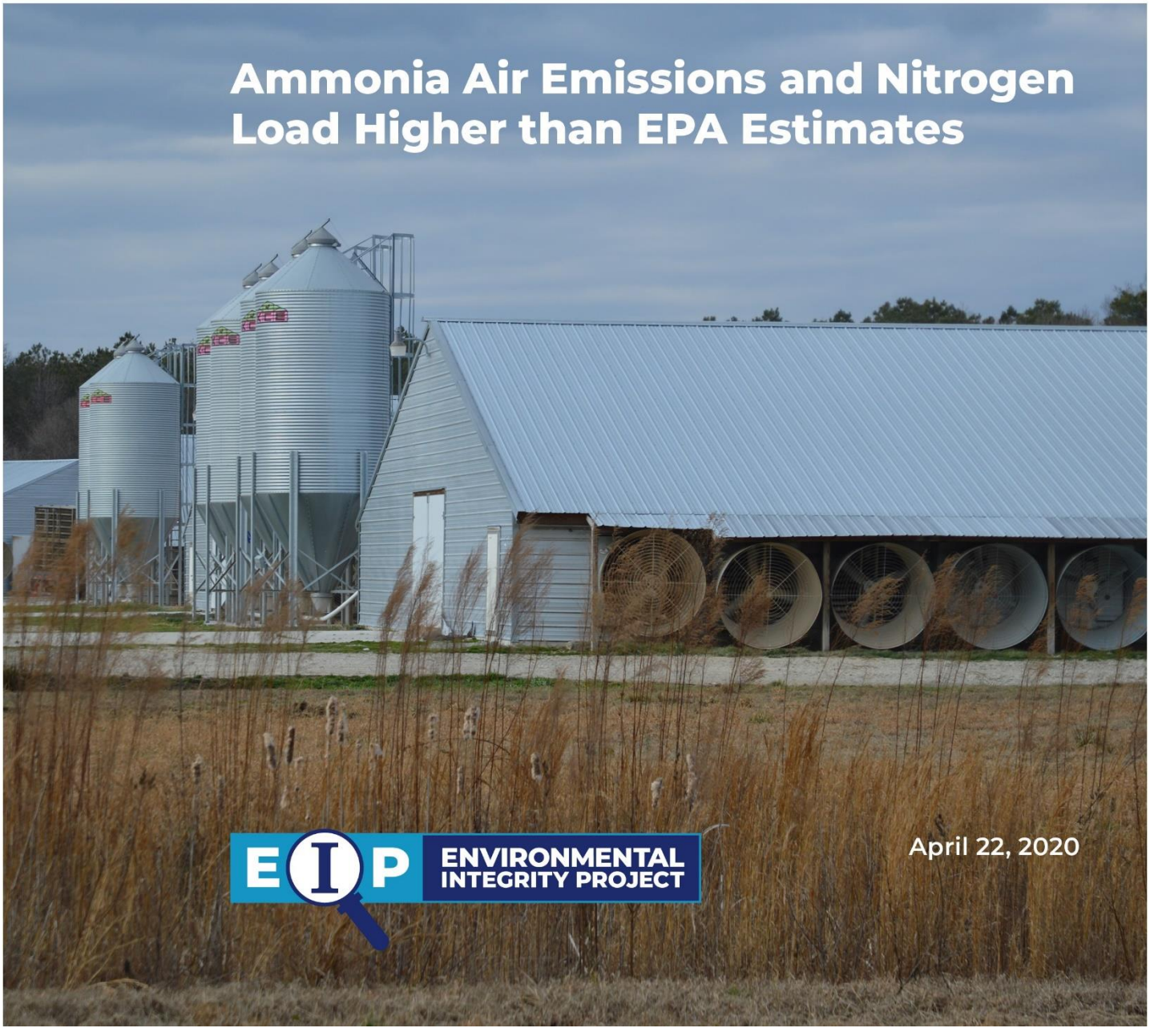
Poultry Industry Pollution in the Chesapeake Region

Ammonia Air Emissions and Nitrogen Load Higher than EPA Estimates



ENVIRONMENTAL INTEGRITY PROJECT

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ACKNOWLEDGEMENTS

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THE ENVIRONMENTAL INTEGRITY PROJECT

The Environmental Integrity Project (http://www.environmentalintegrity.org) is a nonpartisan, nonprofit organization established in March of 2002 by former EPA enforcement attorneys to advocate for effective enforcement of environmental laws. EIP has three goals: 1) to provide objective analyses of how the failure to enforce or implement environmental laws increases pollution and affects public health; 2) to hold federal and state agencies, as well as individual corporations, accountable for failing to enforce or comply with environmental laws; and 3) to help local communities obtain the protection of environmental laws.

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Poultry Pollution in the Chesapeake Region

Executive Summary

When many people think about the contributions of the poultry industry to water pollution in the Chesapeake Bay, they consider only manure runoff. Farmers working for Perdue and other companies raise more than a billion chickens a year for the meat industry in the region – including 600 million on the Delmarva Peninsula, 182 million in Virginia's Shenandoah Valley, and 164 million in Pennsylvania.[1] Contract farmers also sell about 18 million turkeys for slaughter (mostly in Virginia) and keep about 25 million hens at a time for the egg industry (mostly in Pennsylvania).[2] All of these birds produce about 5.7 billion pounds of manure annually,[3] which is often over applied to farm fields that are already saturated with nutrients. This leads to runoff of nitrogen and phosphorus into waterways, stimulating excessive growth of algae and low-oxygen "dead zones" that can kill fish and crabs. The Bay region states have developed strategies to reduce this pollution, including by requiring farmers to follow manure-management plans and phosphorus limits in some areas, and by encouraging the planting of strips of trees and vegetation along streams to act as filters.

However, the poultry industry also pollutes the Chesapeake Bay through a second pathway that is not even monitored, let alone controlled. Industrial-scale chicken houses – windowless, airplane hangar-like metal structures often twice the length of a football field -- have large exhaust fans that blow ammonia from the poultry waste out into the community. These air emissions, combined with ammonia rising from chicken manure spread on farm fields, fall back down onto land and water in the Bay watershed. The emissions contribute significantly to nitrogen pollution in the nation's largest estuary, because ammonia breaks down into nitrogen in the environment.[4] Ammonia can also harm the health of neighbors downwind, triggering coughing, asthma attacks, watery eyes, and the irritation and inflammation of throats and nasal passages.[5] A 2018 study by Johns Hopkins researchers found that people who live near poultry houses in Pennsylvania are 66 percent more likely to be diagnosed with pneumonia.[6]

Industrial scale poultry operations in the Chesapeake Bay region are releasing ammonia air pollution that contributes about 12 million pounds of nitrogen water pollution into the estuary every year.

This report by the Environmental Integrity Project (EIP) examines data from the federal and state Chesapeake Bay Program,[7] emissions estimates from the most recent scientific studies, and numbers from the U.S. Department of Agriculture's most recent farm census. EIP used the Bay Program's computer modeling of

pollution entering the estuary to evaluate the total nitrogen load from the poultry industry, including both the runoff of manure spread on fields as fertilizer, and ammonia that rises from chicken houses and litter before falling back down in the Chesapeake Bay watershed. EIP adjusted the Bay Program numbers – which are based on EPA estimates – by using a review of more recent scientific studies of ammonia emissions from poultry barns than EPA used to provide more realistic estimates of total emissions and nitrogen pollution in the Bay. In our definition of "poultry" we include not only chickens raised for meat (called "broilers,") but also chickens used for eggs ("layers"), turkeys, and other poultry. By "Bay" pollution load, we mean pollution entering the tidal waters of the Chesapeake Bay, often described as the "delivered load." (For a detailed discussion of methodology and sources, see Appendix A.)

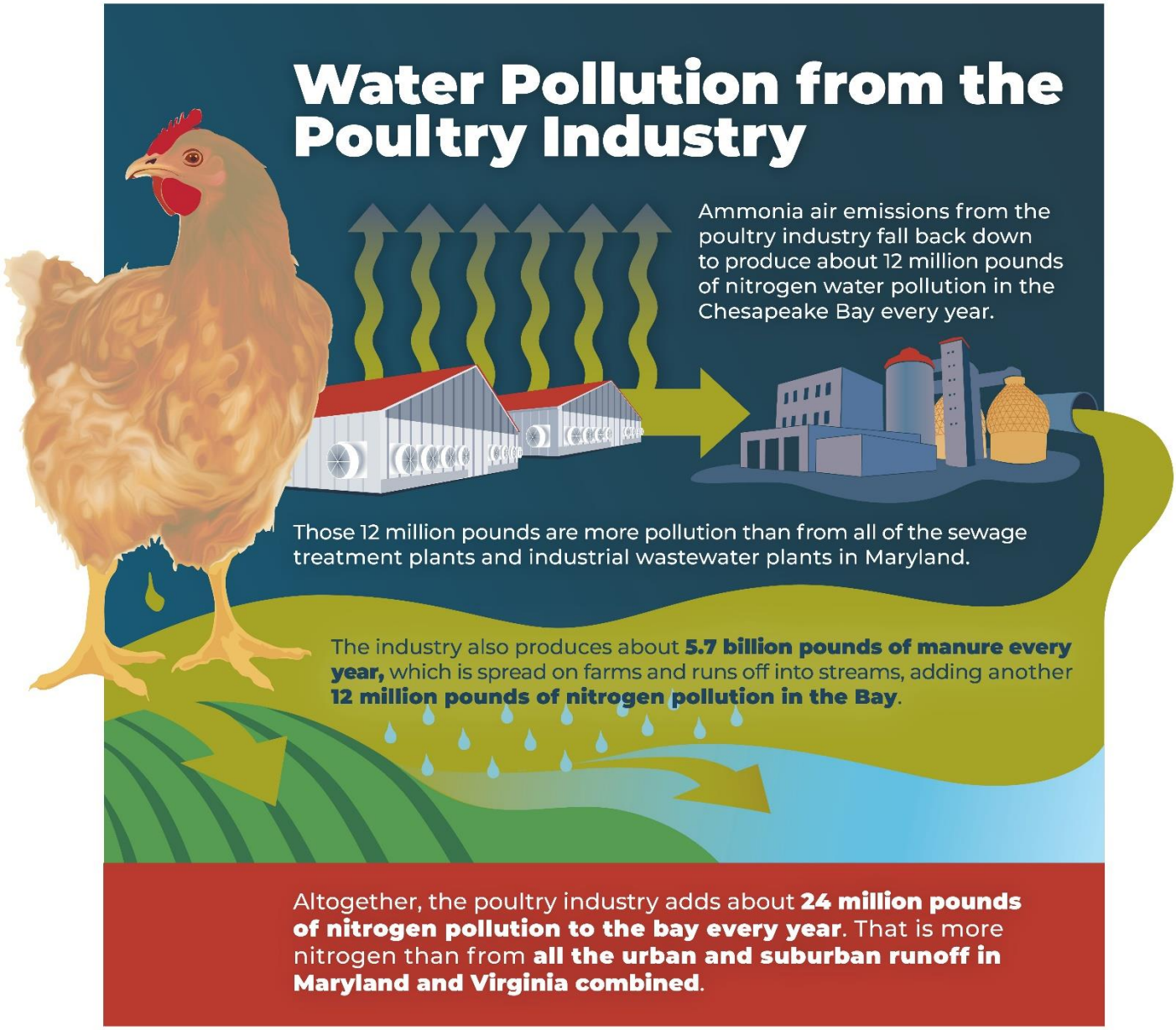
The impact of ammonia on the Chesapeake Bay is significant. This report concludes that ammonia emissions from poultry operations contribute about 12 million pounds of nitrogen pollution to the Bay every year.[8] To put those 12 million pounds into context, they exceed the total nitrogen pollution from all the sewage and industrial wastewater plants in Maryland (which released 10 million pounds of nitrogen in 2018) or Pennsylvania (9 million pounds) and almost as much as Virginia (12.6 million pounds from sewage and wastewater).[9] The poultry ammonia total does not include runoff from manure spread on farm fields, which adds another 12 million pounds of nitrogen to the estuary every year. Altogether, if the ammonia and runoff are combined, the poultry industry adds a total of 24 million pounds of nitrogen to the Chesapeake Bay ever year. That is more nitrogen than from all of the urban and suburban stormwater runoff in Virginia and Maryland combined (which was 20 million pounds in 2018). It is also 17 times more nitrogen pollution than in all the overflows from the combined sewage and stormwater systems in the Chesapeake Bay watershed, including those in Washington, D.C., and Harrisburg, Pennsylvania.[10]

Table 1: Nitrogen Pollution Entering Bay from Poultry Industry (lbs in 2018)

State	Nitrogen from ammonia emissions	Nitrogen from ammonia emissions (adjusted)	Nitrogen runoff from poultry manure	Total nitrogen from poultry entering the Bay
DE	508,015	752,114	1,483,306	2,235,420
MD	2,802,139	3,324,251	2,066,499	5,390,750
NY	77,478	81,433	59,185	140,618
PA	4,017,257	4,258,587	5,757,462	10,016,049
VA	2,139,000	2,473,710	2,322,844	4,796,554
WV	702,972	742,929	709,977	1,452,906
Grand Total	10,246,861	11,633,024	12,399,273	24,032,297

Note: Results are expressed as annual pounds of nitrogen entering the tidal waters of the Chesapeake Bay in 2018.[11] Numbers are from the Chesapeake Bay Program Bay Model, with the "adjusted" correcting for the likely underestimate in ammonia in the program's watershed model (see Appendix A). We apportioned the ammonia falling directly onto the Bay between the portions of the estuary in Maryland and Virginia.[12]

For a version of this chart with a separate line item for ammonia falling directly onto the Bay, see Table 6 on page 15. Our adjusted ammonia totals (the total amount of nitrogen entering the Bay from ammonia emissions) are about 14 percent, or 1.4 million pounds, higher than the totals implied by the Bay Program's watershed model. This is in part because the model relies on ammonia emissions estimates from EPA's 2011 National Emissions Inventory, which is in turn based on outdated ammonia emissions studies, including, for example, studies of European broiler operations from the 1980s and 1990s.



