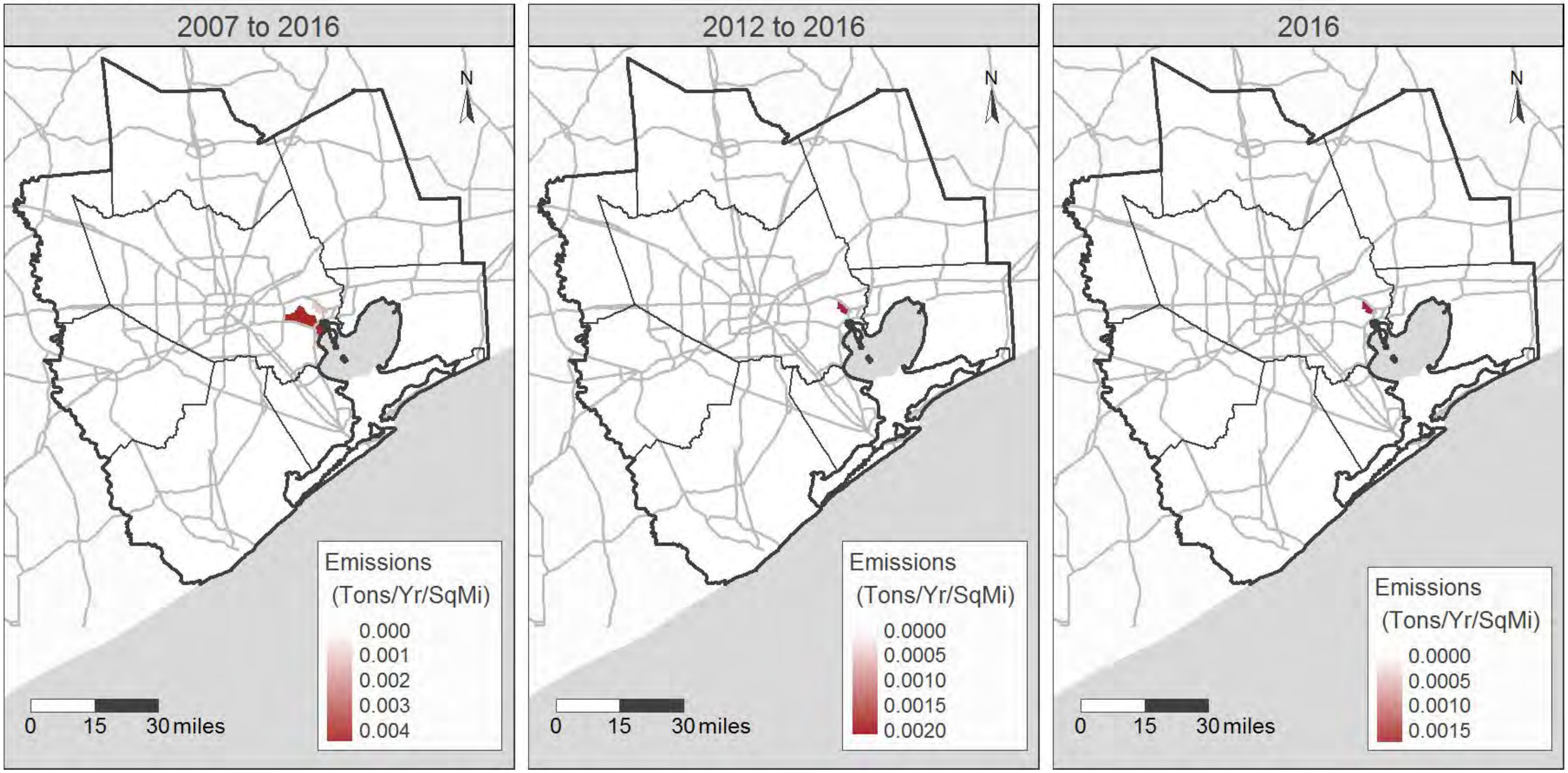



Naphthalene
2007 to 2016
2012 to 2016
2016
N
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0
15
30 miles

Phenanthrene



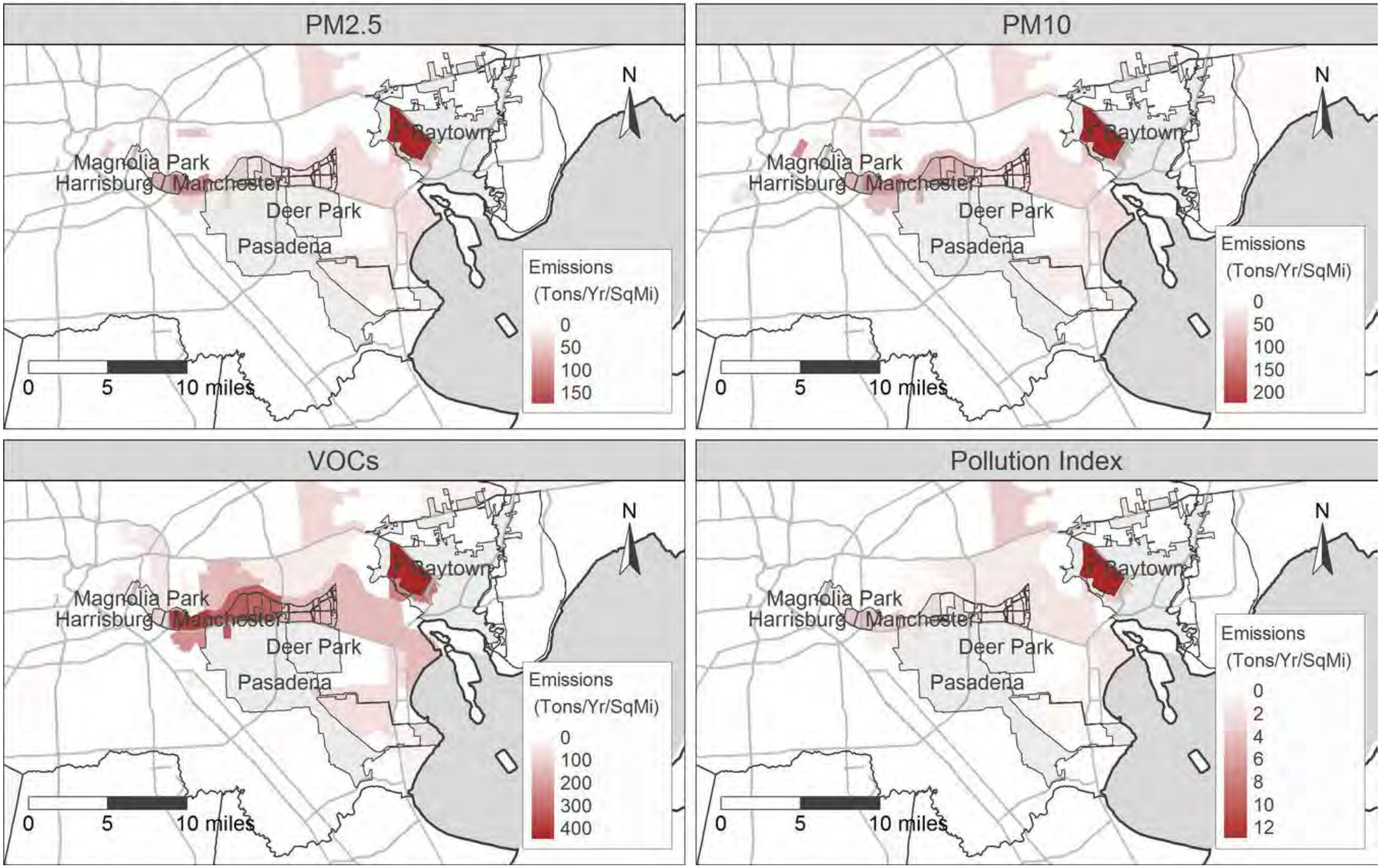
Pyrene



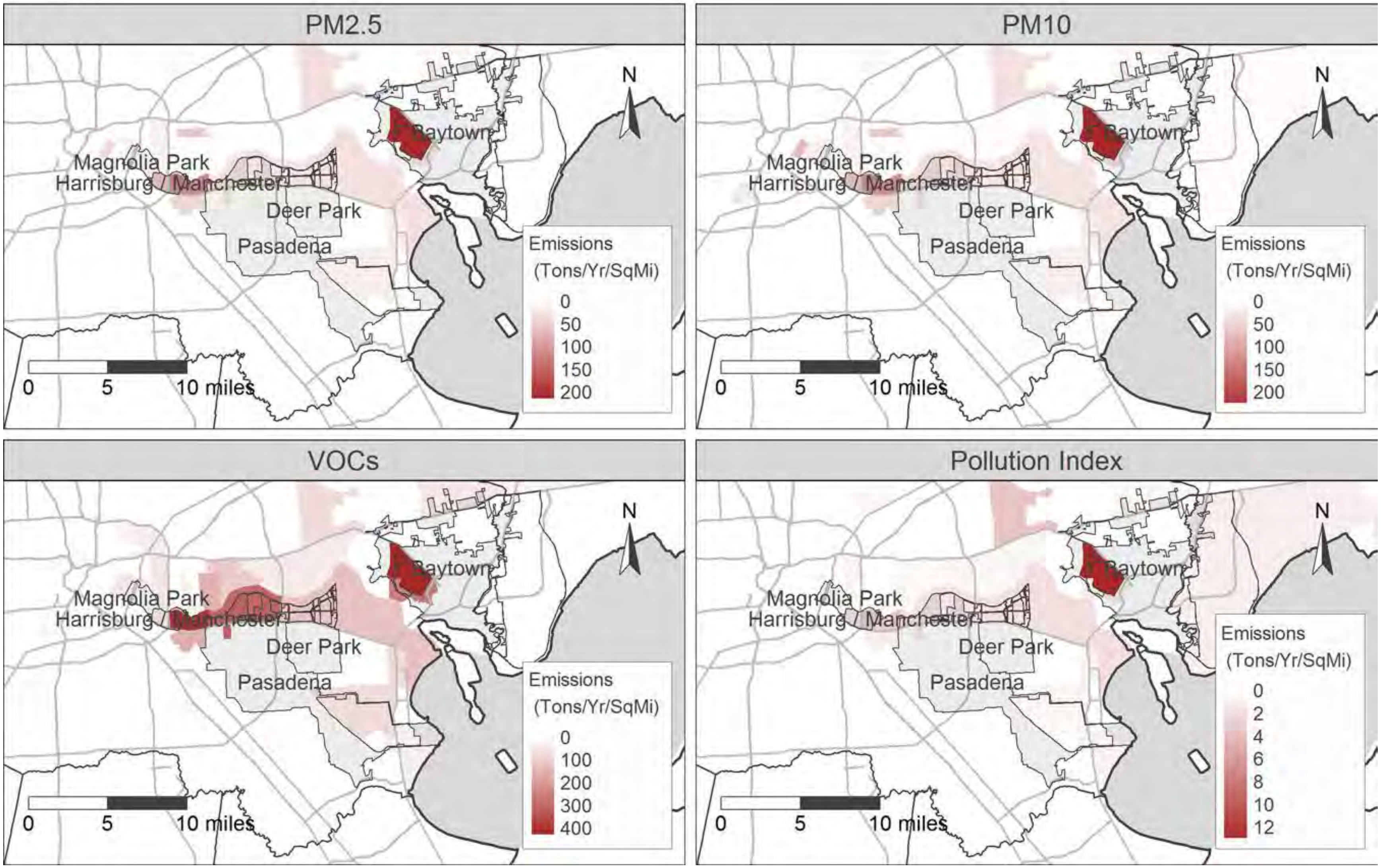
2007 to 2016
2012 to 2016
2016
N
Emissions
(Tons/Yr/SqMi)
0.000
0.001
0.002
0.003
0.004
0.0000
0.0005
0.0010
0.0015
0.0020
0.0000
0.0005
0.0010
0.0015
0 15 30 miles

Appendix D: Additional Ship Channel Maps of Four Pollution Categories

2012 to 2016


PM2.5
PM10
VOCs
Pollution Index
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0
50
100
150
200
300
400
2
4
6
8
10
12
0
5
10 miles