Based on more recent research, ammonia emissions from modern American broiler barns can be significantly higher because U.S. chicken companies grow larger birds, work in different climates, and follow different farming practices. We documented this problem in a 2018 report, and derived a set of emissions factors for ammonia from broiler barns.[13] In this report, EIP incorporated these more up-to-date emissions factors for broilers, and we also used updated emissions factors for layers and turkeys. Finally, we made use of more recent inventory and production data from the U.S. Department of Agriculture to account for recent growth in the industry.

Our estimate of 24 million pounds of nitrogen per year may still be too low, because the Bay Program model may underestimate the rate at which airborne ammonia deposits onto land and water. A recent study published by researchers from North Carolina State University suggested that ammonia deposition on Maryland's Eastern Shore may be two to three times higher than previously assumed. For a full discussion of that report, see Appendix B.

Of course, poultry is only one part of the agricultural sector across the Chesapeake Bay watershed. All farms add a total of more than 119 million pounds of nitrogen pollution to the estuary on an annual basis, according to EPA figures.[14] That total agricultural share of pollution is more than three times the combined total from all the municipal sewage plants and industrial wastewater treatment plants in the watershed, and represents about 45 percent of the total nitrogen pollution entering the Bay from all sources, according to EPA.[15]

The exhaust fans on industrial-scale poultry houses blow ammonia, particles of fecal matter, bacteria and other pathogens into the surrounding community. Neighbors sometimes complain of asthma attacks, pneumonia, and other illnesses.

Reducing that agricultural pollution has been a challenge in part because the federal Clean Water Act requires enforceable permits with numeric pollution limits for sewage plants and other facilities with pipes that dump directly into waterways, but not for farm fields or agricultural air pollution. Federal and state permitting requirements for poultry houses and other animal feeding operations include some rules on the storage and management of manure, to discourage runoff into nearby streams. But, so far, no permits require the monitoring or control of

ammonia or other air emissions. That leaves a major source of pollution, as well as a threat to public health, unchecked and largely unknown.

This report recommends the following policy steps to address the problem:

1) EPA should update the ammonia emission estimates it uses to simulate nitrogen loads to the Bay to reflect the most recent available science.
2) All large new animal feeding operations should be required to install air pollution monitors and report their emissions on an annual basis to state environmental agencies and the EPA.
3) EPA should establish safety thresholds for ammonia that apply to the fenceline areas between poultry operations and neighboring residents, to help protect local communities from excessive levels of ammonia.
4) States and the EPA should require poultry houses to install effective air pollution control systems, including filters to capture particulate matter being blown by poultry house exhaust fans out into the community.
5) Poultry companies should pay for the planting of more trees and forested areas around chicken houses, to protect neighbors and to help catch and reduce ammonia emissions.
6) Because the Chesapeake Bay region states are already struggling with the overproduction of manure, lawmakers should impose limits on the approval of new permits for large animal feeding operations, especially in areas that produce more manure than crops can use.

The big picture is that air emissions from factory farms cause both environmental harm and public health threats for families who live nearby. For this reason, more air pollution monitoring and controls are needed. This report provides a discussion of the most recent science and agricultural census data on chicken farms and other broiler operations across the Chesapeake region.

We then illustrate the real-life impact of poultry air pollution with profiles and photos of families living downwind from industrial scale poultry houses in Maryland, Pennsylvania, and Virginia.

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Nitrogen Pollution from Poultry

Ammonia is a chemical compound of nitrogen and hydrogen with a pungent smell that is produced, among other places, in the guts of animals as a byproduct of food digestion. In the environment, ammonia breaks down into its component parts, liberating the nitrogen, which acts as a nutrient to feed algae blooms and low-oxygen "dead zones" in the Bay.

The Environmental Integrity Project estimated the total nitrogen load from poultry operations in the Chesapeake Bay watershed for the year 2018. That was the most recent year for which complete data were available from the Chesapeake Bay Program's computer modeling of pollution flowing into the estuary.[16] We extracted from these total estimates the amount of nitrogen delivered into the Bay from the land application of poultry litter, and added to this the ammonia air emissions that rise from poultry houses and manure before falling back down onto the land and water.[17] By limiting our numbers to just the nitrogen entering the *tidal waters of the Bay,* we focused on the ecological impact of the nitrogen on the estuary itself and not on the freshwater streams and rivers that are its tributaries. The methods we used are described in detail in Appendix A.

Nitrogen pollution from poultry tends to be concentrated in certain hot spots. The counties with the highest per-acre nitrogen load are in three areas: The lower Susquehanna River in Pennsylvania, the Delmarva Peninsula, and Virginia's Shenandoah Valley.

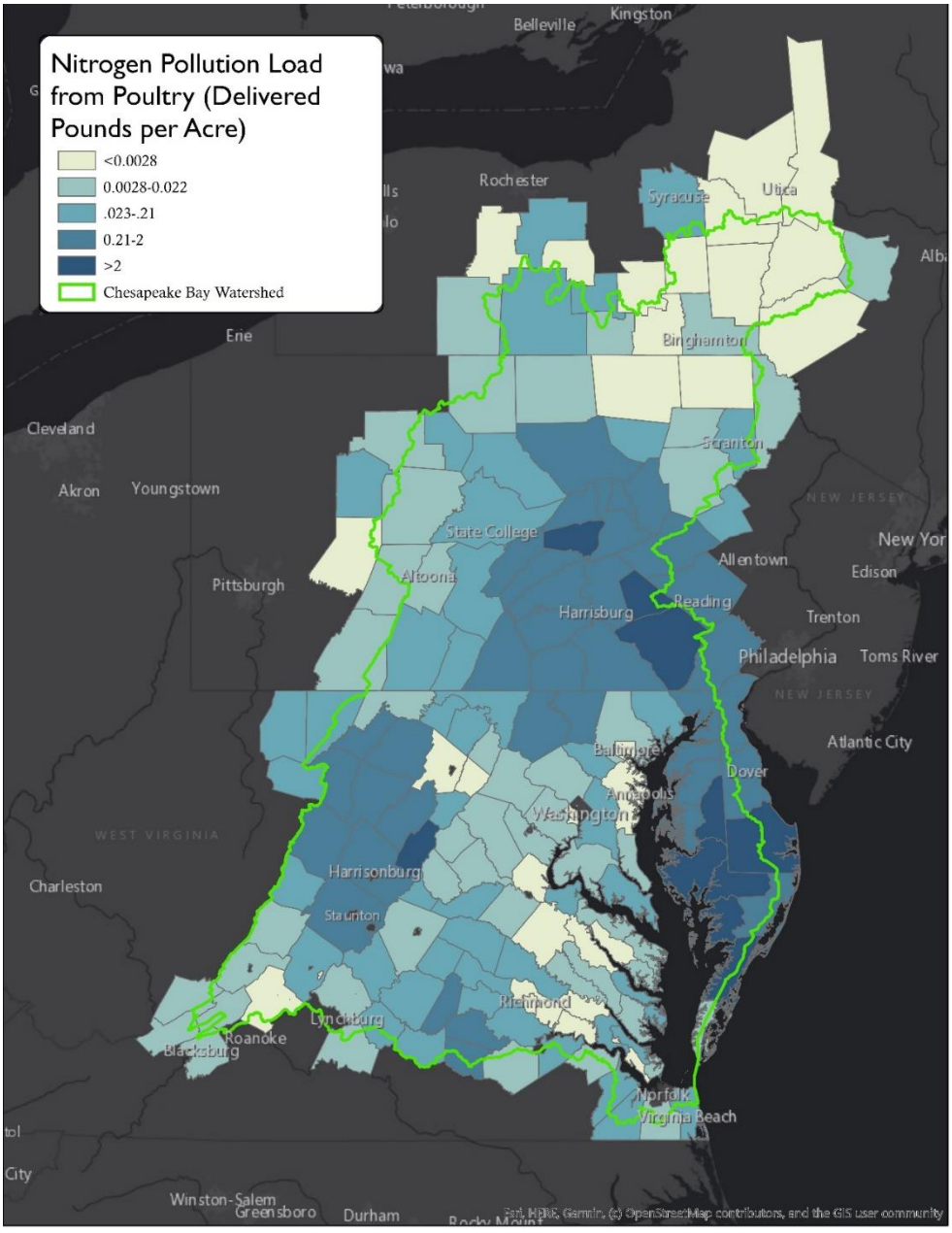
Table 2: Top 10 Counties for Most Poultry Nitrogen Pollution Entering the Bay (pounds in 2018)

County	Nitrogen from ammonia air emissions entering the Bay	Runoff of nitrogen from manure	Total nitrogen pollution entering Bay from poultry
Lancaster, PA	955,417	2,358,676	3,314,092
Sussex, DE	446,005	1,372,170	1,818,175
Rockingham, VA	287,659	751,730	1,039,389
Lebanon, PA	212,599	536,327	748,926
Caroline, MD	211,069	455,774	666,843
Snyder, PA	177,152	446,623	623,774
Dauphin, PA	313,296	278,561	591,857
Dorchester, MD	283,788	275,791	559,579
Somerset, MD	187,562	351,516	539,079
Wicomico, MD	285,806	219,121	504,927

Numbers above reflect nitrogen load in pounds entering the Chesapeake Bay's tidal waters in 2018, based on Chesapeake Bay Program numbers. See Appendix A for methods.

The pollution hot spots are roughly the same when the counties are ranked on a per acre basis, as opposed to a total nitrogen load basis. The map below shows a breakdown per acre in Bay region counties.

County Breakdown of Nitrogen Pollution Entering Bay, 2018



This map shows the total nitrogen load from the poultry industry per acre entering the Chesapeake Bay from poultry from each county, with the darker blue colors representing higher concentrations of pollution. For additional maps showing ammonia-related nitrogen pollution from poultry, see Appendix C.

Of course, there are different types of poultry farms in the Chesapeake Bay watershed – including those that raise chickens for meat ("broilers"), egg-laying chickens, turkeys, ducks, and other birds. As mentioned earlier in this report, the industry produces more than a billion broilers in the region every year, and sells about 18 million turkeys for slaughter (mostly in Virginia's Shenandoah Valley). Farmers keep about 25 million hens at a time for the egg industry (the majority in Pennsylvania). All these varieties of birds produce different amounts of manure, ammonia and nitrogen pollution. Below is a chart showing the different amounts of nitrogen entering the Bay from each type of poultry:

Table 3: Nitrogen Pollution Entering Bay from Types of Poultry in 2018 (lbs)

Type of Poultry	Nitrogen from ammonia	Nitrogen from runoff	Total nitrogen entering Bay
Broilers	8,026,122	8,147,014	16,173,136
Layers	1,755,809	2,749,433	4,505,242
Turkeys	1,407,782	1,016,293	2,424,074
Other Poultry	443,311	486,533	929,844
Grand Total	**11,633,024**	**12,399,273**	**24,032,297**

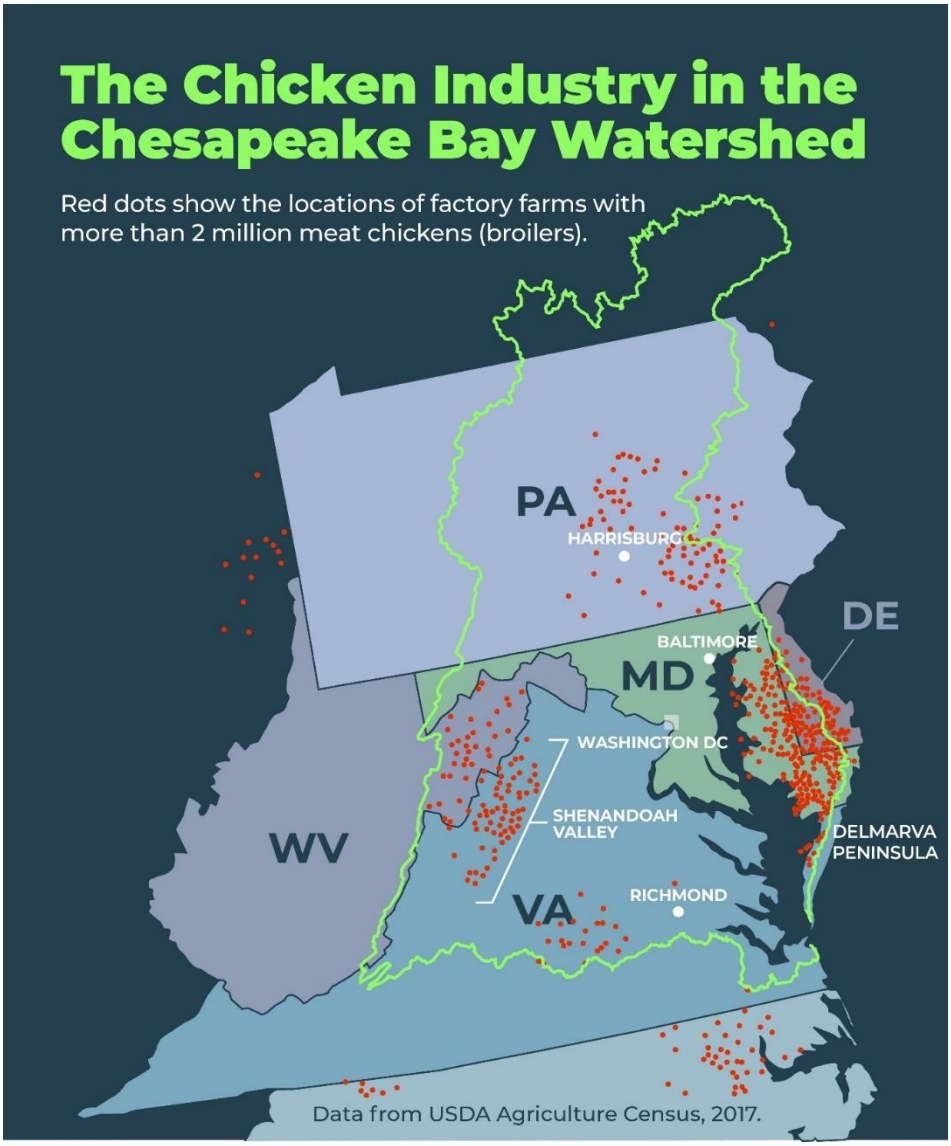
Note: Numbers only include poultry within the Chesapeake Bay watershed. "Other poultry" includes pullets, ducks, and all other forms of poultry. Based on Chesapeake Bay Program numbers. See Appendix A for methods.

Across the Chesapeake Bay watershed, about two thirds of the poultry industry's nitrogen pollution comes from broilers, which is also a rapidly growing sector in some areas, such as in south central Pennsylvania the Shenandoah Valley in Virginia.

History and Scale of the Chesapeake Broiler Industry

The modern poultry industry has its origins back in the 1920s on the Eastern Shore of Maryland. After World War I, Arthur Perdue invented the factory-style poultry production methods – with giant metal buildings packed with thousands of animals – that have now spread around the world and to other livestock industries, including the raising of hogs and turkeys.[18]

A key to the industry's growth was that the meat company – in industry parlance, the "integrator" – owns the chickens and makes most of the profits from processing and selling the birds, while requiring contract farmers to borrow large sums of money to build and maintain chicken houses according to terms dictated by the company. The contract farmers assume all the responsibility for disposing of the waste.[19] Over the decades, this factory-style farming spread to Virginia's Shenandoah Valley, central Pennsylvania, and elsewhere.



In total, farmers in the U.S. grew about nine billion broiler chickens in 2018, with Georgia, Alabama, and Arkansas now the biggest producers.[20] Maryland and Virginia rank numbers 10 and 11, and Pennsylvania ranks 14. The scale of both the poultry houses and the chickens themselves – fattened by specialized diets and antibiotics – have continued to grow larger over the last century since Perdue's innovations.

The most recent numbers from the U.S. Department of Agriculture farm census, which is conducted every five years, suggest that the overall broiler industry grew by about six percent in the Chesapeake Bay states between 2007 and 2017, with 1,012,953,727 broilers

sold in Bay watershed counties at the beginning of that decade, and 1,073,683,072 at the end.[21] (And it is worth noting that the agricultural census figures are just estimates, and the real numbers may be different).

The growth of the industry was not even across the region, however, with some areas experiencing spikes in chicken house construction and other areas declines. As an example of areas with uneven growth, Maryland as a whole experienced a four percent increase in broilers produced between 2007 and 2017. However, Dorchester County (on the southern part of the Eastern Shore) witnessed a 35 percent drop in broiler production, while Caroline County (on the mid Shore) experienced an 18 percent increase over this decade, according to the U.S.D.A. estimates. Of all the Bay region states, Pennsylvania experienced the largest growth, with a 19 percent rise in the number of broilers produced in counties that drain into the Chesapeake Bay from 2007 to 2017. York and Lebanon counties in Pennsylvania had the highest growth rates, with the number of chickens grown in York County rising 87 percent, to 4.9 million, in 2017, and Lebanon experiencing a 73 percent growth, to 27 million broilers. The overall growth in Virginia was only four percent. However, in Virginia's Shenandoah Valley, farms grew 15 percent more broilers in 2017 than in 2007, with Augusta County producing 45 percent more birds and Rockingham 38 percent more. Below is a chart illustrating the different increases:

Table 4: Broiler Chickens Raised, and Manure Produced, in Chesapeake States

State	Broilers Produced in 2007	Broilers in 2017	Change	Manure in 2007 (lbs)	Manure in 2017	Change
MD	295,911,411	306,955,125	4%	336,431,474	422,351,664	15%
DE	246,098,878	262,807,807	7%	366,846,867	433,938,433	18%
PA	137,353,085	163,582,244	19%	182,685,961	210,069,927	15%
VA	244,809,617	255,620,381	4%	280,702,674	339,990,000	21%
WV	88,772,940	84,703,496	-5%	83,473,689	75,757,729	-9%
NY	7,796	14,019	80%	9,583	18,325	91%
TOTAL	1,012,953,727	1,073,683,072	6%	1,280,150,248	1,281,476,896	16%

Note: Figures are from USDA Agricultural Census estimates on broilers (meat chickens) for counties in Chesapeake Bay watershed. Manure figures are from EPA per bird estimates, and reflect different average weights over time in different states.

As shown in the manure numbers above, the amount of waste produced by the broiler industry in each state did not change at the same rate as the number of birds grown – or at the same rate as other states. This is because, in general, the broilers have been getting heavier, and heavier chickens produce more manure (and more ammonia). However, farms differ from place to place, and so the changes in average bird weights vary.

Broiler Weight

Poultry companies over last half century have used selective breeding techniques, specialized diets, antibiotics, and dietary supplements to engineer birds that grow faster and larger and therefore have more meat.[22]

Nationally, the average market weight for a broiler chicken in 2018 was 6.26 pounds. That was an increase of 12 percent from 5.58 pounds a decade earlier, and two and a half times the average weight of a chicken (only 2.5 pounds) back in 1925.[23] In the Chesapeake Bay region, the trend has been similar, with increasingly large birds. The average weight of a broiler in bay states was 5.76 pounds in 2018 – compared to 5.28 pounds in 2009.

For this report, EIP examined broiler production data from U.S. Department of Agriculture to determine the average weight of broilers over the last decade in Delaware, Maryland, Pennsylvania, Virginia, and West Virginia.[24] No data were available for New York, so we assumed that New York broilers weighed as much as the average broiler from the other five states.

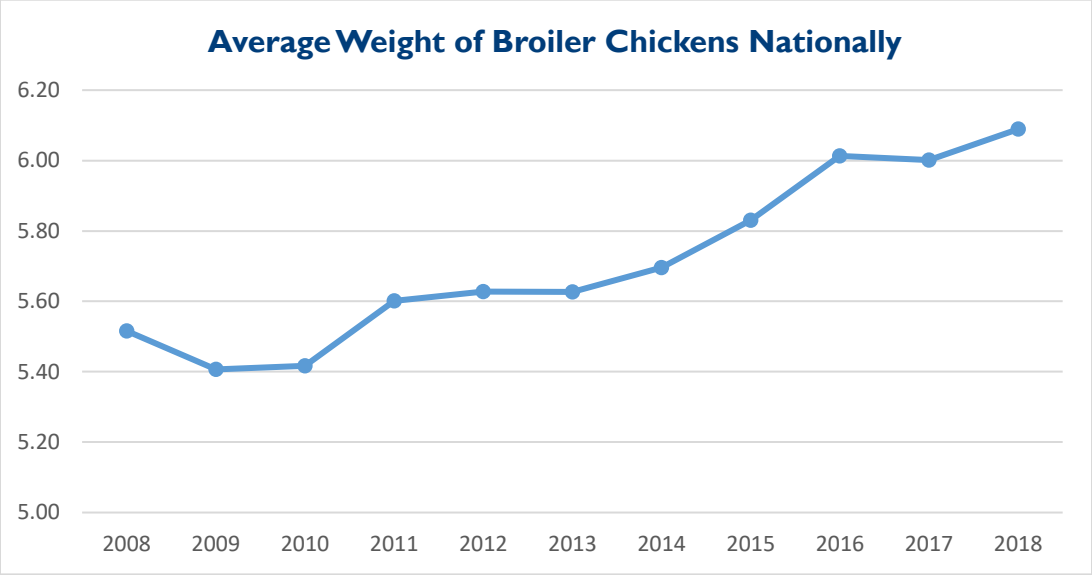


Chart above shows increasing weight of an average chicken raised for meat ("broiler" chickens) from 2008 to 2018, according to data from the U.S. Department of Agriculture.

It should be noted that broiler weight varies significantly from state to state over time. The average broiler weight in Delaware, for example, has been rapidly growing and is now roughly double the average West Virginia broiler, where the weight has been relatively constant. The table below shows average broiler weight in each Bay state from 2008 through 2018.

Table 5: Average Weight of Broilers, By State (In Pounds)

Year	Delaware	Maryland	Pennsylvania	Virginia	West Virginia	Average Bay Broiler Weight
2008	6.50	5.40	5.80	5.00	4.10	5.36
2009	6.90	4.80	5.70	5.00	4.00	5.28
2010	6.94	4.77	5.62	5.16	3.95	5.29
2011	7.00	5.30	5.60	5.30	4.00	5.44
2012	7.10	5.30	5.60	5.40	4.00	5.48
2013	7.10	5.30	5.60	5.40	4.00	5.48
2014	7.10	5.40	5.50	5.50	3.90	5.48
2015	7.20	5.70	5.60	5.60	3.80	5.58
2016	7.30	6.10	5.60	5.70	3.90	5.72
2017	7.20	6.00	5.60	5.80	3.90	5.70
2018	7.30	6.00	5.70	6.00	3.80	5.76

The above chart shows the varying weights of chickens raised for meat in the different Chesapeake region states, from 2008 to 2018, according to U.S. Department of Agriculture data. The final column shows the average weight per broiler chicken in the whole Bay watershed.

Heavier birds produce more manure. To determine manure production, EIP applied a weight-based manure production estimate that EPA used in creating its most recent computer modeling of pollution inputs into the Chesapeake Bay.[25]

We conclude that the one billion broilers grown in the region produced about 1.5 billion pounds of manure in 2017, which was a 16 percent rise over 2007, although the number of birds grown only increased by about six percent over this time period. More manure means more waste that needs to be managed, and also more ammonia rising into the atmosphere. Both can lead to more pollution in the Chesapeake Bay.

Varying Estimates of Ammonia Emissions

EPA's current estimates of how much ammonia is produced per broiler chicken are outdated and should be replaced by findings from more recent and relevant scientific studies.[26] The agency is in the process of reviewing new data, but has been undergoing this review process for more than a decade. As of 2018, the Chesapeake Bay Program – which is led in part by EPA – was still using old emissions estimates from EPA's 2011 National Emissions Inventory (NEI) in its computer modeling of pollution entering the estuary.[27] The estimates in the 2011 NEI were based on European studies of pollution from its chicken industry.[28] Specifically, EPA relied on Dutch studies from 1988 to 1998 that examined emissions in the Netherlands, England, and Germany.[29]

Using these old studies, EPA estimated that emissions from chicken houses could be expressed as 0.22 pounds of ammonia per broiler per year.[30] However, these European studies are not representative of U.S. poultry operations because European farms generally grow lighter birds, Europe is generally cooler than the U.S., and farming practices are

different on each continent. For example, European farmers tend to replace the litter in their chicken houses after each flock, while American broiler operations repeatedly reuse litter. All of these factors cause American broiler emission rates to be significantly greater than European rates.

A growing body of science, published in peer-reviewed journals over the last 16 years and reviewed by the Environmental Integrity Project, shows that North American broiler barns can produce twice as much ammonia as European barns, with a mean emissions rate of 0.43 pounds of ammonia per broiler per year.[31] For example, researchers working with EPA between 2007 and 2009 performed studies at four broiler houses in Kentucky and California that concluded that emissions from chickens were significantly higher than those in Northern Europe.[32] In 2005 and 2006, researchers examined four Arkansas chicken houses and also found higher average ammonia emissions than those EPA has been assuming,[33] as did scientists examining farms in Texas,[34] Maryland,[35] Pennsylvania,[36] and Mississippi[37] between 2003 and 2014.

New scientific research suggests that air pollution from chicken houses, like this one in York County, Pennsylvania, contribute about 1.4 million pounds more nitrogen pollution into the Chesapeake Bay every year than EPA has estimated.