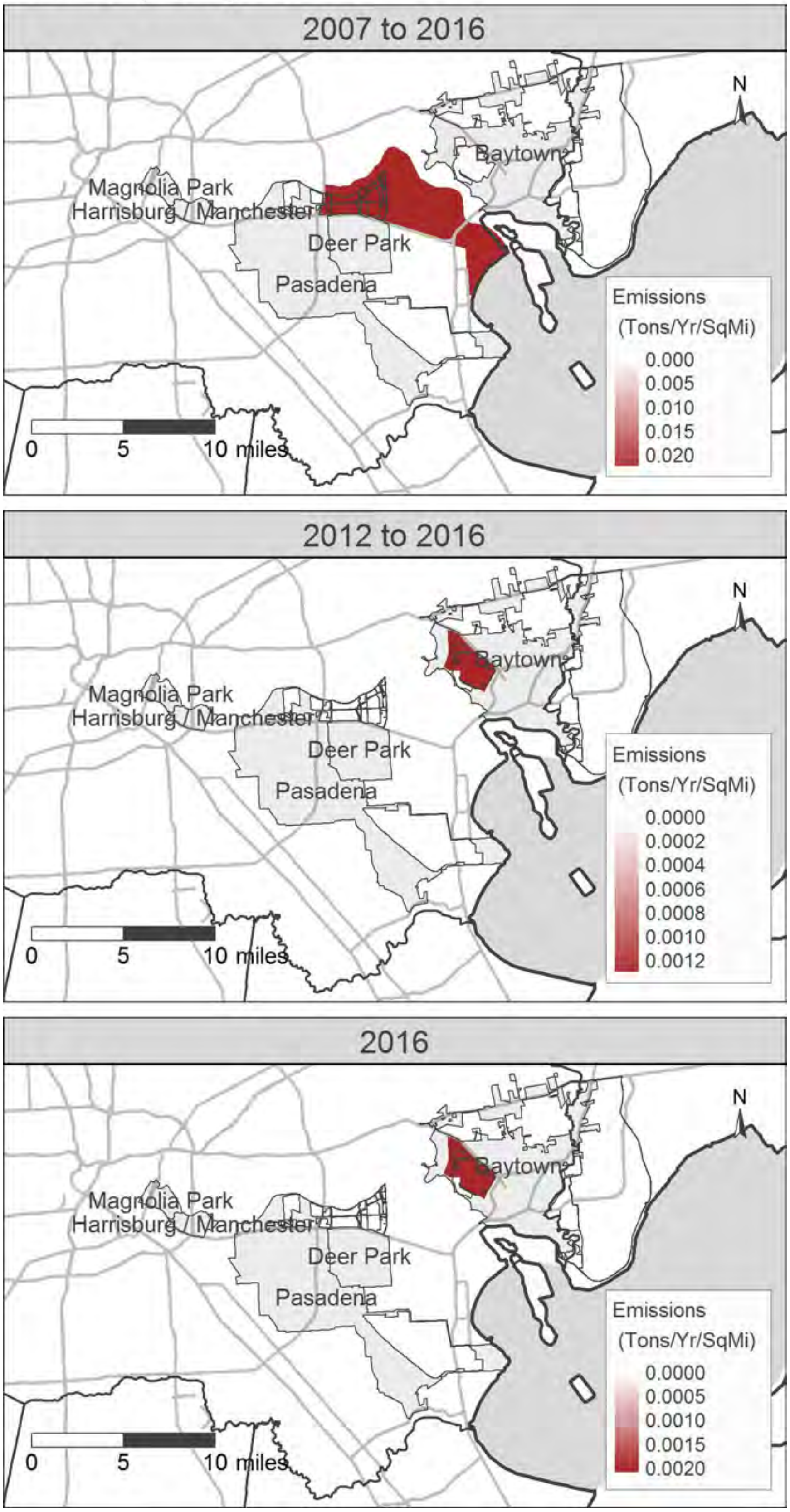
2016



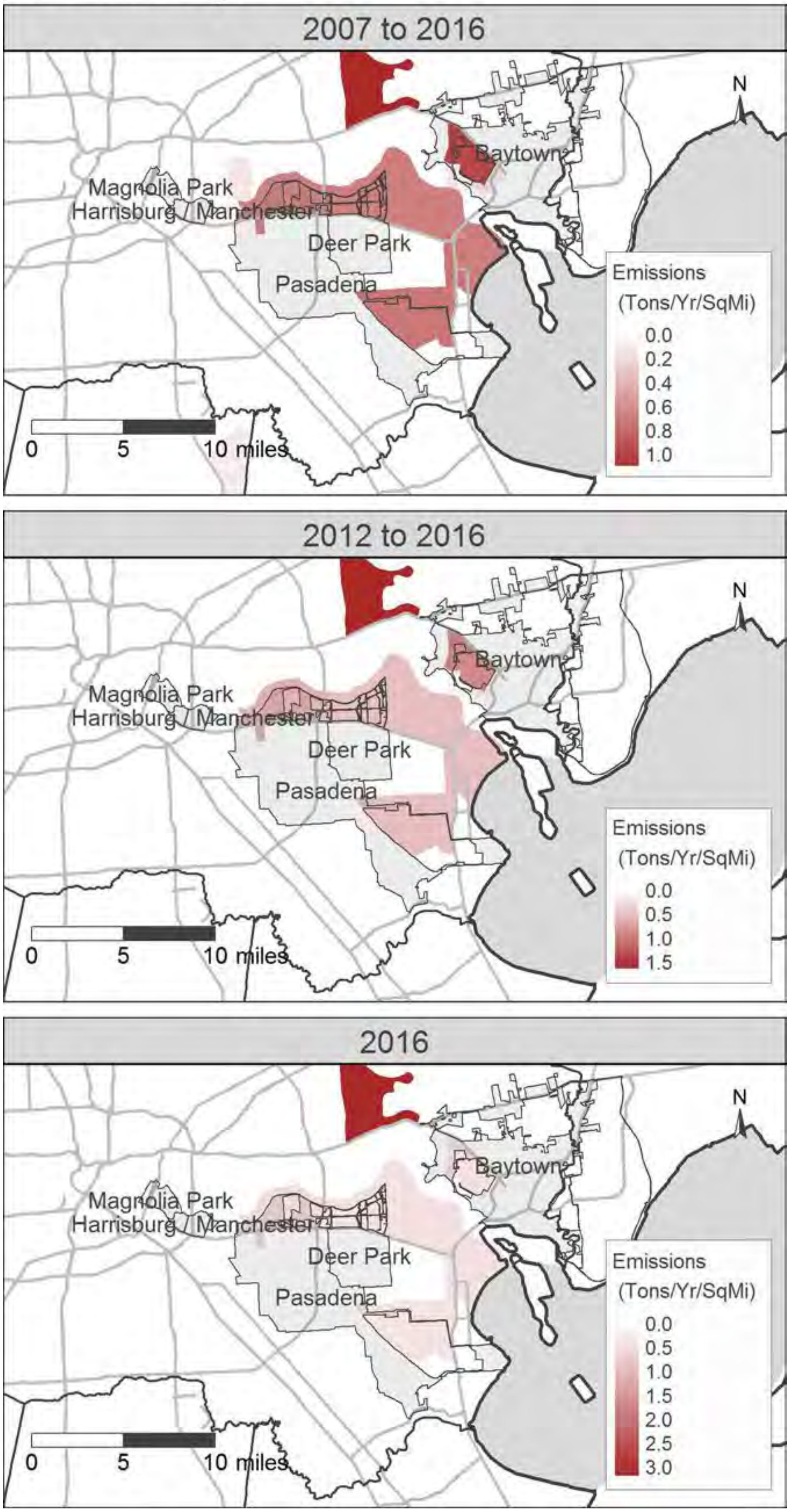
PM2.5
PM10
VOCs
Pollution Index
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0
50
100
150
200
0
100
200
300
400
0
2
4
6
8
10
12
0
5
10 miles