Impact of Higher Rates of Ammonia Emissions

In order to account for the changes in ammonia emissions estimates and the most recent science, as well as changes in the poultry industry (including the rapidly increasing size of broilers), EIP made a series of adjustments to our calculations of the nitrogen load from poultry. These adjustments are described in detail in Appendix A. In short, we increased the nitrogen load to the Bay attributable at the state level[38] to the "dry deposition" of ammonia – that is, ammonia that deposits as a gas on water and land. We adjusted only the "dry deposition" because the Bay Program's computer modeling of "wet deposition" – meaning the ammonia falling to earth in wet precipitation – is mainly based on direct measurements of ammonia in rainfall, so it is not affected by EPA's assumptions about ammonia emissions.

Our adjusted results are presented below. The bottom line is that EIP estimates that about one million more pounds of nitrogen are entering the Chesapeake Bay each year from poultry-related ammonia than the Bay Program currently assumes. Regardless of whether one uses the raw or the adjusted ammonia estimates, ammonia emissions are responsible for

roughly half of the total nitrogen entering the Bay from both the poultry industry's air emissions and runoff pollution.

Table 6: Nitrogen Pollution from Chesapeake Region Poultry Industry in 2018 (pounds).

State	Nitrogen from ammonia emissions	Nitrogen from ammonia (adjusted)	Nitrogen from runoff of poultry manure	Total poultry-related nitrogen	Total poultry-related nitrogen (adjusted)
DE	508,015	752,114	1,483,306	1,991,322	2,235,420
MD	1,801,341	2,188,068	2,066,499	3,867,840	4,254,567
NY	77,478	81,433	59,185	136,663	140,618
PA	4,017,257	4,258,587	5,757,462	9,774,719	10,016,049
VA	1,205,677	1,414,130	2,322,844	3,528,521	3,736,974
WV	702,972	742,929	709,977	1,412,948	1,452,906
Ammonia falling directly onto the Bay[39]	1,934,121	2,195,763		1,934,121	2,195,763
Grand Total	10,246,861	**11,633,024**	12,399,273	22,646,133	**24,032,296**

Note: Results are expressed as delivered pounds of nitrogen entering the tidal waters of the Chesapeake Bay, adjusted to account for the likely underestimate in ammonia emissions in the Chesapeake Bay Program's watershed model. See Appendix A for methods.

However, the above numbers may still be lower than reality, because more ammonia may be falling back down onto the land and water than is reflected in this estimate. The evidence for this can be found in a recent study published by researchers from North Carolina State University, which suggests that ammonia deposition may be two to three times higher than previously assumed. Specifically, that study estimates that poultry production on Maryland's Eastern Shore results in the annual deposition of about 23 million pounds of ammonia just on land.[40] That could mean 3.8 million pounds of nitrogen from the ammonia entering the Bay every year, just from Maryland's Eastern Shore.[41] By contrast, the Bay Program's estimates suggest that only about 2 million pounds of nitrogen enter the Bay annually from the ammonia landing in Maryland.[42]

EPA has, in some contexts, acknowledged the evolving state of the science. For example, in 2017 EPA issued guidance for estimating and reporting ammonia emissions that recommended emissions factors of between 0.41 and 0.75 pounds of ammonia per broiler per year.[43] However, EPA has not incorporated this guidance into its official calculations for how much pollution is flowing into the Chesapeake and other waterways.

EPA's Delay in Updating Ammonia Numbers

A EPA study of ammonia emissions from poultry operations has been stalled for almost a decade.

Back in 2004, EPA announced that it would be conducting a "groundbreaking" study of air emissions from factory farms.[44] That $15 million project was to be funded by livestock industry groups—the National Pork Board, National Milk Producers Federation, United Egg Producers, and National Chicken Council—as part of a compliance agreement with EPA.[45] Farms that participated in the study would receive immunity from air pollution and hazardous waste enforcement actions by the EPA. Livestock operators contributed from $200 to $100,000 each depending on the size and number of the factory farms they wanted to receive immunity from EPA for possible violations. Using this funding, EPA's National Air Emissions Monitoring Study monitored 24 sites at animal feeding operations in nine states over two years to measure releases of ammonia, particulate matter, hydrogen sulfide, and volatile organic compounds.[46]

The project stalled in 2013 after the EPA Science Advisory Board rejected the proposed methodology for the study.[47] Since then, the effort by EPA to monitor or regulate air pollution from factory farms has slowed down, with no final emissions estimates as of 2020. EPA may produce its own official updated ammonia estimates from this research, but it has not yet. "EPA is currently analyzing the data," the agency's website said in March 2020.[48] The agency plans to release its updated draft models for ammonia, hydrogen sulfide, and particulate matter emissions from poultry farms in November 2020.[49] After that, EPA says it will conduct a "stakeholder review period" and then finalize all emission estimating methodologies at a date "to be determined."

Efforts to Require Air Monitoring and Pollution Limits

None of the Chesapeake region states or EPA require poultry houses to install monitoring or air pollution control devices, and so scientific data on the amount of pollution escaping from poultry operations is limited. One local exception to the lack of pollution control devices is in south-central Pennsylvania, where the Codorus Township Board of Supervisors passed a local health ordinance on August 6, 2015, in reaction to a proposal by an egg company, the Hillandale Corp., to build four additional huge chicken houses to hold two million birds.[50] The ordinance requires any future industrial-scale animal feeding operations to install air pollution control filters and ultraviolet lights on their exhaust fans, to catch

particulate pollution and kill pathogens. (For more on this example in Pennsylvania, see page 22).

In 2017, 2018, and 2019, Maryland lawmakers introduced a bill called the "Community Healthy Air Act" that would have required the Maryland Department of the Environment to conduct air monitoring at factory farms and assess the health risks to nearby residents.[51] The legislation was supported by public health professionals, environmentalists, many local residents, as well as the National Association for the Advancement of Colored People on Maryland's Eastern Shore. "In Wicomico County, one of the top broiler producing counties in Maryland, the rate of emergency room visits due to asthma among adults is double the rate of the state overall," wrote more than two dozen doctors and nurses in a 2019 letter of support for the bill that was signed by, among others, Assistant Professor Keeve Nachman of the Johns Hopkins Bloomberg School of Public Health.[52]

Neither the EPA nor the states require any monitoring or air pollution control equipment on animal feeding operations, even though they produce large amounts of ammonia and other pollutants.

Opposed to the air monitoring proposal were the Maryland Farm Bureau, the poultry industry, Maryland Chamber of Commerce, and some Eastern Shore lawmakers. Stephan Levitsky, a vice president at Perdue Farms, testified: "We believe this bill is not needed at this time, based on currently available air sampling and emission studies and pending information from planned ambient air sampling."[53] Levitsky was referring to an upcoming joint study known as the "Lower Eastern Shore Ambient Air Quality Monitoring Project" by the Keith Campbell Foundation for the Environment, the Maryland Department of the Environment, and the Delmarva Poultry Institute, a trade organization.[54]

In 2020, Maryland legislators debated a pair of bills that would have banned the Maryland Department of the Environment from approving any more new permits or expansions for poultry operations that produce more than 300,000 birds per year.[55] One argument for the proposed pause in new approvals was that the state still lacks adequate data on the amount of air pollution from animal feeding operations. "Emissions from these factory farms are linked with negative health consequences," said State Del. Vaughn Stewart of Montgomery County, a sponsor of the bill.[56]Another argument offered by advocates of the bill is that poultry operations in Maryland produce hundreds of millions of pounds more manure than

can be spread on local farm fields, many of which are already saturated with nutrients.[57] Strongly opposed to the ban on new permits were the Maryland Farm Bureau and the poultry industry. Holly Porter, executive director of the Delmarva Poultry Institute, a trade group, testified about the industry's impact on local business: "The bill … would devastate the Delmarva economy that is fueled by the $3.5 billion value and more than 20,000 jobs directly tied to this community."[58]

The Health Impact of Factory Farms

Beyond just ammonia, poultry houses – which often house as many as 45,000 chickens at a time – can also release microscopic particles of manure and other pollutants, which can trigger asthma attacks. The buildings also emit hydrogen sulfide (which can cause nausea, watering eyes, and coughing), as well as pathogens, endotoxins, and other potential health hazards, according to studies by scientists at Johns Hopkins School of Public Health and other universities.[59] Researchers have found that the airborne contaminants can pose a health risk to nearby residents.[60] The intense odors from large animal feeding operations can also disrupt people's quality of life.[61]

Trucks loaded with chickens rumble down once-quiet rural roads in Somerset County, Maryland, to move birds from warehouse-sized buildings to slaughterhouses.

One 2018 study by Johns Hopkins researchers that examined poultry factory farms in Pennsylvania found that people living nearby and exposed to emissions were 66 percent more likely to be diagnosed with community-acquired pneumonia.[62] A 2015 review of available medical literature found consistent associations between living near factory farms and a variety of health-related problems, including asthma attacks, lung disease, fevers, stress, and infections with methicillin-resistant Staphylococcus aureus (MRSA).[63] A 2017 study found that living near animal feeding operations was associated with higher rates of people who required asthma medications and hospitalizations.[64] And a 2018 study linked poultry operations to infectious diahhrea and campylobacteriosis in people who live nearby.[65]

Beyond medical impacts to nearby residents, air pollution and water contamination from industrial-scale poultry operations can also degrade property values of nearby homeowners, increase truck traffic on once-quiet rural roads, and cause harm in other ways.

To illustrate these health and quality of life problems, EIP profiled three residents living near animal feeding operations in Pennsylvania, Maryland, and Virginia.

LOCAL PROFILE: MARYLAND

When a City of Industry Sprouts in the Field Next Door

This aerial photo shows Sam Berley's home at bottom right and the six new poultry houses built in 2015 by an adjacent property owner.

Princess Anne, Md. – A quarter century ago, Sam Berley and his wife Patricia bought a white clapboard house with a porch on 10 acres of land on Maryland's Eastern Shore, surrounded by nothing but fields and forests. They had two kids, a boy and a girl. And for years, they enjoyed the rural serenity, with Sam working as a special education teacher in the Somerset County public schools.

Then, in 2015, everything changed. The family farmer next door sold the property to a real estate investor. In place of the corn fields a Frisbee throw away from the Berleys' porch, the new owner built six chicken houses holding a total of 270,000 birds.

Now, instead of looking out on a field of golden grain, every morning Berley gazes from his porch over a waste pond to windowless metal buildings, grain silos, gravel roads, trucks heaped with chicken cages, and heavy equipment.

The landlord – who lives and works elsewhere as a real estate agent – is rarely around, Berley said. But the roaring of the exhaust fans is incessant, day and night, as they blow dust and pollutants onto Berley's property and into his lungs.

"The ammonia smell from urine and feces is so strong, and so offensive, it's hard to breathe sometimes," said Berley, who suffers from asthma. "There are other chicken houses down the road that are even closer than these. When I drive by, half the time I have to hold my breath until I've passed. The odor is just overwhelming."

Air monitoring at Sam Berley's home found levels of ammonia from the adjacent chicken houses much greater than background levels. "It's hard to breathe sometimes," said Berley, who suffers from asthma.

Air monitoring by the Environmental Integrity Project near Berley's home from September 2016 through August 2017 found ammonia levels that averaged more than 20 times higher than background levels measured at Blackwater National Wildlife Refuge.

In addition, soon after the poultry houses opened next door, Berley's drinking well water became contaminated, requiring the family to use bottled water for drinking and cooking. As result of all the odors, contamination, truck traffic, and other problems, Berley estimates that his home has dropped in value by perhaps 70 percent, from $100,000 to perhaps $30,000, making the property difficult to sell.

"So you've got environmental costs, with the air and water being polluted. But you also have the economic costs, such as the falling property values," Berley said.

Table 7: Hot Spots for Broiler Industry Growth in Maryland

Location	Chickens Produced in 2007	Chickens in 2017	Change	Manure in 2007 (lbs)	Manure in 2017	Change
Caroline County	50,524,965	59,634,292	18%	62,585,811	82,053,175	32%
Worcester County	57,937,906	63,739,795	10%	71,745,365	87,702,098	22%
Wicomico County	53,098,623	57,869,664	9%	65,752,810	79,625,153	21%
Somerset County	58,143,551	62,226,553	7%	72,000,019	85,619,969	19%

The above chart shows Maryland counties with the highest percentage growth in chickens raised for the meat industry from 2007 to 2017, according to U.S. Department of Agriculture data. Manure is in pounds.

When Berley moved in 25 years ago, there were eight chicken houses on his street, including a small one on the family farm next door. Now there are more than 40. The new houses are also much larger – each holding about 45,000 chickens, instead of about 30,000.

According to estimates from the U.S. Department of Agriculture's census of farms, the number of chickens sold for meat in Somerset County rose from 58 million in 2007 to 62 million in 2017, a seven percent increase. But because the broilers keep getting heavier, the amount of waste that Somerset's broilers produced rose from 72 million pounds in 2007 to 86 million pounds in 2017.

"Somerset County is the poorest county in the state of Maryland," Berley said. "And these huge operations and the companies that oversee them target the poorer counties because it's easier to move more chicken houses in. There's less opposition, because they say, 'Hey, think of the tax dollars that are going to go into your county.' Tax dollars are well and good, but the other costs – the environmental and social costs – are just too high."