Appendix E: Ship Channel Maps of 19 Pollutants of Concern

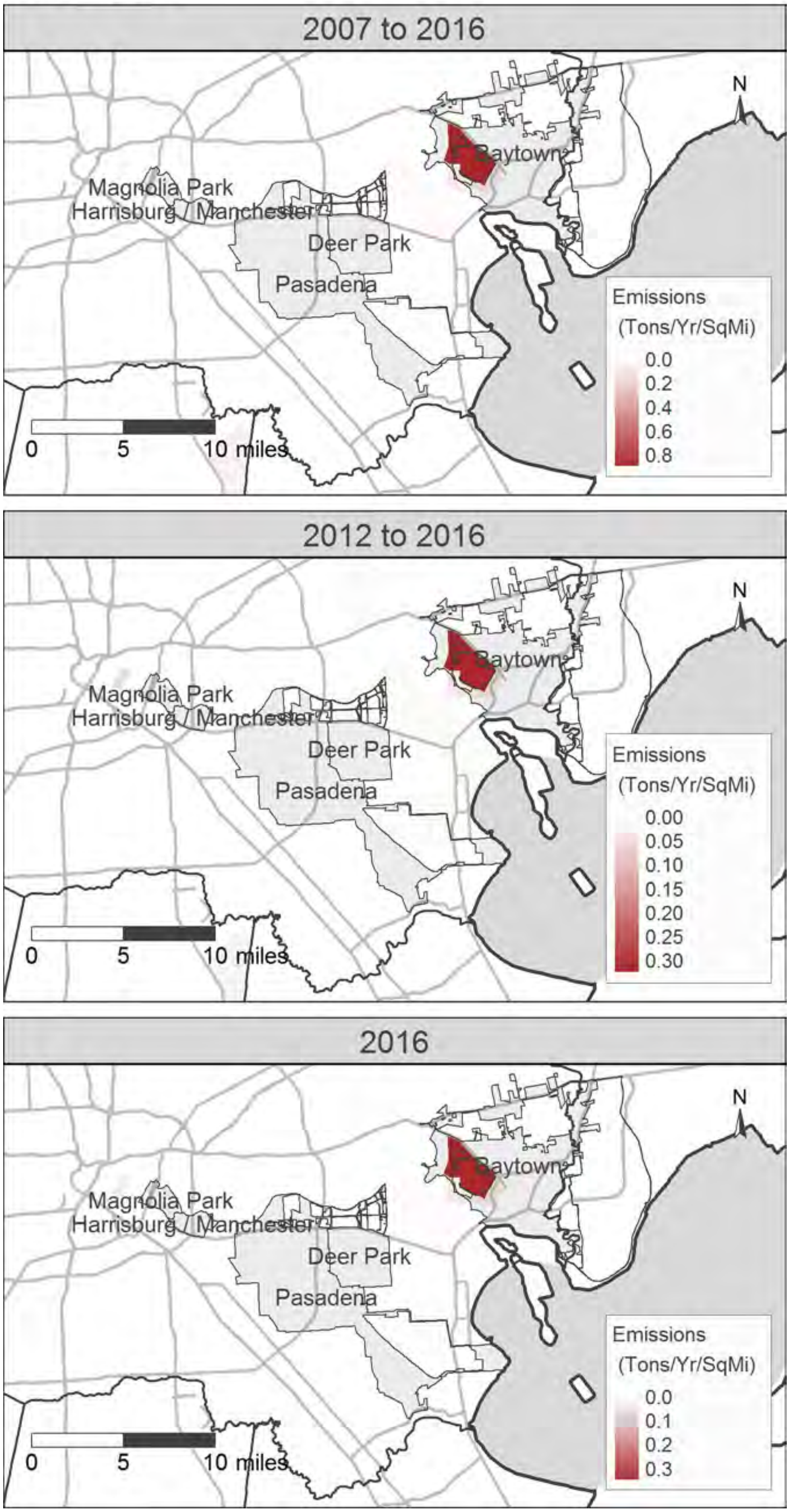
Acenaphthylene



Acetaldehyde

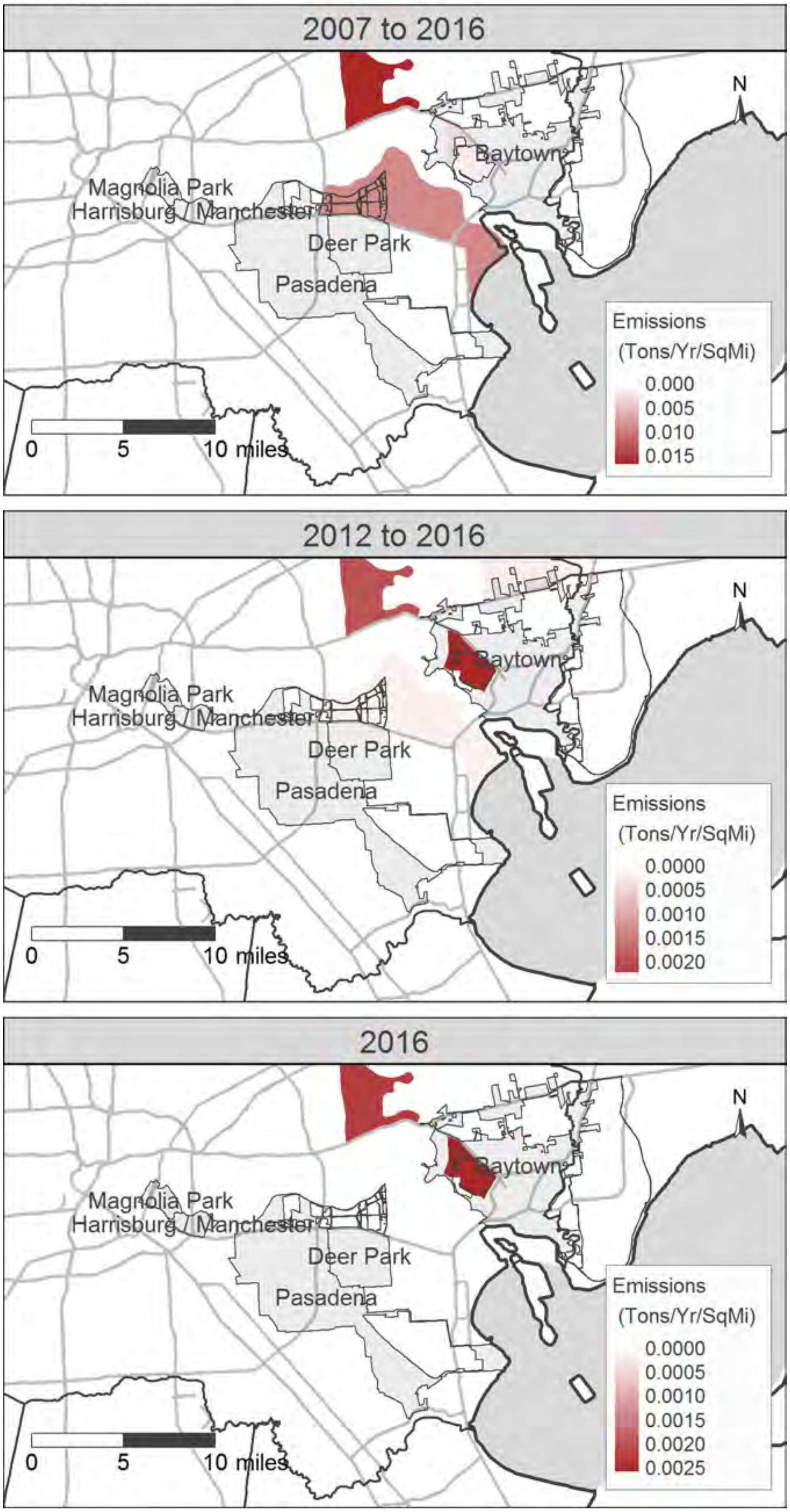


Acrolein

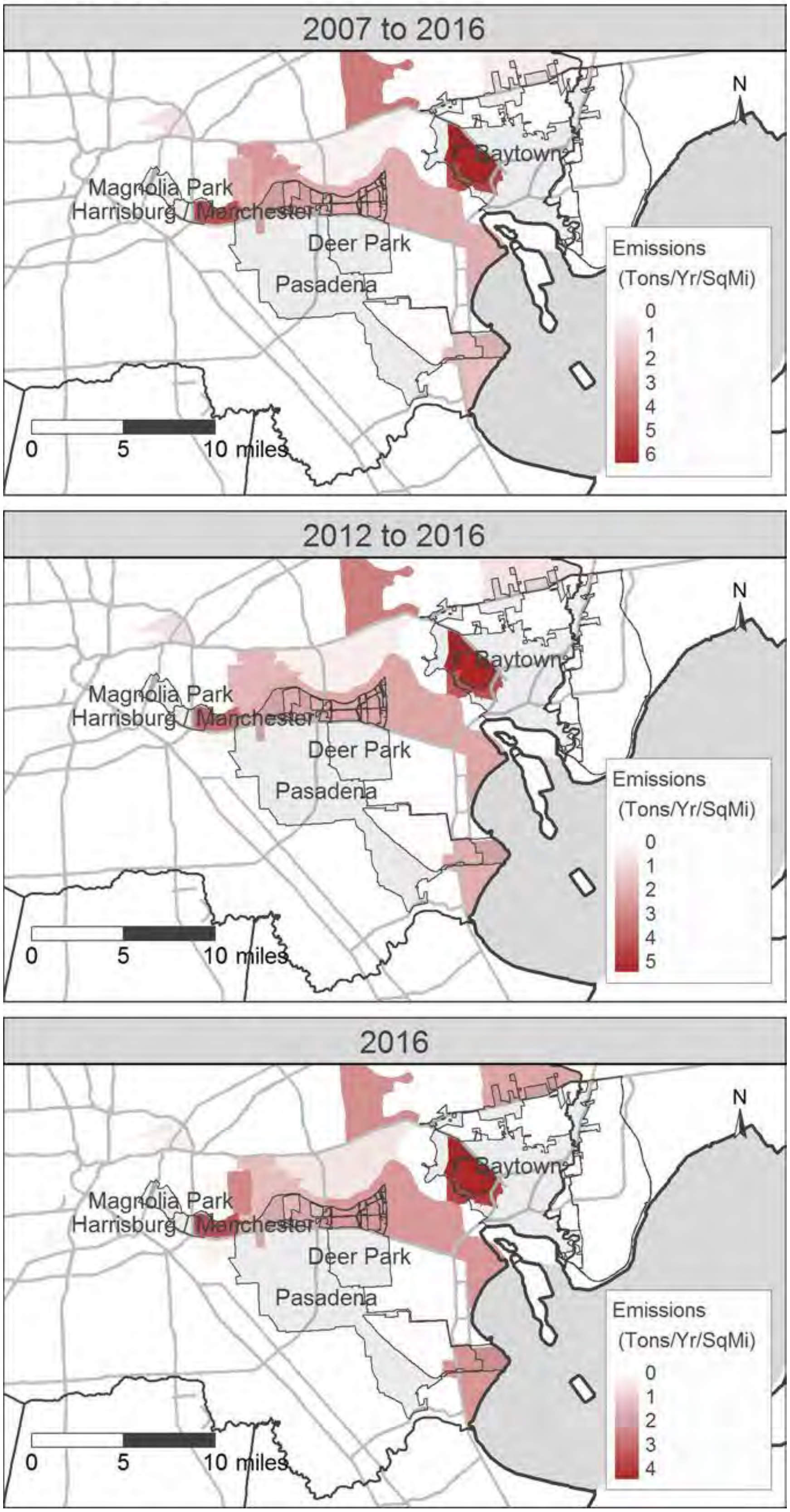


2007 to 2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
Emissions
(Tons/Yr/SqMi)
0.0
0.2
0.4
0.6
0.8
0
5
10 miles
2012 to 2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
Emissions
(Tons/Yr/SqMi)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0
5
10 miles
2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
Emissions
(Tons/Yr/SqMi)
0.0
0.1
0.2
0.3
0
5
10 miles

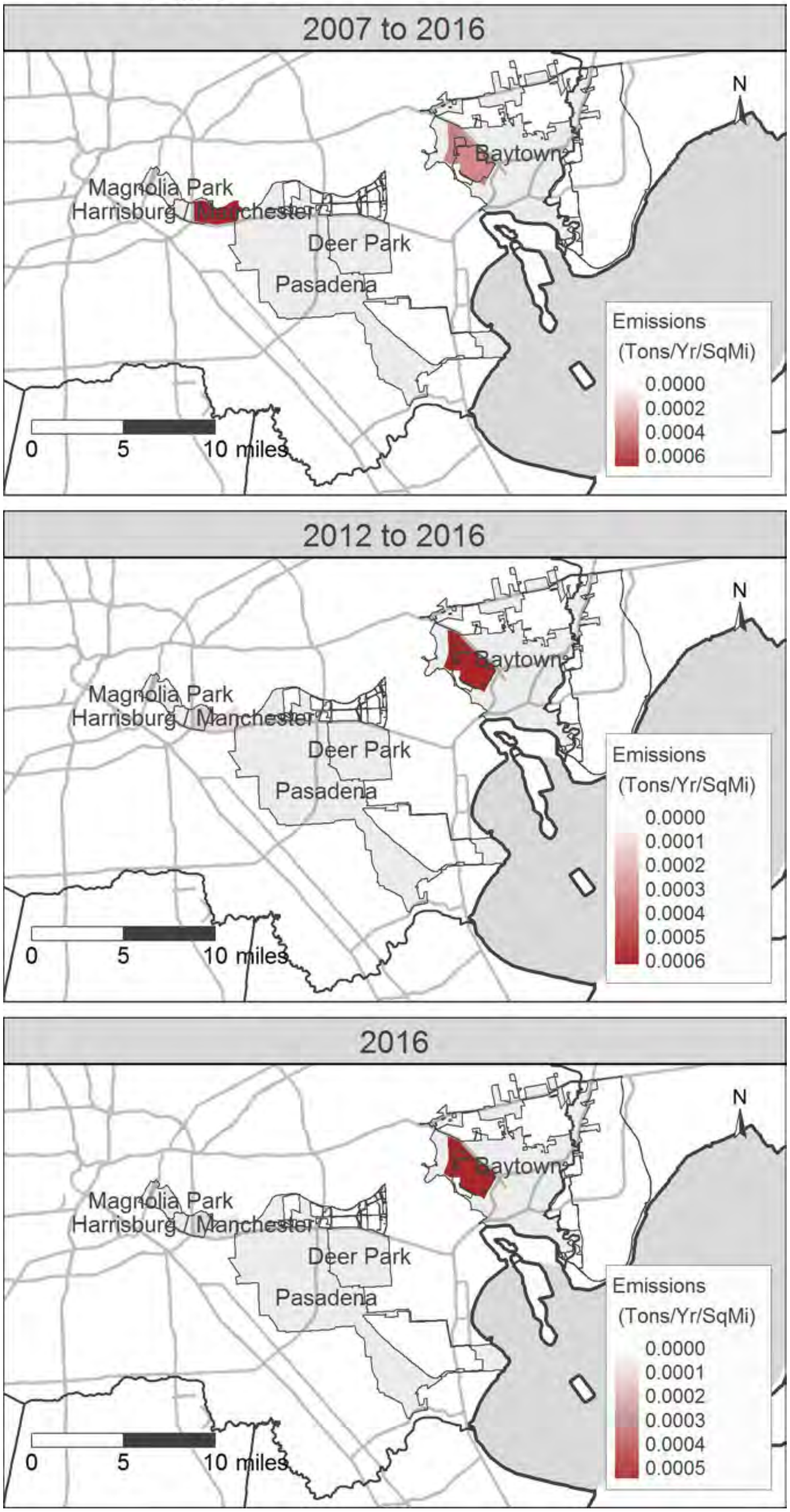
Anthracene


2007 to 2016
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.000
0.005
0.010
0.015
0
5
10 miles
2012 to 2016
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0000
0.0005
0.0010
0.0015
0.0020
0
5
10 miles
2016
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0000
0.0005
0.0010
0.0015
0.0020
0.0025
0
5
10 miles

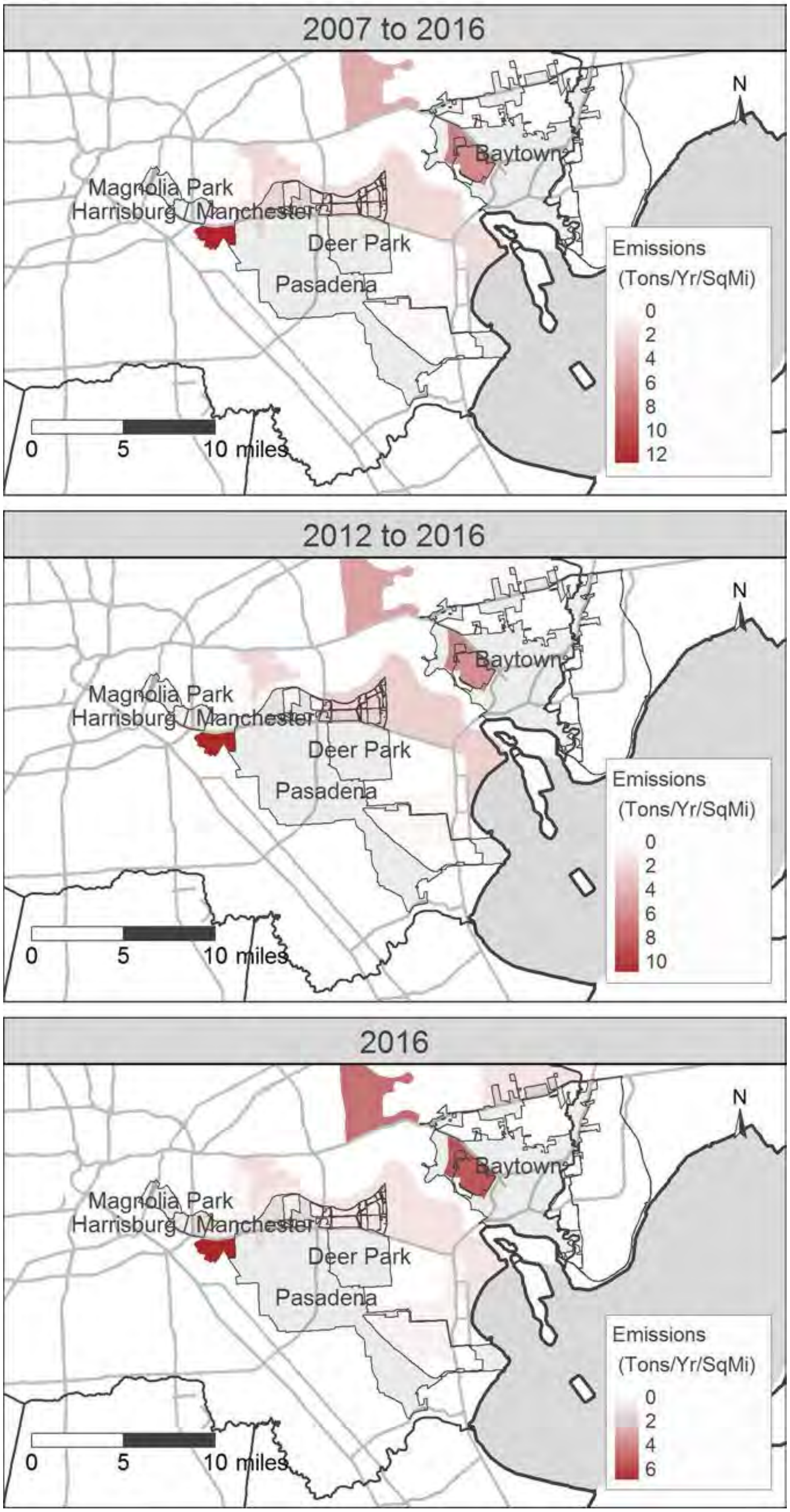
Benzene


2007 to 2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
0
5
10 miles
Emissions
(Tons/Yr/SqMi)
0
1
2
3
4
5
6
2012 to 2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
0
5
10 miles
Emissions
(Tons/Yr/SqMi)
0
1
2
3
4
5
2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
0
5
10 miles
Emissions
(Tons/Yr/SqMi)
0
1
2
3
4