For more than a year, Berley worked with another local resident, Lisa Inzerillo, to try to convince the county to approve better public health protections for people who live next to CAFOs. Together, they advocated for a requirement that new chicken houses install air pollution control filters on their fans. That effort failed, as did their suggestion for a temporary moratorium on approvals for large new CAFOs. However, the county did approve a slighter larger setback requirement (50 additional feet) between future chicken houses and nearby homes.

Sam Berley, a special education teacher, loves his home and his vintage 1948 Chevy. But he estimates that his property overall has dropped about 70 percent in value because of the poultry houses built next door.

"The poultry industry just went nuts because they did not want any air pollution control filters," Inzerillo recalled. "It's like the poultry industry bought the whole Eastern Shore and they feel like they can do whatever they want with it."

LOCAL PROFILE: PENNSYLVANIA

Fighting Factory Farms with a Public Health Law

Spring Grove, Pa. – For years, Brian Kaltreider, a construction contractor, worked on a pet project for his family. He moved and rebuilt an 1864 log house so that it offered all the modern conveniences in the scenic wooded hills of York County.

With his own hands, he laid 150 tons of stone for the foundation. He carved wooden pegs to secure the rough-cut beams. He crafted a covered porch, where he and his wife and kids could relax in rocking chairs.

"This cabin has been my only real dream in life," said the 50-year-old builder, as he played with his beagle, Yuengling, beside a pile of firewood beneath his porch.

Then, a few years ago, the dream turned into a nightmare. An industrial chicken operation with 1.3 million birds started dumping tons of manure into the fields behind the cabin.

"The flies would be all over you, all the time, even when you went to the bathroom," Kaltreider said. "We had a neighbor across the street with two young kids who just moved out, that's how bad the flies were. They just couldn't take it anymore."

Instead of surrendering his home because of pollution from a factory farm, Brian Kaltreider fought back and passed a local public health law that has discouraged future construction of CAFOs in his township.

Kaltreider and his family nearly moved out, too, when they heard that the owner of the egg facility – the Hillandale Gettysburg LP corporation – was proposing to build four additional industrial-scale buildings and add two million more chickens.

The expansion was part of a trend. The number of chickens in York County has grown by 87 percent over the last decade, rising from 2.6 million broilers a year in 2007 to 4.9 million annually in 2017, according to estimates from the U.S. Department of Agriculture. That near doubling was among the highest rates for any county in the Chesapeake Bay watershed, and it meant that the amount of chicken manure spread in local farm fields nearly doubled to 6.3 million pounds a year.

Table 8: Hot Spots for Broiler Industry Growth in Pennsylvania

Location	Chickens Produced in 2007	Chickens in 2017	Change	Manure in 2007	Manure in 2017	Change
York County	2,633,566	4,924,806	87%	3,502,765	6,324,364	81%
Lebanon County	15,626,022	26,962,357	73%	20,783,333	34,624,665	67%
Snyder County	13,283,321	17,712,428	33%	17,667,432	23,217,639	31%
Union County	7,719,646	10,415,342	35%	13,267,487	13,375,230	30%

This table shows the PA counties with highest percentage growth in chickens raised for the meat industry from 2007 to 2017, according to U.S. Department of Agriculture estimates.

At the time, Kaltreider was serving as a supervisor on the Codorus Township Board. But he resigned his position so he could work as an advocate against the massive Hillandale project. Over a period of several months, Kaltreider rallied his neighbors and formed a group called Friends of York County Family Farms. They fought the expansion of the poultry operaration, including by sampling local streams to document the harm the manure was causing to local water quality.

"It was amazing. We had some of the biggest turnouts at the township level, ever, for the meetings on the project," Kaltreider said. "We even had to hold one meeting outside, with people standing outside in the rain, because there were so many people interested."

Table 9: Hot Spots for Egg Industry Growth in Pennsylvania

Location	Layer Inventory in 2007	Layer Inventory in 2017	Manure in 2007	Manure in 2017	Change in Manure Generation
Northumberland County	131,286	847,956	33,924,177	219,111,024	546%
Lancaster County	7,086,263	13,914,918	1,831,083,627	3,595,601,592	96%
Snyder County	300,957	569,521	77,767,003	147,163,685	89%
Franklin County	1,173,886	1,728,944	303,331,027	446,757,487	47%

This chart shows the PA counties with the most growth in chickens raised for the egg industry ("layer" chickens) from 2007 to 2017, according to U.S. Department of Agriculture estimates.

Among the local residents Kaltreider recruited to help was Maria Payan, a consultant with a nonprofit organization called the Socially Responsible Agriculture Project. She also lived beside a broiler chicken factory farm in York County and had been fighting to protect her family's health.

Payan said she was acutely aware of the large volumes of ammonia that poured out of chicken houses. Four huge poultry barns, holding a total of about 100,000 birds, opened up across the street from her home.

"My son would get off the bus and just throw up because it was just that odorous outside at times," said Payan. "I was running him to the doctor's office for tightness of the chest,

rashes all the time. I mean, it was not normal. I called 911 one time at night, because we were actually dizzy in our own house because of all the ammonia."

She and Brian Kaltreider and his neighbors were helped in their battle against the factory farms by attorneys at Food & Water Watch, a national, nonprofit advocacy group. In the end, Kaltreider's coalition won their fight against the Hillandale egg farm expansion project.

On August 6, 2015, the Codorus Township Board of Supervisors voted to deny a set of plans for the Hillandale project. The board also approved a local health ordinance that requires any future poultry houses to install air pollution control filters and ultraviolet lights on their exhaust fans to catch particulate pollution and kill pathogens. The law prohibits any new large animal feeding operations that would be within two miles of any other existing factory farms and requires $10,000 permitting fees for large new facilities.

Brian Kaltreider points to the Hillandale Farm egg production facility in York County that had been proposing to expand with four more buildings and two million more chickens.

Scott Edwards, Director of the Food and Water Justice Program at Food & Water Watch, said that the Codorus Township health ordinance had the effect of not only stopping the Hillandale project (at least temporarily) but also discouraging any new CAFO applications from coming to the township.

"The density requirement essentially stopped the expansion of the CAFO industry in the township," said Edwards. "I think ordinances like this one would absolutely be helpful across the Chesapeake Bay watershed and elsewhere. It's an absurdity of the industry that state environmental agencies don't even know what pollutants are coming out of these facilities, let alone require any pollution controls for them."

LOCAL PROFILE: VIRGINIA

Fleeing from the March of Industrial Agriculture

Pungoteague, Va. – At night behind Carlene Zach's farm house, when the spotlight on her dog run blazes into the darkness, it looks like it's snowing, with a cloud of fluffy particles drifting down onto the grass.

Carlene Zach and her husband Peter are trying to sell their 1901 farm house on Virginia's Eastern Shore to escape the ammonia air pollution from a poultry farm next door. But nobody wants to buy the house.

This blizzard falls even in July. The particles are not snow flakes, but feathers and specks of manure. They've been blown into her back yard from an industrial-scale poultry operation that opened next door about two years ago. The 24 chicken houses hold a total of a million birds. Their industrial exhaust fans roar 24 hours a day, creating a foul wind of dust and bacteria.

"In the summertime, when the winds come this way, you can't even be outside," Carlene Zach said, standing in front of her farmhouse, with its wrap-around porch, robin's egg blue shutters, and doormat proclaiming "home sweet home." "You can't even play in the yard."

Before the poultry farm opened two years ago here in Accomack County, Carlene Zach, a 60-year-old retired postmaster, and her husband Peter Zach, 62, a lineman for an electric company, were in good health. But then the ammonia and fecal dust from the chicken houses started drifting through their windows, and the cloying odor triggered incessant coughing, sneezing, and sore throats.

Exhaust fans on 600-foot-long chicken houses blow feathers, dust and particles of manure into Carlene Zach's yard.

"You constantly suffer from upper respiratory infections," she said. "You suffer through the headaches, the stuffy nose, the days when you don't even want to go out and enjoy your property. We've lost the use of the property that we pay taxes on. We can't even sit on the back deck for a barbecue because of the smell. It's obnoxious, and you can never get away from it."

Peter Zach's chronic headaches from sinus infections – which he had never suffered from before – drove him to undergo surgery to open up his inflamed nasal passages. That surgery helped him only temporarily, before the infections returned.

The couple decided they had no choice but to move to escape from the air pollution. Unfortunately, no one wanted to buy a house with giant sheds holding a million animals only 600 feet away. The Zachs dropped their price $50,000, but still found no buyers.

"It's a beautiful house, but we just have to get out of here for health reasons – even if that means just leaving the house empty, unfortunately," said Carlene Zach. "You got to do what you got to do to survive. We are moving to Tennessee, to a farm we found in the mountains."

A Texas-based company bought the land next to the Zach family and built 24 poultry houses that can hold a million birds at a time.

Although family-owned poultry farms have been a part of the fabric of Accomack County for decades, the scale and number of the factory farms have exploded in recent years. In 2014, the county had 254 chicken houses on 51 farms.[66] But then that number was projected to nearly doubled, with 480 houses on 83 farms by 2020, and at least 19 more permitted but not yet built, according to a report by the Accomack County Planning and Zoning Department.[67] While the old generation of houses were 200 feet long, the new facilities are sometimes three times that size.

Carlene Zach loves her four horses and selected her home so she could ride. But she can't even be outside anymore when the wind blows the wrong way, because of all the ammonia from the poultry industry.

The chickens are trucked a few miles down the road to Tyson and Perdue slaughterhouses in Accomack County, which employ 3,040 people. "The local economy benefits from the poultry industry with employment and payroll in the following areas: poultry growers and farm workers, truck drivers, grain elevators, and grain farmers," according to an Accomack County Planning Department report in 2019.

But the industry also has downsides, with increased water and air pollution, truck traffic, and burdensome loans for contract farmers who must follow strict industry dictates to raise the chickens.

Carlene and Peter Zach's decision to move marks a sad end to the couple's love affair with Virginia's Eastern Shore.

Carlene had moved from Florida and purchased the 1901-era home on Pungoteague Road two decades ago. She worked as the postmaster in the nearby town of Melfa (population: 408) and loved riding horses on the weekends. She selected her home because of its 4.75 acres of land for her horses and barn.

It was riding that she met her future husband, Peter. They soon married and moved in together into her farm house, which they remodeled together, adding an elegant library. With their four horses and five dogs, the couple savored the outdoors, galloping through the nearby meadows fringed by loblolly pine trees.

Then, a little more than two years ago, Carlene heard a rumor from a neighbor. The corn and soybean farmer next door had sold his land to a Texas-based corporation that planned to build 24 large chicken houses on contract for Tyson foods.

Carlene Zach remembers riding her horses in a field now dominated by 24 windowless industrial buildings that are raising broiler chickens on contract for Tyson Foods.

Carlene gathered the signatures of 35 neighbors on a petition opposing the project, and together they marched into a meeting of the Accomack County Board of Supervisors. They announced their strong objections. "We were told, 'It's a done deal. There's nothing we can do,'" Carlene recalled.

As soon as the poultry houses opened about two years ago, the waves of air pollution were unbearable. In addition to clouds of feathers, dust, and ammonia, the facility produces tons of manure, which is spread on nearby fields and runs off to contaminate a stream beside the Zachs' home and eventually the Chesapeake Bay.

"It's creating havoc," Carlene Zach said of the expanding poultry industry. "The county board wasn't really ready for the situation. They didn't understand that outside investors are coming in, and that Tyson is one of the largest meat producers in the world. They are now putting in more and more of these industrial facilities and they've got way more manure now than you've got land to spread it on. So it just runs off everywhere, and the ammonia is just too much for us to bear."

Down the road from her house, she climbed atop a sandy hill overlooking what used to be a wind-swept field surrounded by pine forests. She recalled riding on her horse through the field on a beautiful day, a few years ago.

Then she lifted her hand to cover her mouth. A wave of nauseating gas floated up the hill from the 24 windowless buildings with exhaust fans.

"This used to be the most beautiful place on Earth to live," she said. "I mean, the Eastern Shore out here is one of the few places left that isn't developed. And to sacrifice all this beauty for *this type* of industry – it's like a rape of this beautiful land."

Conclusion

The poultry industry in the Chesapeake Bay watershed is growing – especially in the hotspots of south central Pennsylania, the Shenandoah Valley, and parts of the Eastern Shore – and the poultry waste problem is expanding even faster. Because meat companies are engineering birds to become ever heavier, broilers in this region produced 16 percent more manure in 2017 than in 2007. This means more ammonia and more runoff. In total, 5.7 billion pounds of poultry waste is spread on farm fields every year contributing to runoff pollution and low-oxygen "dead zones" in the nation's largest estuary.

The Bay region states are only just beginning to get a handle on the problem of the over-application of manure to soil that is already saturated with nutrients. It's an issue that sparked heated debate in the spring of 2020 over Maryland legislation, for example, that would have temporarily banned permits for any new large poultry houses.