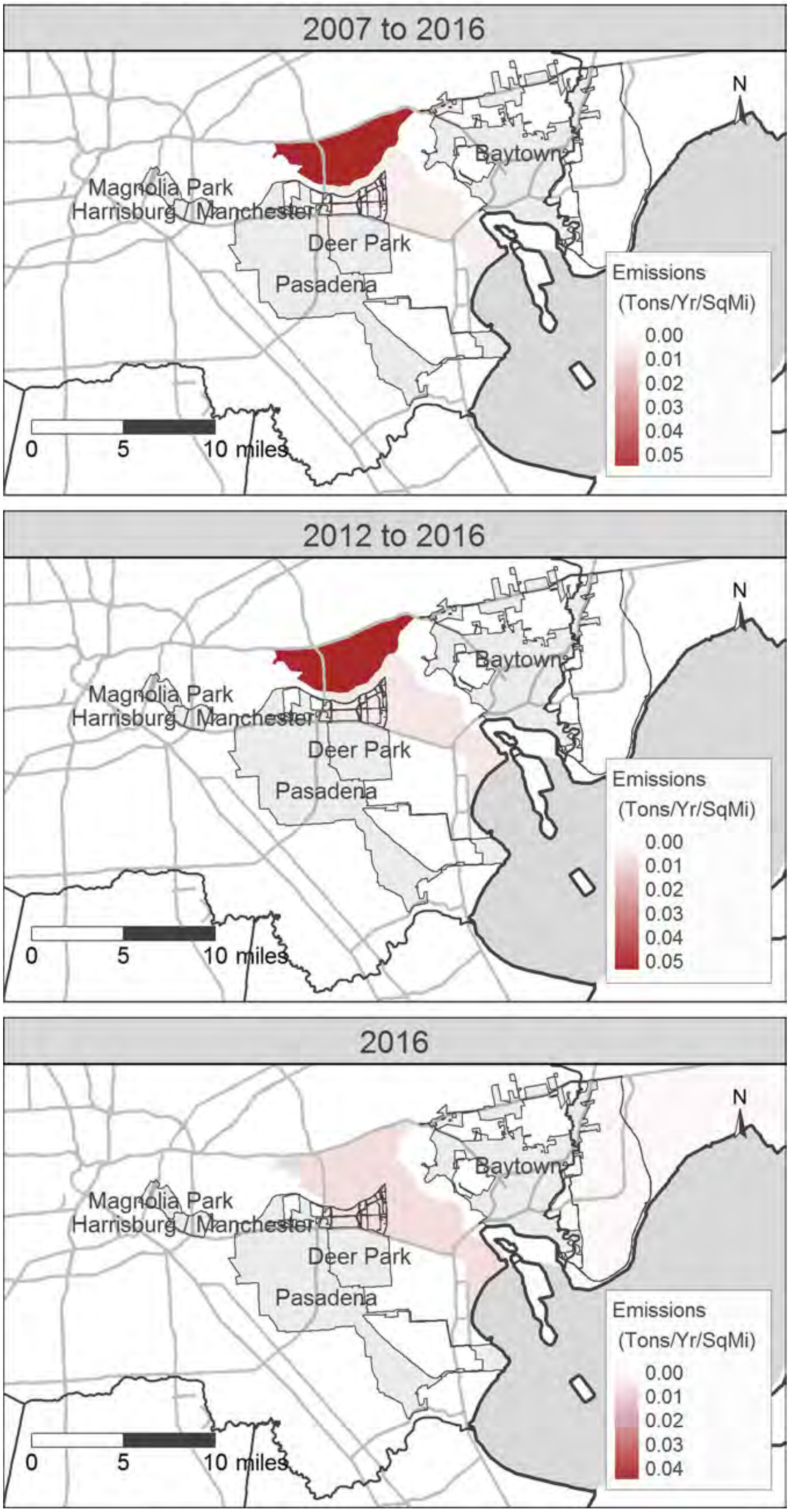
Benzo[a]pyrene



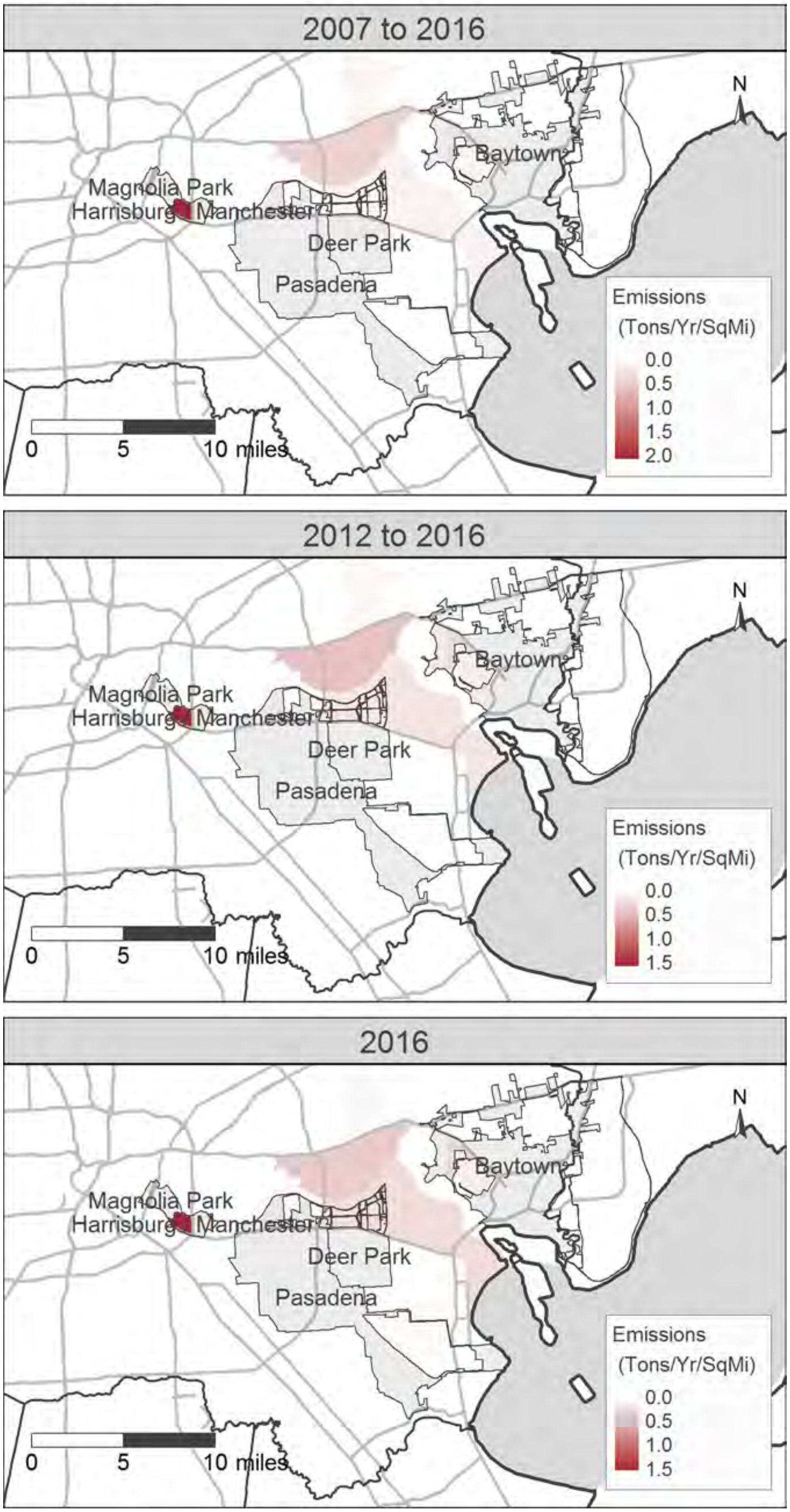
1,3-Butadiene



Carbon tetrachloride

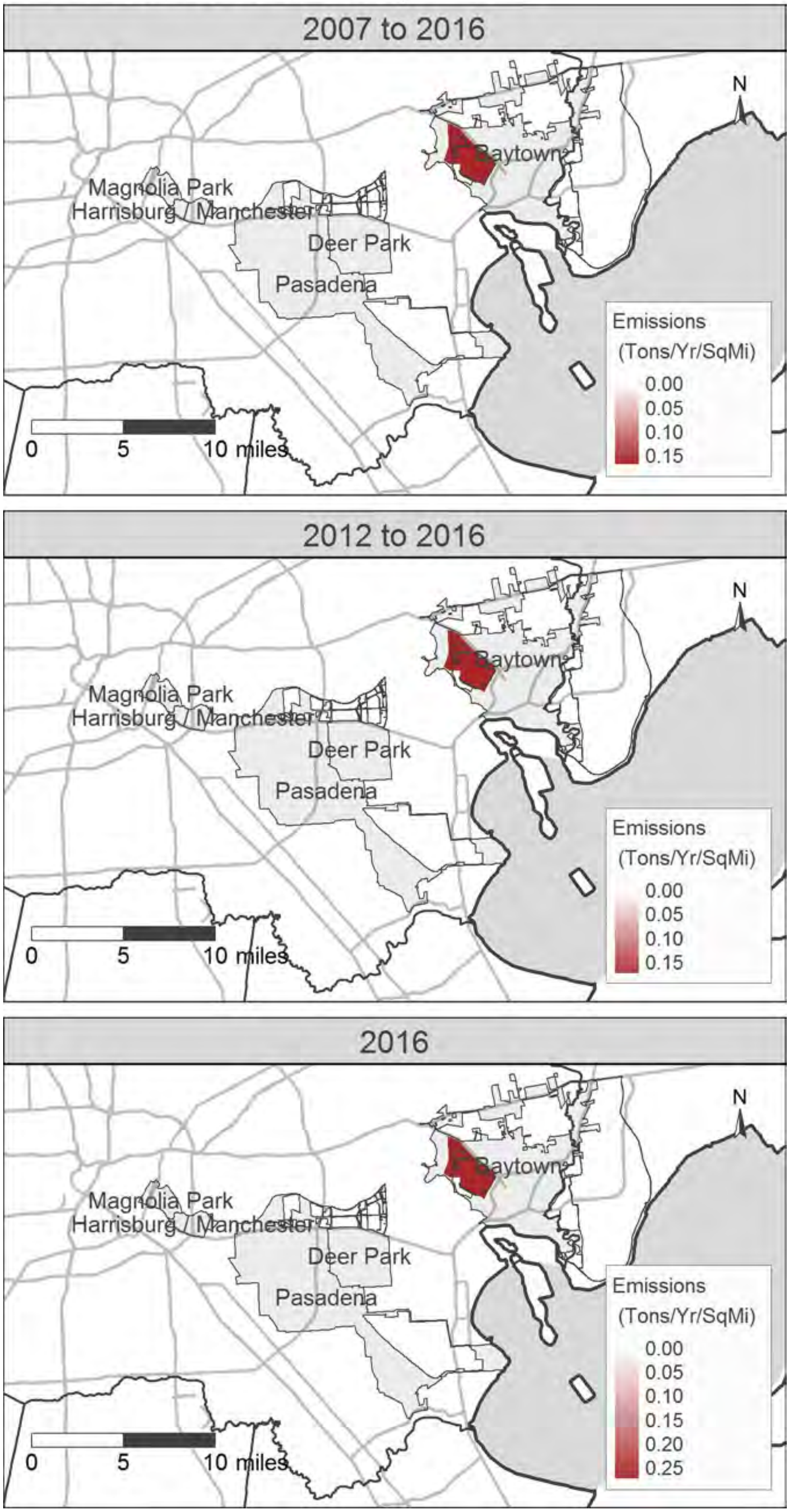


Chlorine

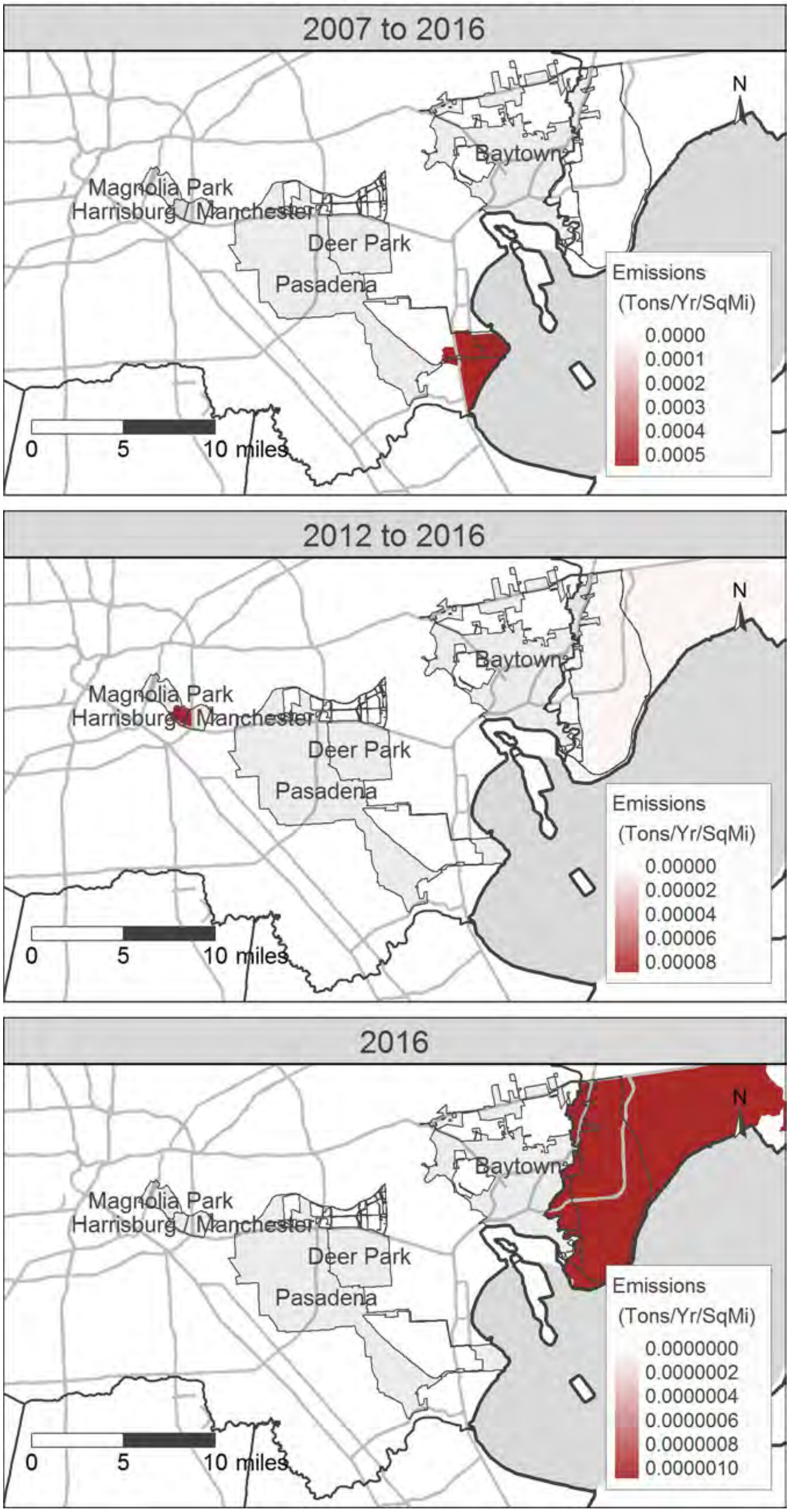


2007 to 2016
N
Baytown
Magnolia Park
Harrisburg
Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
2.0
0
5
10 miles
2012 to 2016
N
Baytown
Magnolia Park
Harrisburg
Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
0
5
10 miles
2016
N
Baytown
Magnolia Park
Harrisburg
Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0
0.5
1.0
1.5
0
5
10 miles