But beyond this, EPA and the Bay states continue to struggle with even accurately quantifying the ammonia air emissions problem. Federal and state regulators remain far from implementing a strategy for controlling and reducing this source of pollution. The Environmental Integrity Project's analysis of the most recent science suggests that EPA has been underestimating the amount of nitrogen entering the Bay from broiler air pollution by at least a million pounds annually. Overall, the runoff and ammonia pollution from poultry operations are sending about 24 million pounds of nitrogen into the Chesapeake Bay each year. To put that number into context, 24 million pounds of nitrogen is more than the pollution from all the urban stormwater runoff in Maryland and Virginia combined (which was 20 million pounds in 2018).[68] Or to put it another way, the 24 million pounds is twice as much nitrogen as is released every year from all the sewage and wastewater plants in Maryland.

This report recommends the following policy steps to address the problem:

1) EPA should update the ammonia emission estimates it uses to simulate nitrogen loads to the Bay to reflect the most recent available science.

2) All large new animal feeding operations should be required to install air pollution monitors and report their emissions on an annual basis to state environmental agencies and the EPA.
3) EPA should establish safety thresholds for ammonia that apply to the fenceline areas between poultry operations and neighboring residents, to help protect local communities from excessive levels of ammonia.
4) States and the EPA should require poultry houses to install effective air pollution control systems, including filters to capture particulate matter being blown by poultry house exhaust fans out into the community.
5) Poultry companies should pay for the planting of more trees and forested areas around chicken houses, to protect neighbors and to help catch and reduce ammonia emissions.
6) Because the Chesapeake Bay region states are already struggling with the overproduction of manure, lawmakers should impose limits on the approval of new permits for large animal feeding operations, especially in areas that produce more manure than crops can use.

Although strategies for reducing pollution from the poultry industry have been hotly debated in the Chesapeake region for years, an increased sense of urgency is needed with a major Chesapeake Bay cleanup deadline approaching in 2025. The time for action is now: First, through more monitoring and better estimates of pollution; and then, through tighter controls, enforceable limits, and pragmatic steps toward healthier communities and a restored Bay.

Appendix A: Methodology

1. County-level nitrogen load estimates

Our primary focus was on pollution loads in 2018, the most recent year for which complete modeling results could be obtained. We evaluated data from four sources:

- The Chesapeake Bay Program's Chesapeake Assessment Scenario Tool (CAST)[69] provides detailed information for 2018 simulations, and simulations for earlier years, using the Bay Program's new "Phase 6" watershed model. This modeling tool provides various inputs (e.g., land application of nitrogen and phosphorus in manure, atmospheric deposition of nitrogen, point source wastewater pollution loads, etc.) and outputs (e.g., pounds of nitrogen delivered to the Chesapeake Bay). The CAST website appears limited to pollution coming from land and non-tidal waterways, and does not provide estimates of nitrogen deposition directly to the surface of tidal waters in the Bay watershed.
- The Bay Program's Chesapeake Progress website[70] provides separate estimates of total nitrogen (and phosphorus and sediment loads). This website does include estimates of nitrogen deposition to tidal waters.
- The Bay Program's modeling makes use of ammonia emissions estimates from the EPA National Emissions Inventory (NEI), so we also use these estimates to characterize the extent to which ammonia emissions come from various forms of livestock at the county level. For example, the 2011 NEI assumes that 41 percent of the ammonia emissions in Lancaster County, PA came from poultry in 2011. We therefore assumed that 41 percent of ammonia deposition in Lancaster County could be attributed to poultry. We have been critical of the NEI in the past, and remain critical – the NEI is often unreliable, omitting large sources of emissions[71] and using emissions factors that conflict with the best available science.[72] Nevertheless, the NEI estimates are baked into the Bay Program modeling, so we turned to these estimates where necessary to interpret and analyze Bay Program modeling results. However, we also adjusted our results at the state level to account for improvements in ammonia emissions estimates since 2011. Our adjusted results are presented in Table 1 of this report, and our methods for making the adjustments are explained in section 2 below.
- Finally, we found that we needed expert assistance in extracting, interpreting and analyzing data from the Bay program's CAST website, so we commissioned a report and database from KCI Technologies, Inc. (Attachment A).

To estimate how much ammonia air pollution from the broiler industry is entering the Chesapeake Bay, KCI and EIP looked at "delivered load" to the Bay (meaning the amount of pollution actually entering the estuary), described in the Bay Program model as the "edge of tide" load (meaning the amount entering the Bay's tidal waters.) The delivered load is less than the amount of nitrogen deposited on land, and it accounts for things like nutrient uptake by crops and other plants and nutrient dynamics in streams and rivers.

In order to calculate the delivered load associated with poultry, we started with the delivered load for each county. KCI Technologies helped us extract, for each county, the following components of delivered load:

- Direct load for pullets, turkeys, broilers, and layers. These are mostly made up of the land application of poultry manure (70 percent of total), but also include loads from pasture (12 percent of total) and from feeding spaces (18 percent of total).[73]
- Atmospheric deposition. This component of load is largely invisible in most summaries of Chesapeake Bay nitrogen loads, because the nitrogen load is assigned to the land use in place where the ammonia deposits. Ammonia depositing on forested land, for example, is typically reported as "natural" or forest load.

In order to estimate how much of the atmospheric deposition came from poultry-related ammonia, we had to make four simplifying assumptions.

- First, we assume that ammonia's contribution to delivered nitrogen load is proportional to its share of deposition. For example, the Bay Program estimates that 59 percent of the atmospheric nitrogen deposition in Sussex County is in the form of ammonia. We made the assumption that 59 percent of the delivered nitrogen load that the Bay Program assigns to atmospheric deposition originated as ammonia deposition.
- Second, we assume that all of the ammonia depositing in a county was emitted in that county for purposes of attributing ammonia deposition to various sources of emissions. This is a simplifying assumption, but it is not unreasonable for two reasons. First, most emitted ammonia deposits close to the source. For example, a recent North Carolina State University study of Maryland's Eastern Shore estimated that 40 percent of ammonia emissions deposit within 2.5 km of the source.[74] Second, counties tend to be similar to neighboring counties. For example, poultry is the source of 84 percent of the ammonia emissions in Sussex County, Delaware, and 92 percent of the ammonia emissions in neighboring Wicomico County, Maryland. Assuming that 84 percent of the ammonia depositing in Sussex County comes from poultry makes sense, even if some of the ammonia originated in neighboring counties, because the poultry contribution to ammonia emissions in those counties is similar.
- Third, we assume that poultry's contribution to deposition in a given county is proportional to its contribution to ammonia emissions from that county in the 2011 NEI:

  $$EOT\ poultry\ ammonia\ load =$$

  $$EOT\ AtmDepN * \frac{Ammonia\ Deposition}{Total\ Deposition} * \frac{Poultry\ Ammonia\ Emissions}{Total\ Ammonia\ Emissions}$$

  Where "EOT AtmDepN" is the delivered nitrogen load attributable to atmospheric deposition.

For example, consider Somerset County, Maryland. The 2018 delivered nitrogen load from atmospheric deposition in Somerset County was 353,015 pounds. According to CAST, 55 percent of nitrogen deposition in Somerset County is in the form of ammonia. According to the 2011 NEI, 96 percent of Somerset County ammonia emissions come from poultry. We therefore assume that delivered nitrogen load coming from poultry-related ammonia emissions amount to [353,015 pounds * 0.55 * 0.96], or 187,562 pounds.

Finally, in order to account for ammonia that deposits outside of county boundaries (i.e., directly onto tidal water), we assumed that the fraction of atmospheric nitrogen deposition to tidal water coming from poultry was equal to the share of atmospheric nitrogen deposition to land and non-tidal water coming from poultry.[75]

Poultry numbers were taken from the 2007, 2012, and 2017 USDA census, where number of broilers produced were specified for each state and county. USDA census data can be found at online at this address. The Census of Agriculture is taken only once every five years.

2. State-level adjustments

For 2018 model runs, the dry deposition of ammonia was simulated using 2011 National Emissions Inventory estimates of ammonia emissions.[76] Recognizing that these emissions estimates are outdated, we attempted to adjust our estimates of delivered nitrogen load to account for changes in the industry and in emissions factors since the 2011 NEI.

We began by reviewing the draft 2017 NEI to see whether we could calculate simple ratios of emissions in 2017 to emissions in 2011. However, there are a number of problems with the 2017 NEI. First, the only three poultry categories in the livestock data file are broiler confinements, turkey confinements, and layer confinements with dry manure management systems. There are no ammonia emissions estimates for manure storage or land application for any poultry category, and no estimates for layer confinements with wet manure management. These gaps make it impossible to construct an "apples to apples" comparison of ammonia emissions from poultry for the two years. Second, there are some estimates in the 2017 NEI that seem highly unlikely. For example, ammonia emissions from layer confinements with dry manure systems in Pennsylvania declined by 50 percent between the 2011 and 2017 NEIs. Yet according to the USDA census of agriculture, the layer population in Pennsylvania increased by 46 percent between 2007 and 2017. It seems virtually impossible that ammonia emissions from layer confinements actually declined by 50 percent. Given the data gaps and likely errors in the 2017 NEI, we chose to ignore it.

Instead, we made state-level adjustments for three factors that have changed since 2011 – industry growth, new science on ammonia emissions factors for layers and turkeys, and the effect of increasing broiler weight on ammonia emissions from broilers.

a. Industry growth

First, we attempted to account for the fact that some parts of the industry in some states have grown substantially. For example, between 2007 and 2017, the number of layers in Pennsylvania increased by 46 percent.

b. Emissions factors for layers and turkeys

Second, we attempted to account for the fact that the emissions factors for layer and turkey confinements may also be outdated and incorrect.

For layer confinements, the 2011 NEI used two different emissions factors, one for "dry manure operations," and one for "wet manure operations." These equate to 1.1 and 0.3 grams of ammonia per bird, per day, respectively.[77] More recently, a 2015 paper assembled nine studies of layer emissions.[78] These studies show a distinct difference between the emissions rates from two types of layer operations – "high-rise/deep pit" facilities and manure belt facilities. The deep pit facilities, where manure is only cleaned out once or twice each year, have ammonia emissions on the order of 200 to 300 grams of ammonia per animal unit (500 kg of weight) per day. Manure belt systems, on the other hand, have much more regular manure removal, and therefore much lower ammonia emissions, on the order of 15 to 30 grams per animal unit per day.

Since farm census data only report layers, without reference to manure management type, we had to derive a single composite emissions factor. We began by converting the above-cited estimates to units of grams per bird per day by assuming an average layer weight of 1.55 kg, and then averaging the emissions factors for each manure management type. We then used a 2016 Chesapeake Bay Program inventory to sort the layer industry into different manure management types. Specifically, we assumed that 61 percent of layer operations in the Bay watershed use deep pit systems, and 5 percent use manure belt systems.[79] For the remaining 34 percent (which use other types of manure management), we assumed, in the absence of better information, an average of the emissions rates for the first two categories. Our composite ammonia emissions factor for Chesapeake Bay watershed layer confinements is 0.75 grams of ammonia per bird per day.

For turkeys, The 2011 NEI used emission factor of 1.24 grams of ammonia per bird per day.[80] We reviewed two studies of ammonia emissions from turkey confinements in Minnesota and Iowa published in 2008 and 2011,[81] and derived a composite emissions factor from these studies which ended up being very close to, but slightly higher than, the NEI estimate: 1.31 grams per bird per day.

Folding these first two adjustments together, we calculated the emissions of ammonia from layer and turkey confinements using inventory statistics from the USDA census of agriculture for 2017 and our literature-based emissions factors.

c. Broiler weight and ammonia emissions

Third, we attempted to account for the fact that the broiler industry is growing bigger birds. Between 2007 and 2017, the number of broilers in the Chesapeake Bay states' inventory has only grown by 2 percent. However, the *production* of broilers – in terms of the total weight of broiler meat producted – has increased much more, because the average bird weight

continues to increase. Between 2007 and 2017, the total pounds of broilers produced and sold has increased by 18 percent. Larger birds generate more manure, litter, and ammonia. The only way to account for the growth in the industry when estimating ammonia emissions is to use an emissions factor based on pounds produced, rather than inventory. For each state, we calculated ammonia emissions by multiplying the broiler production in 2017 (in pounds of broilers produced) by an emissions factor that we derived in 2018: 14.2 grams of ammonia per kilogram of broiler (market weight).[82] We then calculated the ratio of ammonia emissions in 2017 (based on production) to ammonia emissions in the 2011 NEI. The following table provides the state-level results.

Adjusted Estimates of Ammonia Emissions from Broiler Confinements (kg)

	2011 NEI	2017 production-based estimate	Ratio of 2017 estimate to 2011 NEI
DE	5,102,400	12,048,571	2.36
MD	6,509,282	11,852,764	1.82
NY	46,774	n.a.[83]	1.01[84]
PA	2,739,180	6,679,981	2.44
VA	4,352,475	10,362,956	2.38
WV	1,278,301	2,162,894	1.69

In order to estimate changes in the emissions of ammonia from broiler litter in storage or on crop fields, we calculated the ratio of 2017 broiler production (in pounds) to 2007 broiler production.

Given the small populations and numerous gaps in the farm census for other forms of poultry such as ducks and geese, we chose not to adjust the NEI emissions estimates for these birds. For all other sources of ammonia, including layer and turkey litter in storage or land-applied, we calculated the ratio of the 2017 inventory to the 2007 inventory. The following table summarizes the adjustments we made to each poultry source category.