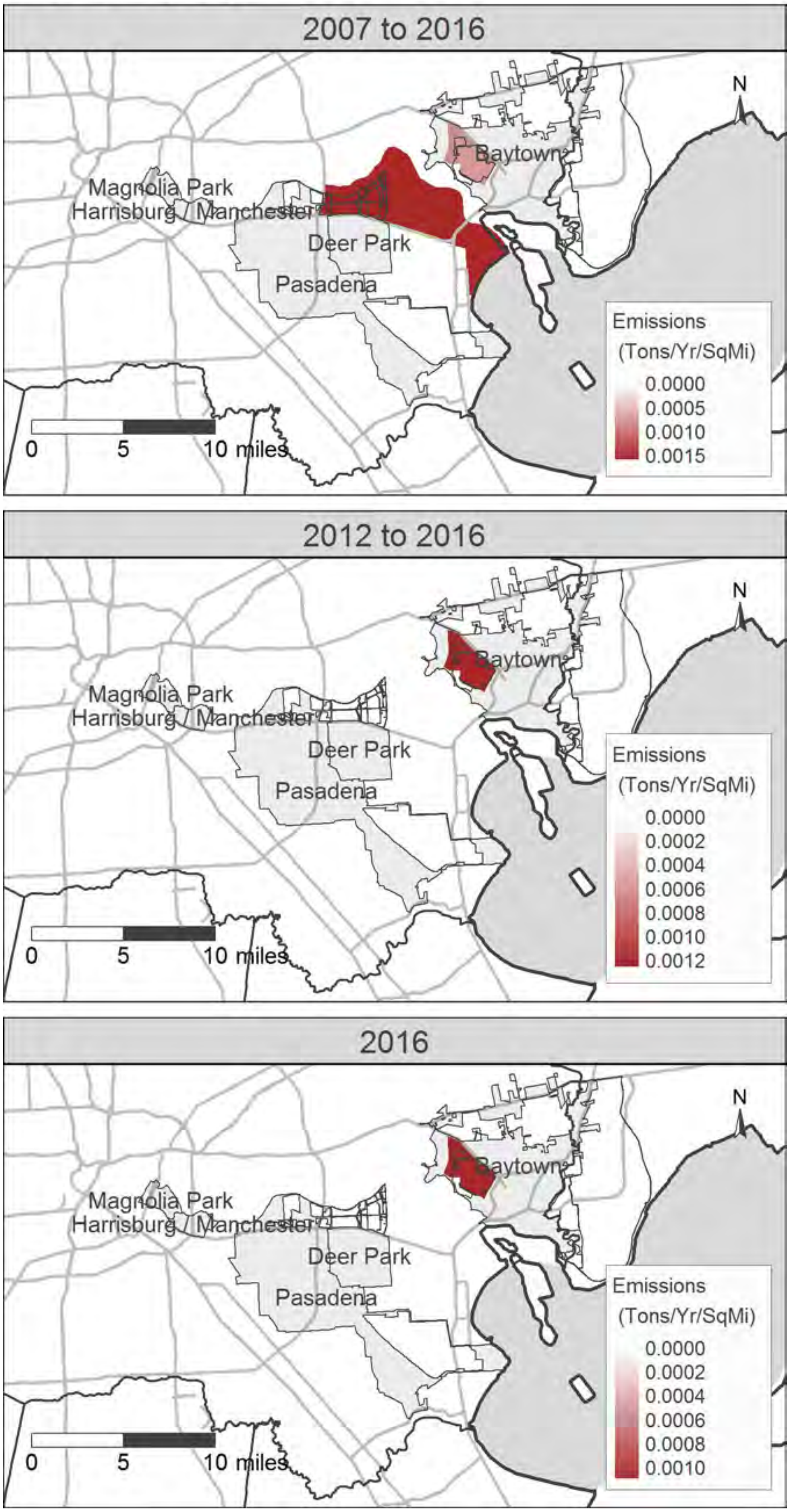
Chromium and compounds



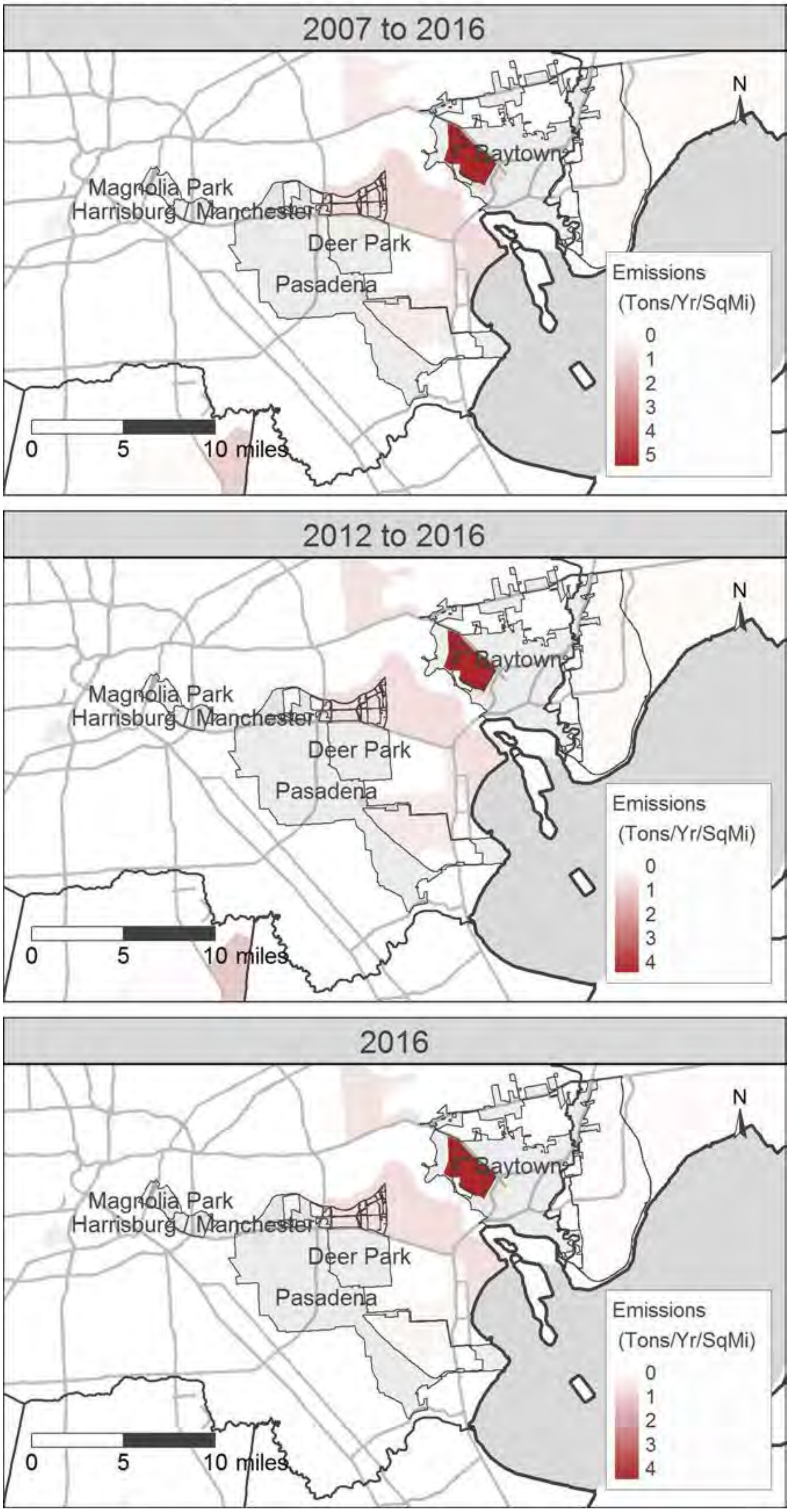
Diaminotoluene (mixed isomers)