Poultry ammonia emission source	Adjustment
Broiler confinements (excluding New York)	Ratio of 2017 production-based emissions estimate to 2011 NEI estimate
Broiler ammonia from storage and land application (excluding New York)	Ratio of 2017 production (pounds) to 2007 production (pounds)
Turkey and layer confinements	Ratio of 2017 inventory-based emissions estimate to 2011 NEI estimate
All other categories, including New York broiler ammonia	Ratio of 2017 census inventory to 2011 census inventory

In each case, we used the final adjustment ratio to adjust the portion of delivered nitrogen load attributable to dry deposition of ammonia from each type of poultry in each state. For example, the total delivered nitrogen load from Maryland in 2018 was 52.8 million pounds. Of that total, 5.3 million pounds came from the atmospheric deposition of ammonia, and 2.8 million pounds came specifically from *dry* deposition of ammonia. Since 34 percent of

the ammonia emissions in Maryland come from poultry, we assumed that 34 percent of the nitrogen load attributed to dry ammonia deposition – 937,000 pounds – came from poultry operations. This 937,000 pound total is the value that we adjusted. In order to calculate an overall adjustment ratio, we adjusted each poultry category as follows:

Adjusting Nitrogen Load from Dry Ammonia Deposition, Maryland Example

Category	2011 NEI (ammonia kg)	2017 estimate method	2017 estimate (ammonia kg)	Ratio
Broiler confinements	6,509,282	2017 production (kg) * 14.2 grams of ammonia per kg of broiler weight	11,852,764	1.82
Broiler litter storage and land application	6,502,773	2011 estimate * (2017 production/ 2007 production)	7,517,057	1.16
Layer confinements	1,033,622	2017 inventory * 0.75 grams of ammonia/bird-d	817,196	0.79
Layer manure storage and land application	77,436	2011 estimate * (2017 inventory/ 2007 inventory)	86,428	1.12
Turkey confinements	101,005	2017 inventory * 1.31 grams of ammonia/bird-d	26,238	0.26
Turkey manure storage and land application	109,033	2011 estimate * (2017 inventory/ 2007 inventory)	26,803	0.25
Other poultry	89,861	No change	89,861	1.00
Total	14,423,012		20,416,347	**1.42**

The overall ratio of 2017 ammonia emissions to 2011 ammonia emissions is 1.42, so we multiplied the 937,000 pounds of delivered nitrogen attributable to dry deposition of poultry ammonia by 1.42, yielding a new total of roughly 1.3 million pounds.

There are at least two critical areas of uncertainty associated with our adjustments that cut in opposite directions. On one hand, we may be underestimating 2017 ammonia emissions by relying on the 2017 farm census. Many counties do not report inventory data to protect confidential information, so the census totals are often incomplete. We followed the 2011 NEI approach and tried to rely on state-level census data where possible, but this only partially fills the gaps. Delaware, for example, only reports county-level data, and not for all counties.

On the other hand, where we assume greater ammonia emissions from confinement barns, one could argue that 'downstream' emissions from storage and land application should be lower, because more of the nitrogen in the litter has volatilized in the barns. We were not able to account for this possibility with the information at our disposal, and as a result we may have overestimated total ammonia emissions to a certain degree.

3. Poultry statistics and manure production estimates

Broiler chicken production data for 2008-2018, measured by head and pounds, were taken from USDA survey datasets, which are conducted annually.[85] No survey data were available for New York; for manure production purposes, we assumed that New York broilers weighed the same as the average broiler from the other five states. For purposes of adjusting delivered nitrogen load from New York, we used broiler inventory data in place of broiler production data.

Manure generation was estimated using manure production factors from the Chesapeake Bay Program's Agriculture Workgroup.[86] The following table outlines the factors and formulas used:

Bird Type	Manure Production Factor/Formula	Measurement Unit
Broiler Chicken	0.312971 X (Average Bird Market Weight) + 0.732730	Lbs of Litter per Bird Produced
Layer Chicken	69.35	Lbs of Manure per Bird in Inventory
Pullet Chicken	49.91	Lbs of Manure per Bird Produced
Turkey	58	Lbs of Manure per Bird Produced

Appendix B:

Discussion of Recent North Carolina State University Research on Ammonia Emissions on Maryland's Eastern Shore

A recent study from North Carolina State University estimated ammonia emissions from poultry on Maryland's Eastern Shore and subsequent ammonia deposition.[87] The study differed from Chesapeake Bay Program modeling and from our analysis in several ways. First, as already noted, the study was limited in its geographic scope to poultry operations on Maryland's Eastern Shore. Second, the study included both broiler and layer operations, while our analyses focused on either all poultry or just broilers.

The study's assumptions about ammonia emissions were in line with EPA assumptions, but both the authors of the study and EPA are likely underestimating emissions from broiler confinement barns. This requires some explanation: Baker et al. estimate ammonia emissions from confinements, storage, and the land application of poultry litter using an emissions factor of 0.55 g NH_3 per bird per day. This is for both broilers and layers, though the authors note that 90 percent of the emissions from poultry in the region come from broilers. The emissions factor used by Baker at al. is very close to the emissions factors used by EPA's National Emissions Inventory (NEI). For example, the 2011 NEI assumed that ammonia emissions from broilers – including emissions from confinements, storage, and land application – were 0.55 g NH_3 per bird per day, the same as Baker et al.[88] The NEI (and, implicitly, Baker et al.) assume that half of this total – 0.27 g NH3 per bird per day – comes from broiler confinements. Our recent literature review found that a more reasonable emissions factor for broiler confinements would be roughly twice that – 0.54 g NH3 per bird per day. In short, Baker et al. and the NEI appear to be undercounting ammonia emissions from broiler barns by roughly half. The analysis presented in this report corrects for that error.

Baker et al. used a different atmospheric fate and transport models than the Chesapeake Bay Program. Specifically, Baker et al. simulate atmospheric fate and transport using a model known as "AERMOD," while EPA uses a combination of regression modeling (for wet deposition) and a model known as "CMAQ" (for dry deposition).

More broadly, our analysis and the Baker study approach the issue from opposite directions. We start with the Chesapeake Bay Program's estimates of delivered nitrogen load, specifically the delivered nitrogen load that can be attributed to the atmospheric deposition of ammonia. We then allocate that load to various sources in the watershed, including broiler chickens and other poultry. Baker et al., on the other hand, start by estimated how much ammonia is being emitted by poultry litter, and then estimating where the emitted ammonia might be landing. With respect to a specific location such as Maryland's Eastern Shore, our analysis asks "how much of the nitrogen coming from that area can be attributed to poultry ammonia emissions?" Baker et al., on the other hand, ask "how much ammonia

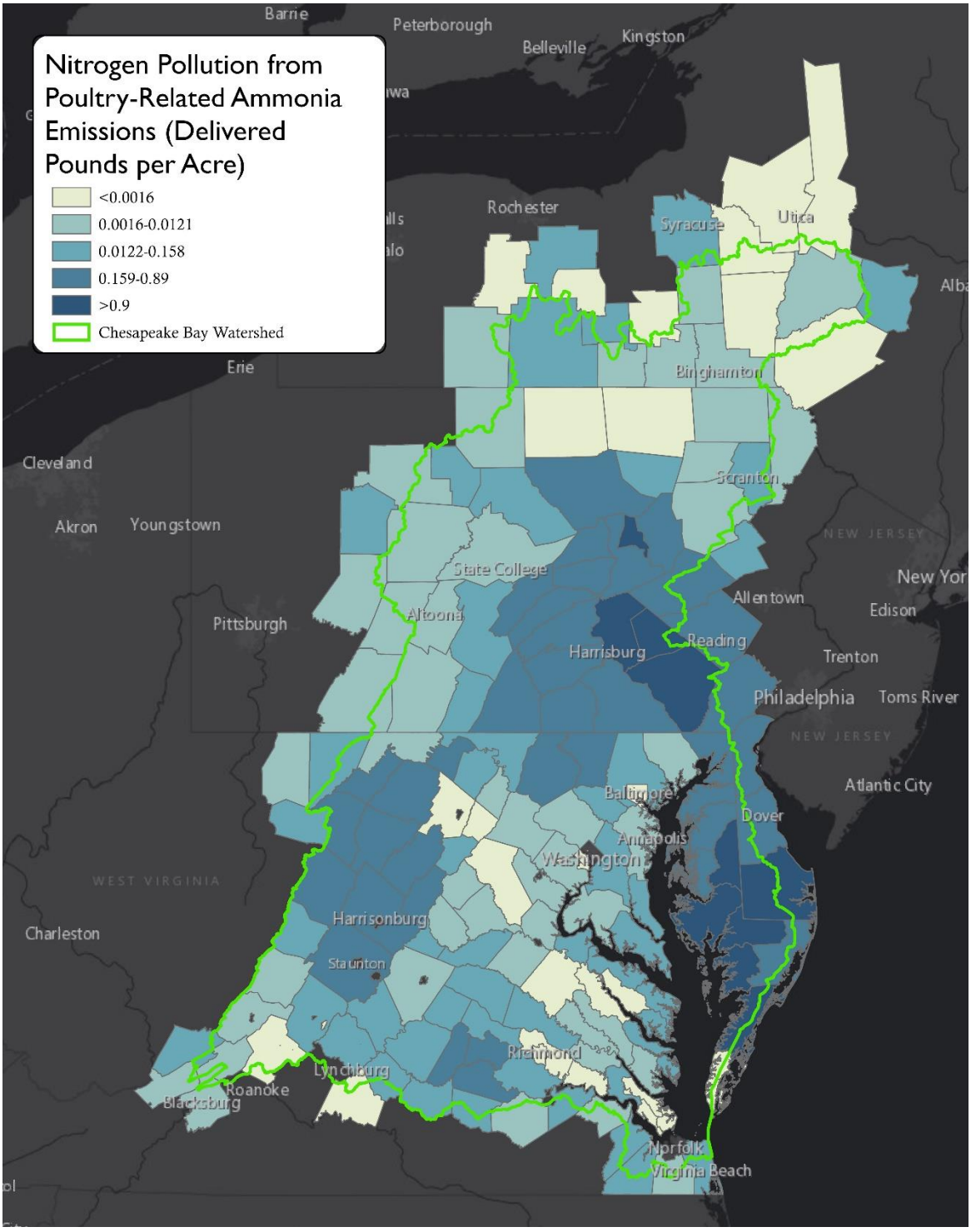
is being emitted by poultry litter in that area, and how much lands in the modeling domain (including areas outside of Maryland's Eastern Shore)?"

Finally, Baker et al. did not estimate the delivered load of ammonia, or the amount of nitrogen reaching the Chesapeake Bay.

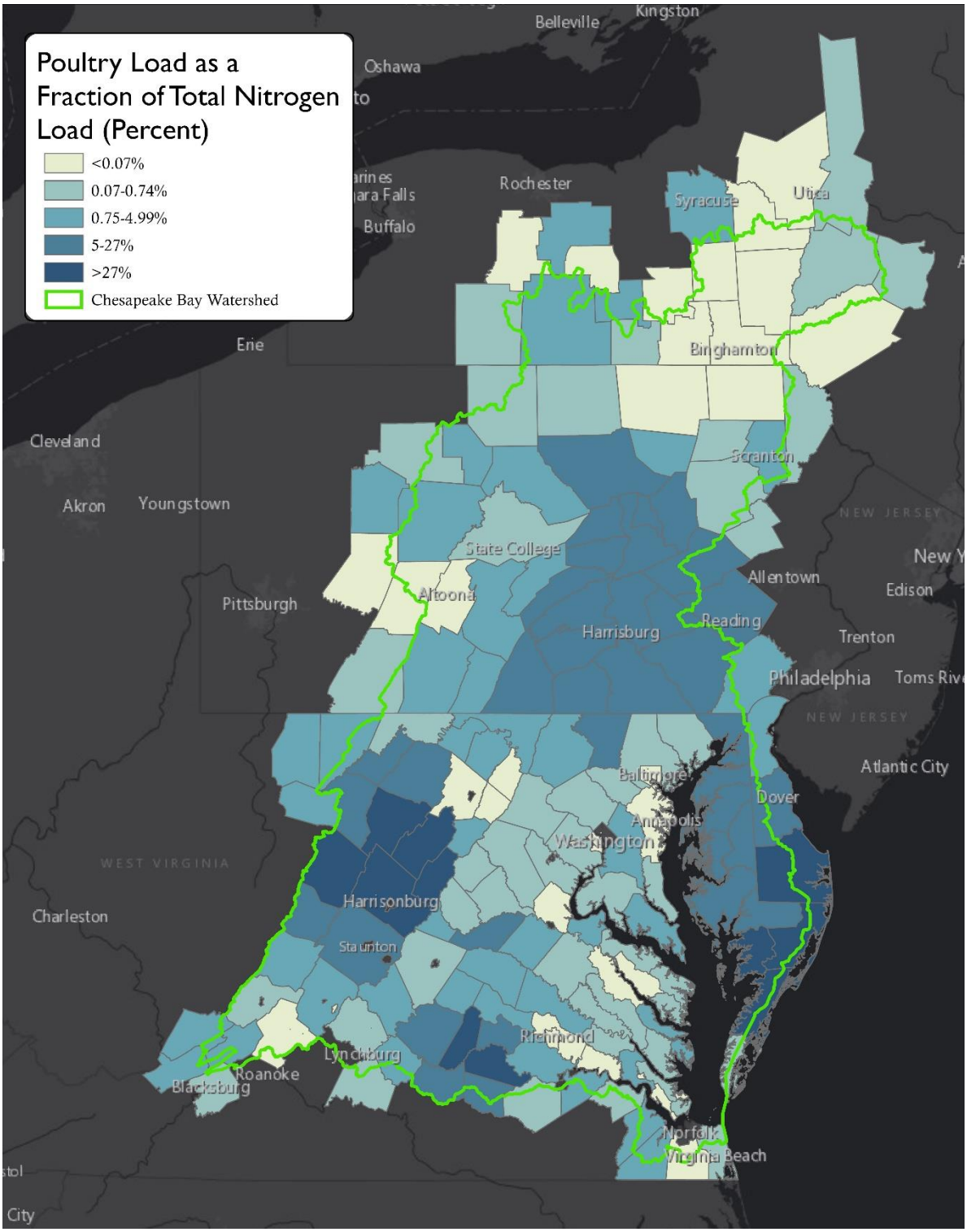
The study had one critically important conclusion (among other important results). Baker et al. estimate that that poultry production on Maryland's eastern shore results in the annual deposition of 11,684 tons of ammonia on land, almost exclusively on the eastern shore.[89] The Bay Program, by contrast, estimates that only 4,466 tons of ammonia deposited on Maryland's eastern shore counties in 2018.[90] If true, these results suggest that the nitrogen load from ammonia might be much higher than the Bay Program assumes, particularly in ammonia hotspots, but potentially overall as well. This applies not just to ammonia from poultry, but also ammonia from dairy and swine operations.