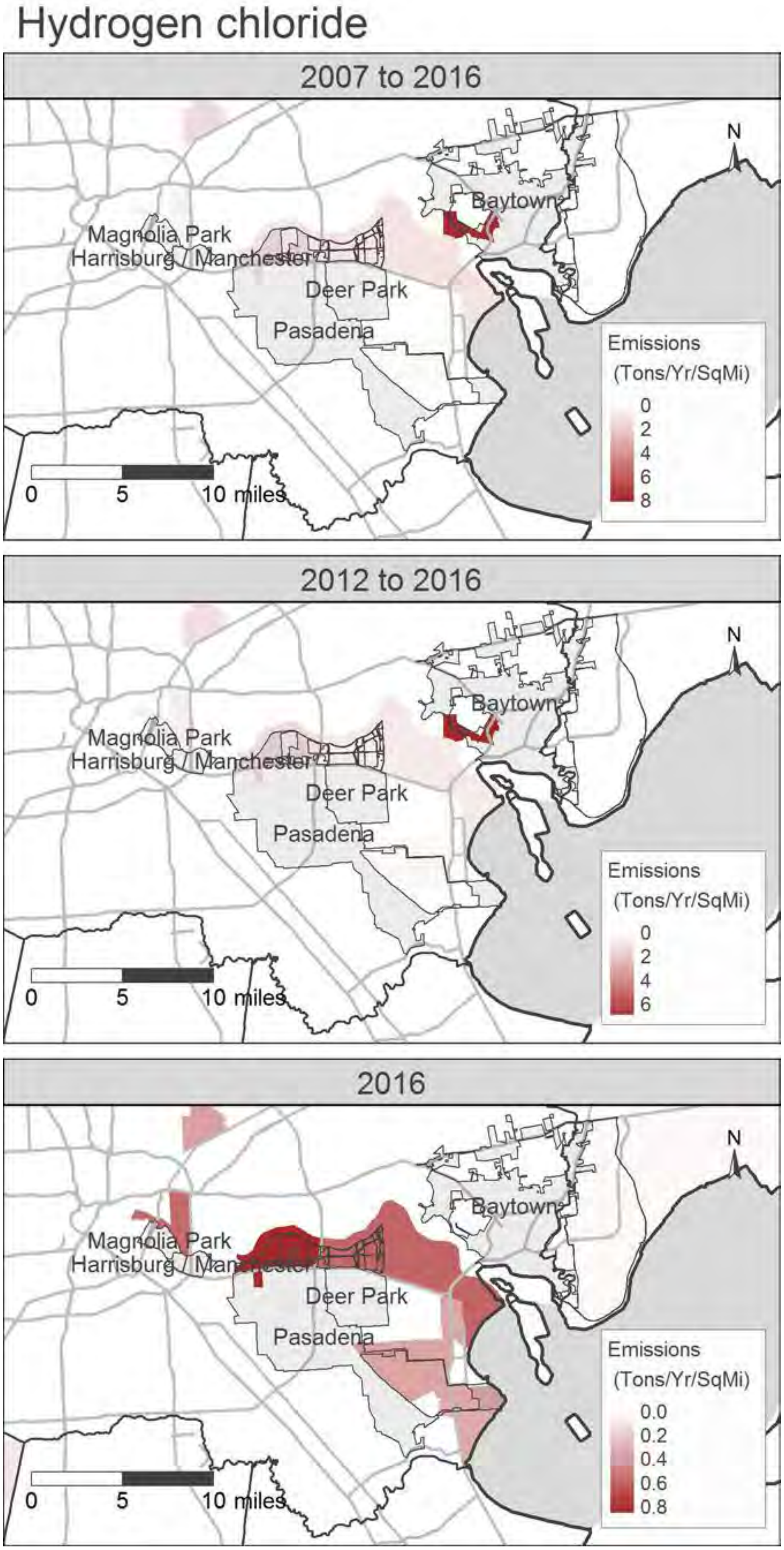


Fluoranthene

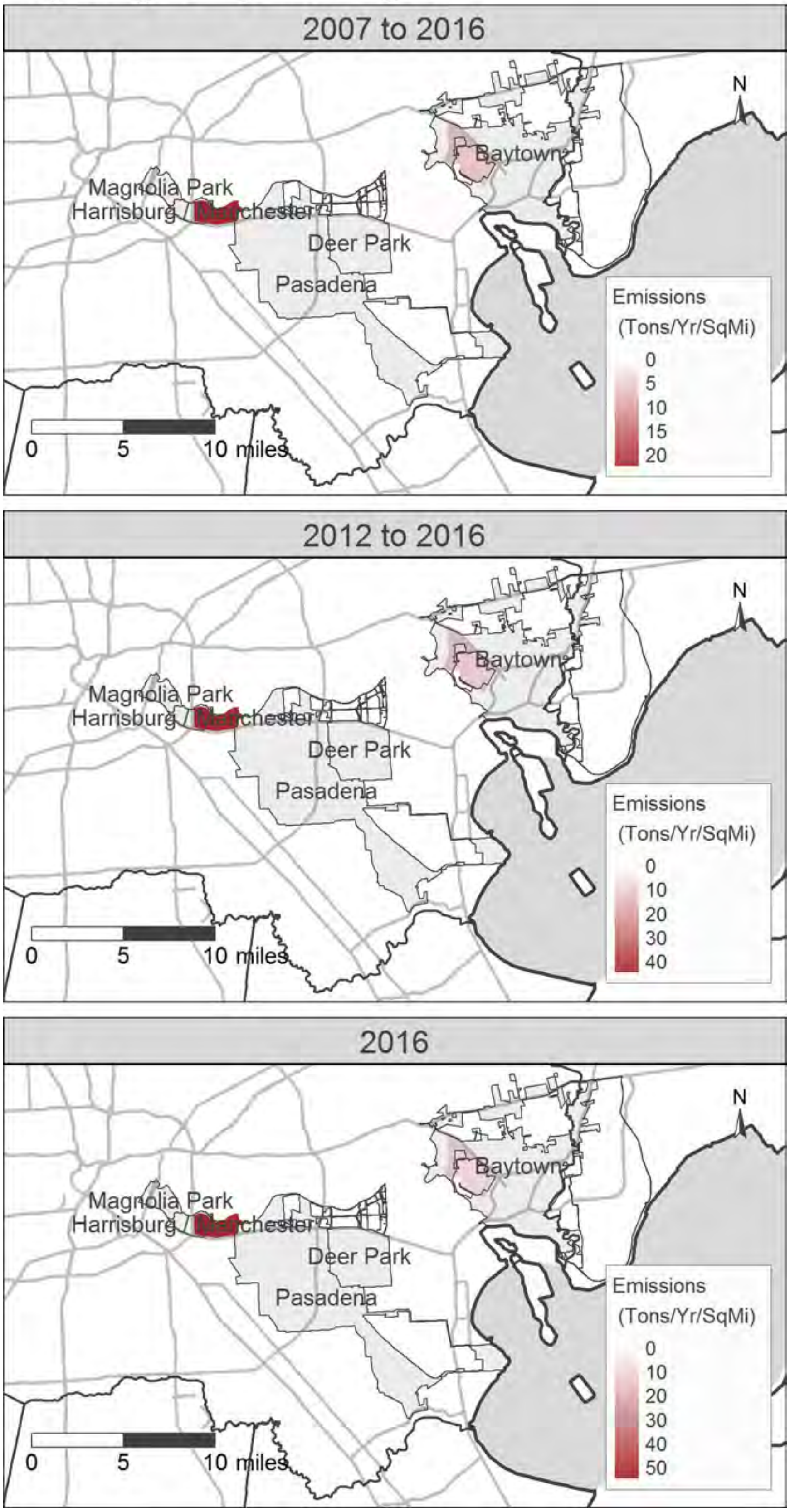


Formaldehyde

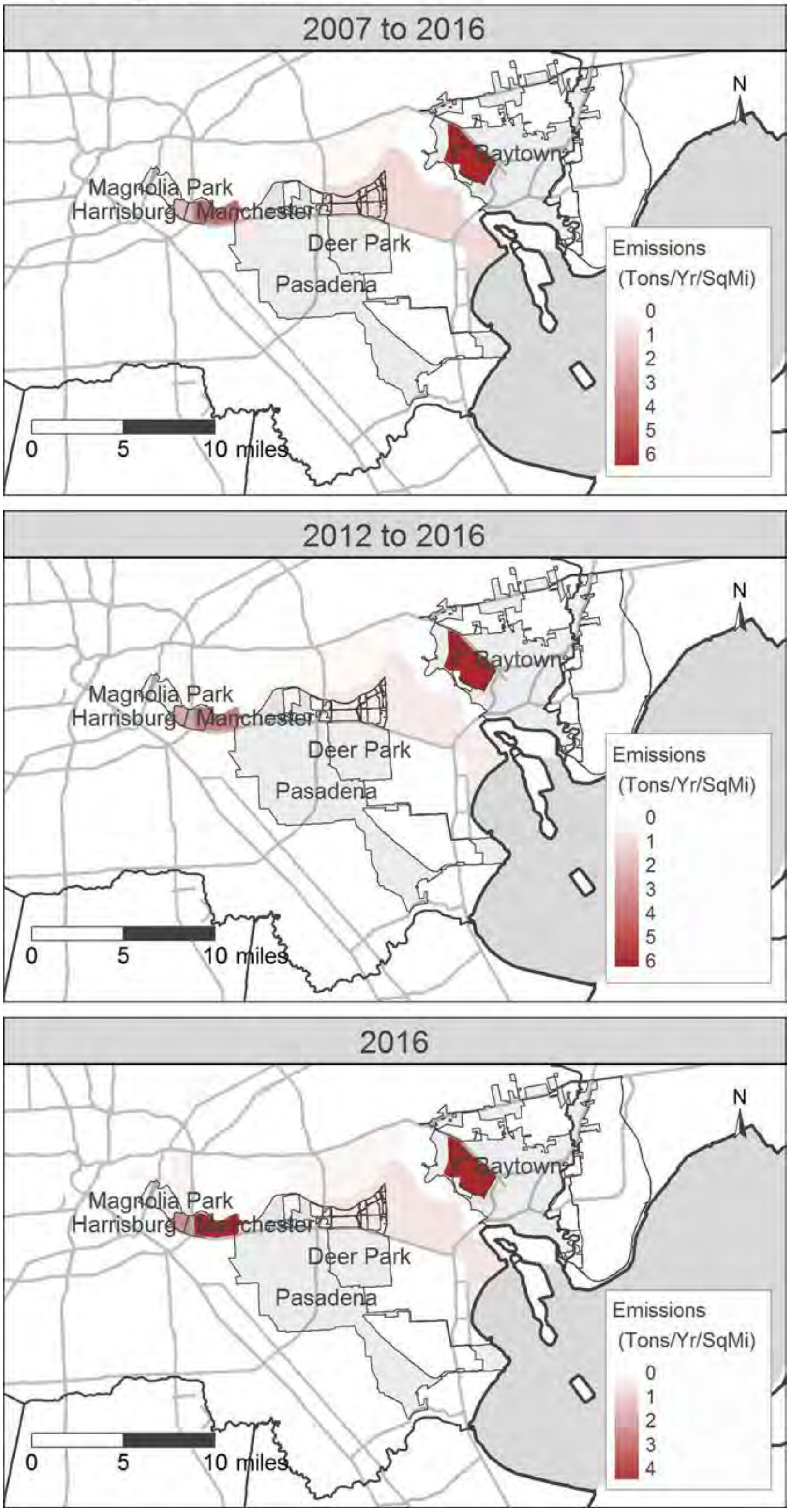



Hydrogen chloride
2007 to 2016
2012 to 2016
2016
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
N
0
5
10 miles
Emissions
(Tons/Yr/SqMi)
0
2
4
6
8
0.0
0.2
0.4
0.6
0.8

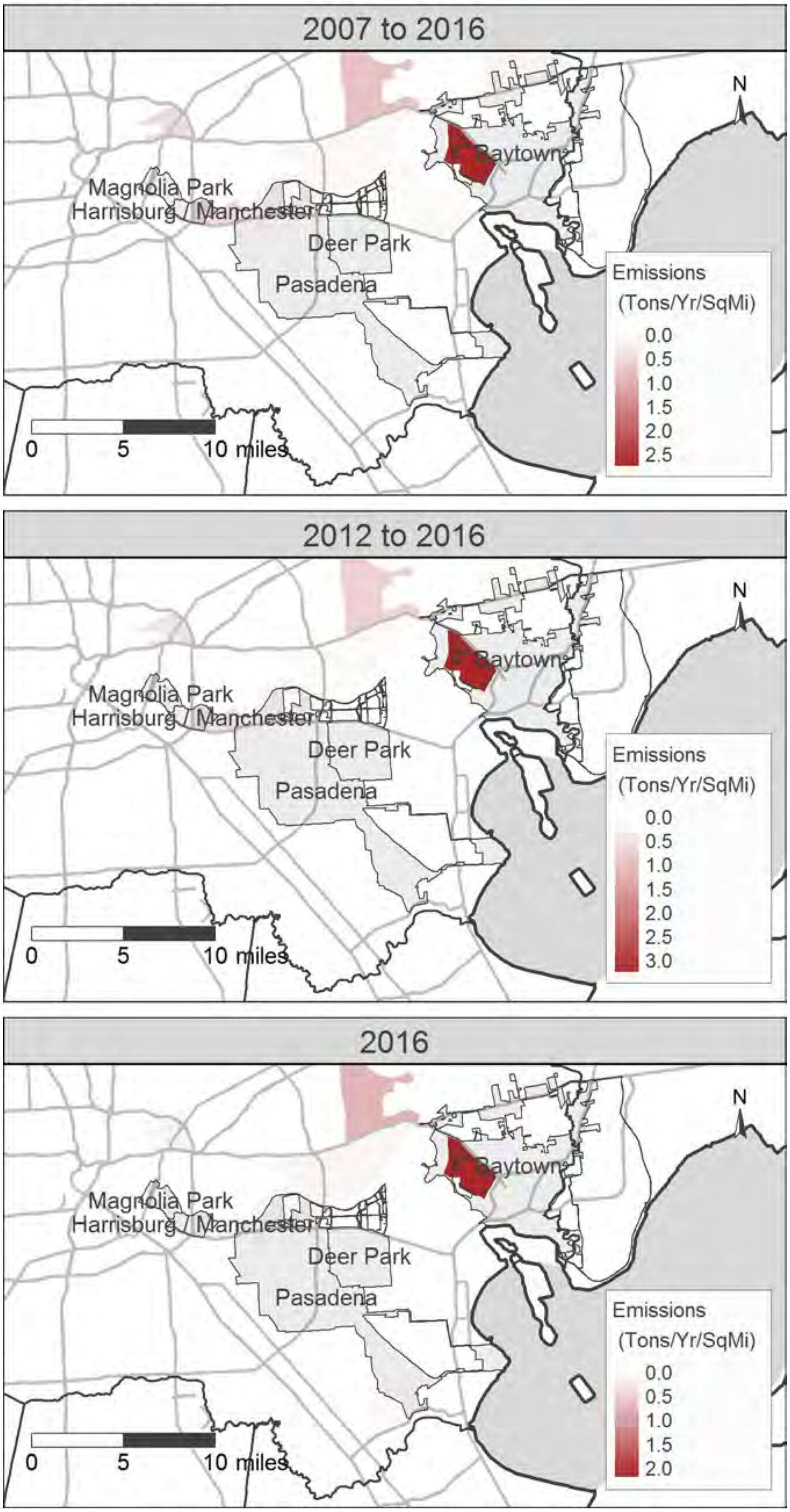
Hydrogen cyanide gas



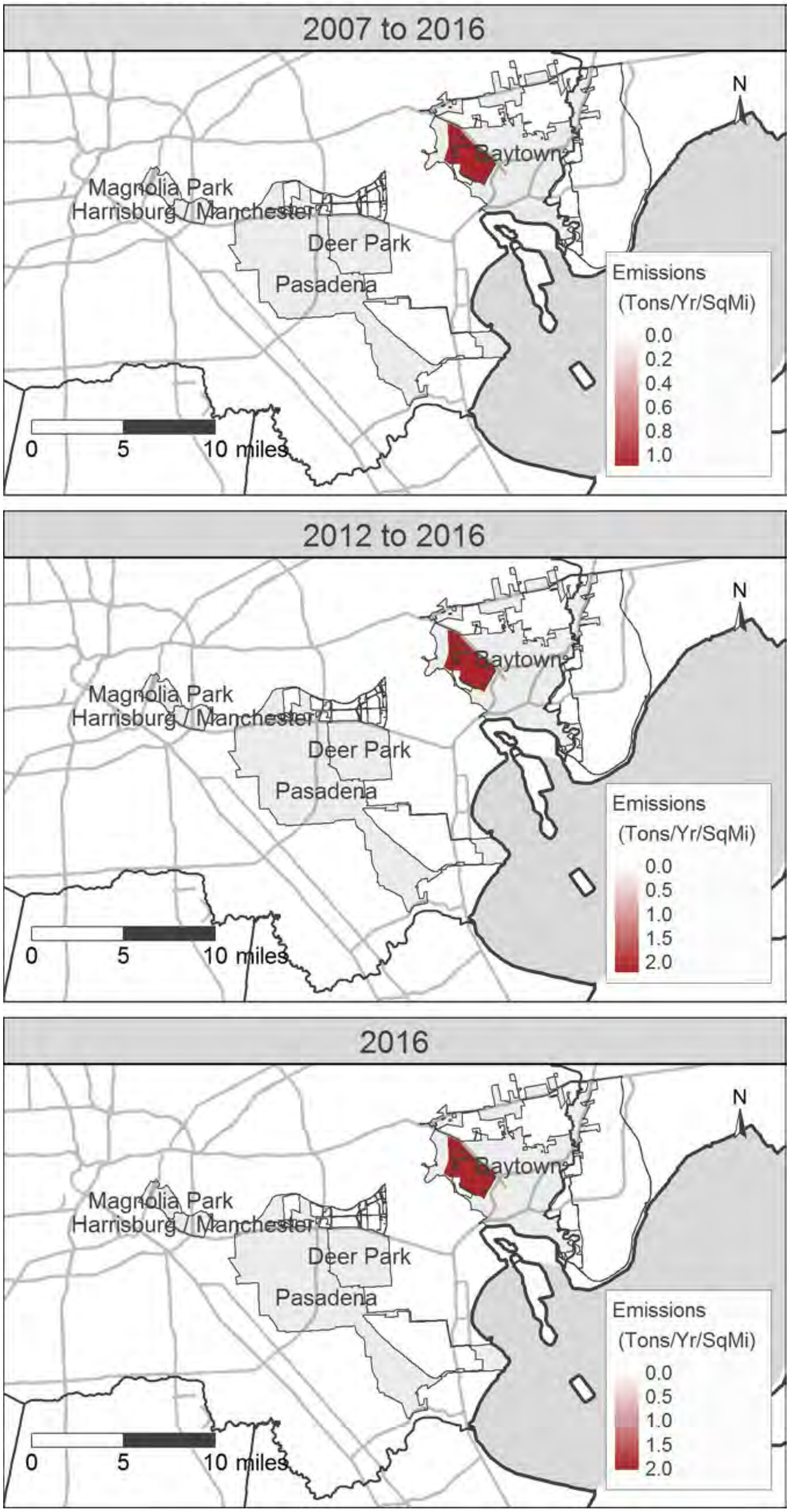
Hydrogen sulfide



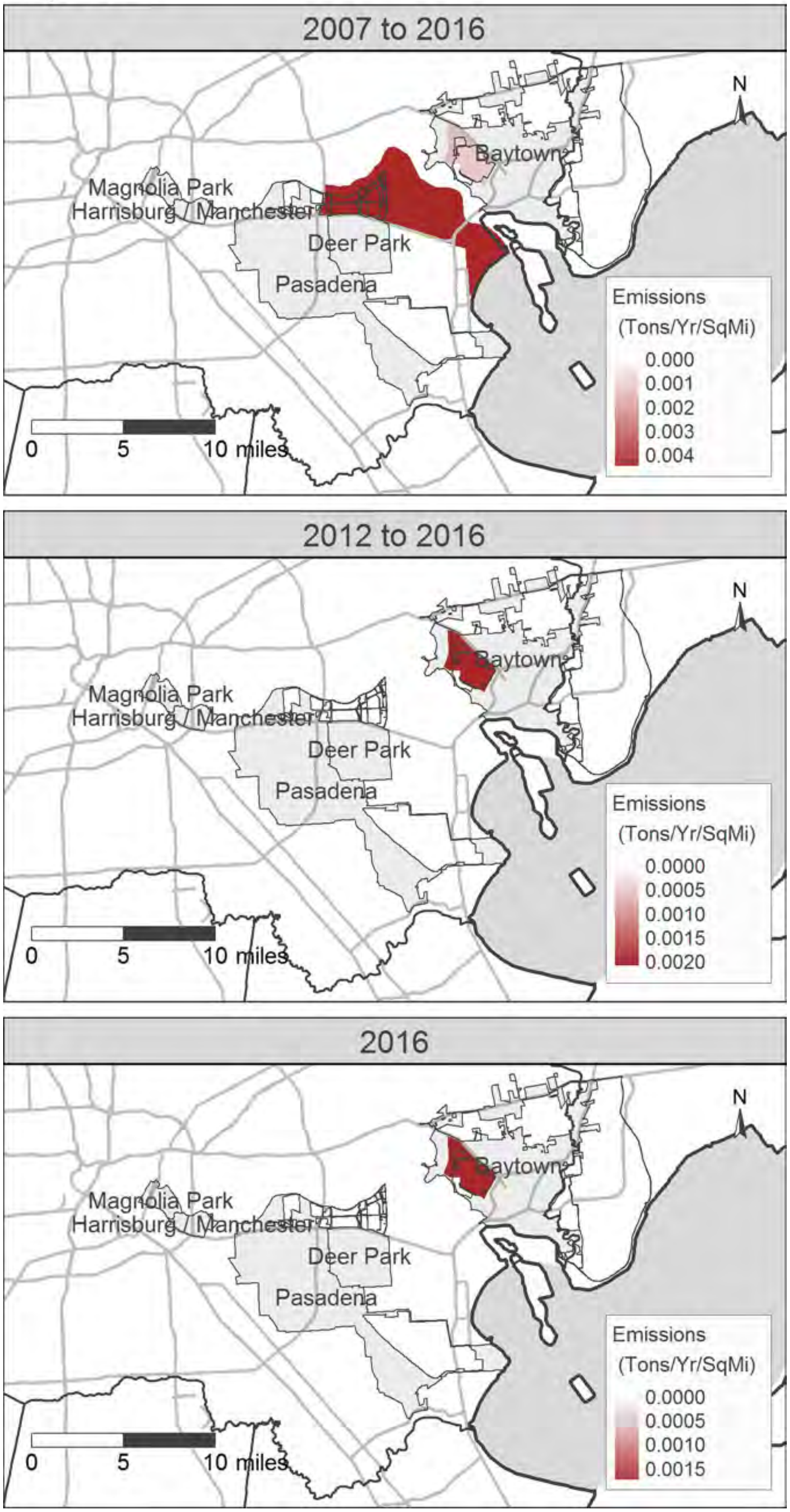
Naphthalene



Phenanthrene

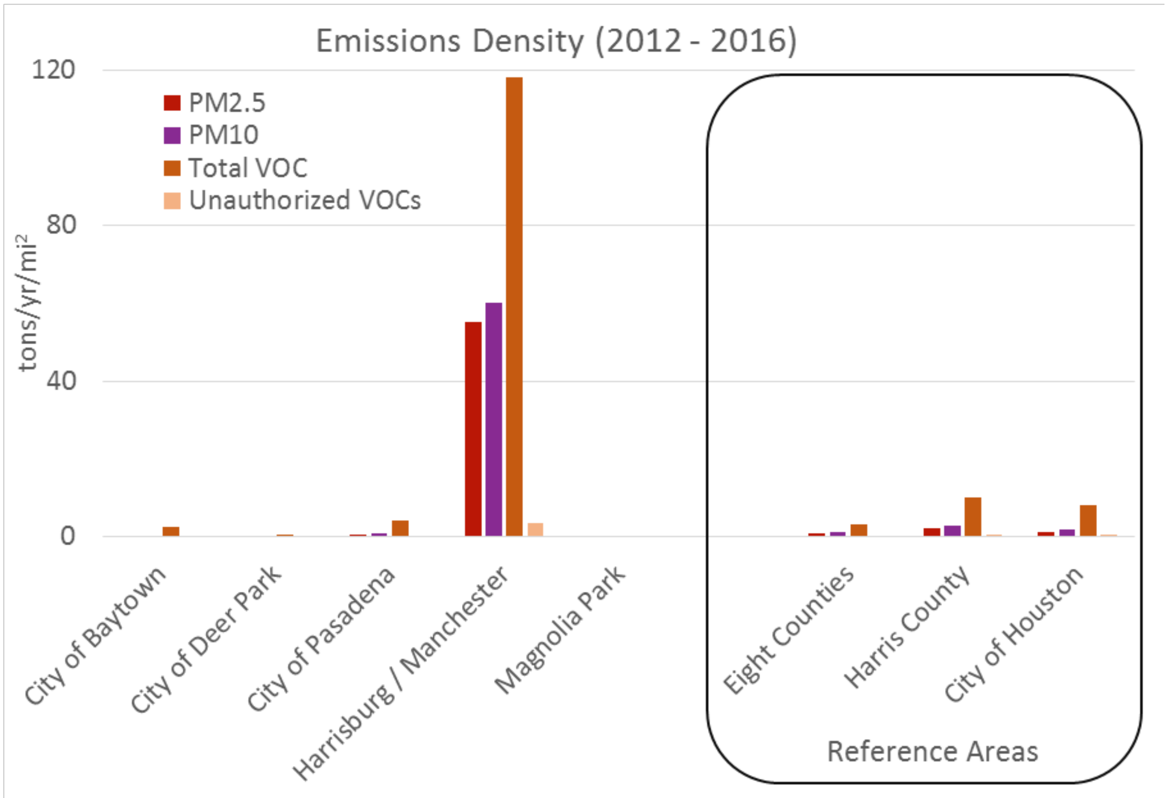


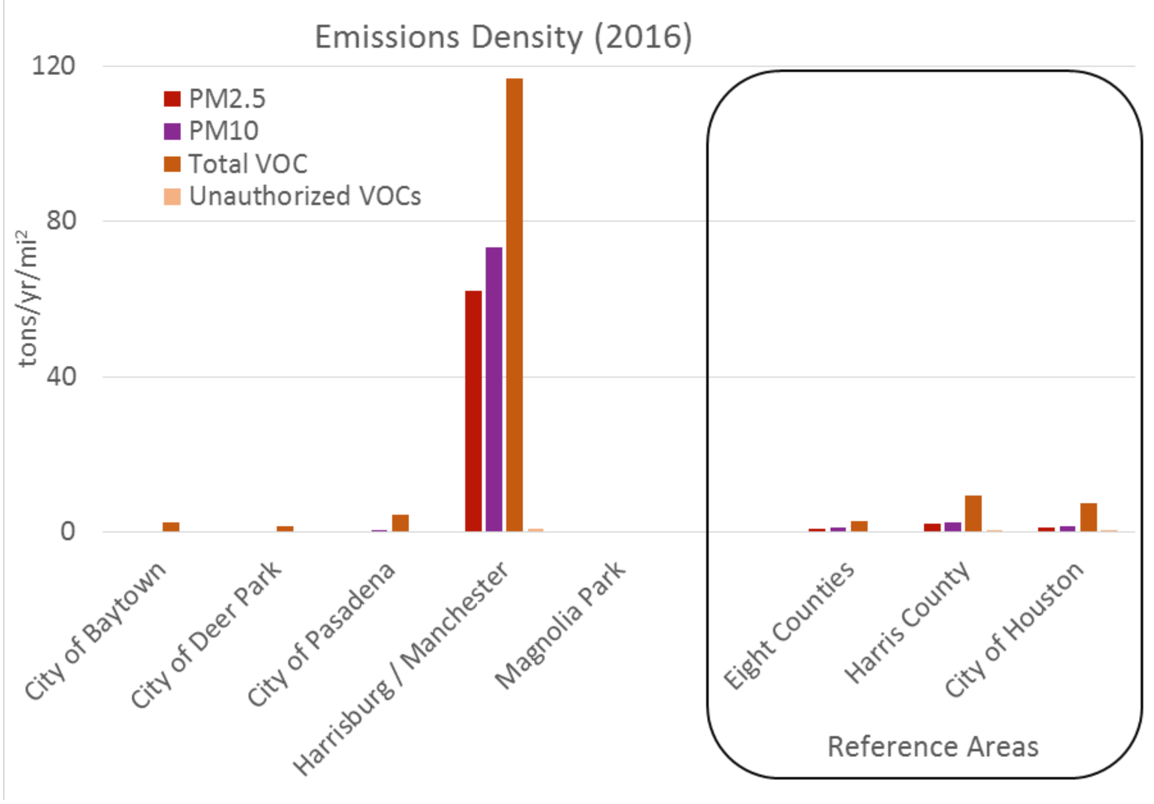
Pyrene



2007 to 2016
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.000
0.001
0.002
0.003
0.004
0
5
10 miles
2012 to 2016
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0000
0.0005
0.0010
0.0015
0.0020
0
5
10 miles
2016
N
Baytown
Magnolia Park
Harrisburg / Manchester
Deer Park
Pasadena
Emissions
(Tons/Yr/SqMi)
0.0000
0.0005
0.0010
0.0015
0
5
10 miles

Appendix F: Emissions for 2012 to 2016 and 2016 in Communities of Interest


Emissions Density (2012 - 2016)
120
80
40
0
tons/yr/mi2
PM2.5
PM10
Total VOC
Unauthorized VOCs
City of Baytown
City of Deer Park
City of Pasadena
Harrisburg / Manchester
Magnolia Park
Eight Counties
Harris County
City of Houston
Reference Areas


Emissions Density (2016)
120
80
40
0
tons/yr/mi2
PM2.5
PM10
Total VOC
Unauthorized VOCs
City of Baytown
City of Deer Park
City of Pasadena
Harrisburg / Manchester
Magnolia Park
Eight Counties
Harris County
City of Houston
Reference Areas

Appendix G: Vulnerability Index and Emissions in Communities of Interest

Demographics and Vulnerability Index in Communities of Interest				
Location	**Poverty (%)**	**Limited-English (%)**	**People of Color (%)**	**Vulnerability Index**
City of Baytown	16.4	8.7	61.3	28.8
City of Deer Park	8.6	2.4	30.5	13.8
City of Pasadena	19.6	12.2	67.3	33.0
Harrisburg / Manchester	28.4	30.1	96.6	51.7
Magnolia Park	28.9	37.2	97.8	54.7
Eight Counties	15.3	9.6	60.6	28.5
Harris County	17.4	11.8	67.0	32.1
City of Houston	21.9	14.0	74.4	36.8

Emissions in Communities of Interest (tons / year / sq mile estimated at the census tract level)												
	2007 to 2016				**2012 to 2016**				**2016**			
Location	**PM2.5**	**PM10**	**Total VOC**	**Unauthorized VOCs**	**PM2.5**	**PM10**	**Total VOC**	**Unauthorized VOCs**	**PM2.5**	**PM10**	**Total VOC**	**Unauthorized VOCs**
City of Baytown	0.11	0.14	2.5	0.052	0.12	0.15	2.6	0.06	0.13	0.16	2.6	0.00022
City of Deer Park	0.000010	0.000010	0.31	NA	0.000021	0.000021	0.62	NA	0.000095	0.000095	1.4	NA
City of Pasadena	1.1	1.31	4.1	0.16	0.58	0.83	4.1	0.2	0.37	0.38	4.4	0.066
Harrisburg / Manchester	58	62	114	6.5	55	60	118	3	62	73	117	0.72
Magnolia Park	0.15	0.15	0.12	NA	0.16	0.16	0.11	NA	0.17	0.17	0.13	NA
Eight Counties	1.0	1.3	3.7	0.24	1.0	1.2	3.3	0.20	0.95	1.1	3.0	0.14
Harris County	2.4	3.4	11	0.71	2.3	3.0	10	0.56	2.3	2.6	9.4	0.49
City of Houston	1.1	2.1	8.1	0.45	1.1	1.9	8.0	0.56	1.2	1.5	7.3	0.53

*NA indicates no reported emissions of this type in this location.