Appendix C: Additional Maps

Map of Nitrogen Pollution Entering Bay from Poultry Ammonia



Map of Poultry Nitrogen Entering Bay as a Fraction of Total Nitrogen from Each County



END NOTES

[1] USDA Agricultural Census numbers for 2017, available at: https://www.nass.usda.gov/Publications/AgCensus/2017/

[2] Figures from 2017 Census of Agriculture, and only include counties within the Chesapeake Bay watershed. Turkey figures are annual sales for slaughter. Laying chicken number is inventory (a one time figure) captured by the 2017 Census of Agriculture.

[3] Manure figure calculated by using USDA Agricultural Census data for 2017, and multiplying it by an estimate of manure-per-pound of bird (for layers) and manure-per-pound-produced (for broilers, turkeys, and pullets) used by the EPA Chesapeake Bay Program.

[4] Ammonia is a chemical that is made up of nitrogen and hydrogen. In the environment, it breaks down into its component parts, liberating the nitrogen.

[5] U.S. Agency for Toxic Substances and Disease Registry, "Public Health Statement for Ammonia," accessed March 16. 2020. Link: https://www.atsdr.cdc.gov/phs/phs.asp?id=9&tid=2

[6] Poulsen, Melissa; Pollak, Jonathana; Sills, Deborah; Casey, Joan; Nachman, Keeve; Cosgrove, Sara; Stewart, Daltonc; Schwartz, Brian, "High-density poultry operations and community-acquired pneumonia in Pennsylvania," Environmental Epidemeology, June 2018. Link: https://journals.lww.com/environepidem/FullText/2018/06000/High_density_poultry_operations_and.5.aspx

[7] The Chesapeake Bay Program is a partnership, founded in 1983, that is led by the U.S. Environmental Protection Agency, but also includes the national Oceanic and Atmospheric Administration, U.S. Geological Survey, University of Maryland Center for Environmental Science and several other federal, state and university partners.

[8]Ammonia is a chemical that is made up of nitrogen and hydrogen. In the environment, it breaks down into its component parts, liberating the nitrogen.

[9] Chesapeake Bay Program, Chesapeake Assessment Scenario Tool (CAST) https://cast.chesapeakebay.net/, (2018 edge of tide (EOT) nitrogen load for wastewater).

[10] Ibid. The Chesapeake Bay tidal ("edge of tide") load of nitrogen from combined sewage overflows totaled 1.4 million pounds in 2018.

[11] Nitrogen entering the Chesapeake Bay from ammonia emissions is also known as the nitrogen "deposition," or the nitrogen that is deposited into the Bay watershed after falling from the atmosphere or being carried by rain.

[12] About 52 percent of the surface area of the Chesapeake Bay is in Maryland, and 48 percent is in Virginia. Calculation of square miles of water in each state from 2012 U.S. Census Statistical Abstract of the United States, page 223, Table 358. "Land and Water Area of States and Other Entities." Link: https://www.census.gov/prod/2011pubs/12statab/geo.pdf

[13] EIP, Ammonia Emissions from Broiler Operations Higher than Previously Thought (Jan. 2018), https://environmentalintegrity.org/reports/ammonia-emissions/ (hereinafter "EIP 2018").

[14] Chesapeake Bay Pogram, Chesapeake Progress, Modeled Nitrogen Loads to the Chesapeake Bay (1985-2025), https://www.chesapeakeprogress.com/clean-water/watershed-implementation-plans

[15] Ibid.

[16] Ibid

[17] We calculated and apportioned the atmospheric deposition of ammonia among various sources of ammonia emissions, including poultry confinement barns, manure storage areas, and land application.

[18] Ellen K. Silbergeld, Chickenizing Farms and Food: How Industrial Meat Production Endangers Workers, Animals, and Consumers, Johns Hopkins University Press, 2016.

[19] Ibid.

[20] National Chicken Council, "Broiler Chicken Industry Key Facts 2019," web page, accessed 2/17/2020. Link: https://www.nationalchickencouncil.org/about-the-industry/statistics/broiler-chicken-industry-key-facts/

[21] U.S. Department of Agriculture farm census data from 2007 and 2017. Note: These numbers include broilers raised in counties that are in all or part in the Chesapeake Bay watershed, including Sussex County, Delaware, the eastern portion of which drains into the Atlantic Ocean.

[22] Wei Zhai, Assistant Professor at Mississippi State University Extension Service, "Why the Rapid Growth Rate in Today's Chickens?" 2018. Link:
http://extension.msstate.edu/sites/default/files/publications/is1950.pdf

[23] National Chicken Council web page, "About the Industry," March 22, 2019. Link:
https://www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-performance/%20

[24] United States Department of Agriculture National Agricultural Statistics Service, "Quick Stats,"accessed April 10, 2020. Link: https://quickstats.nass.usda.gov/?source_desc=CENSUS

[25] EIP used the weight-based manure production estimate described in the Chesapeake Bay Program's Recommendations to Estimate Poultry Nutrients for the Phase 6 Model. The equation is as follows:

Lbs of litter = 0.312971 X (broiler pounds) + 0.732730

The broiler pounds produced in a given state and year was derived from the USDA Survey. Chesapeake Bay Program Agriculture Workgroup, Agricultural Modeling Subcommittee, Poultry Litter Subcommittee, Recommendations to Estimate Poultry Nutrient Production in the Phase 6 Watershed Model (Mar. 2015)

[26] EIP, Ammonia Emissions from Broiler Operations Higher than Previously Thought (Jan. 22, 2018), https://environmentalintegrity.org/reports/ammonia-emissions/.

[27] According to EPA staff, the 2018 watershed model runs used ammonia emissions estimates from the 2011 National Emissions Inventory (NEI). Future runs will start to incorporate more recent emissions estimates from the 2017 NEI. Personal communication with Jesse Bash, staff scientist with EPA's National Exposure Research Laboratory (Oct. 24, 2019).

[28] U.S. EPA, "National Emission Inventory, Ammonia Emissions from Animal Agricultural Operations (revised draft report)" at 3-15, Table 3-8 (2004). Link:
https://www3.epa.gov/ttnchie1/ap42/ch09/related/nh3inventorydraft_jan2004.pdf

[29] Ibid.

[30] U.S. EPA, "National Emission Inventory, Ammonia Emissions from Animal Agricultural Operations" (revised draft report), at 3-15, Table 3-8 (2004). Link: https://www3.epa.gov/ttnchie1/ap42/ch09/related/nh3inventorydraft_jan2004.pdf

[31] EIP, Ammonia Emissions from Broiler Operations Higher than Previously Thought (Jan. 22, 2018), https://environmentalintegrity.org/reports/ammonia-emissions/.
[32] U.S. EPA, "Development of Emissions Estimating Methodologies for Broiler Operations" (Draft), Feb. 2012. Link: https://www.epa.gov/afos-air/development-emissions-estimating-methodologies-broiler-operations-draft-february-2012

[33] P. Moore et al., "Ammonia Emissions Factors from Broiler Litter in Barns, in Storage, and after Land Application," Journal of Environmental Quality 1395 (2011). Link: https://www.ncbi.nlm.nih.gov/pubmed/21869501

[34] R.E. Lacey et al., "Particulate Matter and Ammonia Emission Factors for Tunnel-Ventilated Broiler Production Houses in the Southern U.S.," Transactions of the ASAE 1203 (2003).

[35] R.L. Siefert et al., Characterization of Atmospheric Ammonia Emissions from a Commercial Chicken House on the Delmarva Peninsula, 38 Environ. Sci. Technol. 2769 (2004).

[36] E.F. Wheeler et al., Ammonia Emissions from Twelve U.S. Broiler Chicken Houses, 49 Transactions of the ASABE 1495 (2006).

[37] D.M. Miles et al., Ammonia and Nitrous Oxide Emissions from a Commercial Broiler House, 43 J Environ. Quality 1119, 1123 (2014).

[38] We derived adjusted load estimates at the state level, and not at the county level, because county-level data are not consistently available in USDA resources.

[39] "Atmospheric Deposition to Tidal Water (to be reduced to 15.2 million lbs/yr under Clean Air Act)." Chesapeake Bay Program, Chesapeake Progress – 2018 Progress data, https://www.chesapeakeprogress.com/files/Data_2018_Reducing_Pollution_040519_FINAL_%281%29.xlsx

[40] J. Baker et al., Modeling and Measurements of ammonia from Poultry Operations: Their Emissions, Transport, and Deposition in the Chesapeake Bay, 706 Sci. Total Environ. Article 135290 (March 2020, available online Nov. 24, 2019), https://www.sciencedirect.com/science/article/pii/S0048969719352829

[41] Chesapeake Bay Foundation press release, "New Study Estimates Ammonia Emissions from Poultry Farms on Maryland's Eastern Shore," Dec. 5, 2019. Link: https://www.cbf.org/news-media/newsroom/2019/maryland/new-study-estimates-ammonia-emissions-from-poultry-farms-on-marylands-eastern-shore.html

[42] See Appendix A and Attachment A for methods relating to ammonia deposition expressed as delivered nitrogen load.

[43] U.S. EPA, CERCLA and EPCRA Reporting Requirements for Air Releases of Hazardous Substances from Animal Waste at Farms (Nov. 2017); U.S. EPA, Ammonia and Hydrogen Sulfide Emission Rates for Poultry Operations (Nov. 2017).

[44] Food and Environment Reporting Network, A breathtaking lack of oversight for air emissions from animal farms, (Dec. 2019), https://thefern.org/2019/12/a-breathtaking-lack-of-oversight-for-air-emissions-from-animal-farms/

[45] EPA, Animal Feeding Operations Consent Agreement and Final Order (2005), https://www.epa.gov/sites/production/files/2016-06/documents/afolagooneemreport2012draftappe.pdf

[46] EPA web page, "National Air Emissions Monitoring Study," reviewed in March, 2020. Link: https://www.epa.gov/afos-air/national-air-emissions-monitoring-study

[47] Amanda Peterka, "EPA study of CAFO emissions grinds on with no end in sight
Amanda Peterka, E&E reporter," Greenwire, June, 2014. Link: https://www.eenews.net/stories/1060001938

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[50] The Evening Sun (Hanover, Pa.), "Codorus Township Denies Hillandale Farm Plans," August 6, 2015. Link: https://www.eveningsun.com/story/money/2015/08/06/codorus-township-denies-hillandale-farm-plans/32359713/

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[52] Carolyn Hricko, Keeve Nachman, et al. "Health Community Letter in Support of the Community Healthy Air Act," February, 2019. Available in the files of the Maryland General Assembly library.

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[54] Maryland Department of the Environment, Lower Eastern Shore Ambient Air Quality Monitoring Project, https://mde.maryland.gov/programs/Air/AirQualityMonitoring/Pages/Lower-Eastern-Shore-Monitoring-Project.aspx

[55] Maryland House Bill 1312, sponsored by state Del. Vaughn Stewart of Montgomery County and colleagues; and Senate Bill 0841, sponsored by state Sen. Clarence Lam of Howard and Baltimore Counties and colleagues.

[56] Public testimony of State Del. Vaughn Stewart, D-Montgomery County, on House Bill 1312, during committee hearing on March 4, 2020.

[57] Salisbury University Business, Economic and Community Outreach Network report for the Maryland Department of Agriculture, "A Scenario Analysis of the Potential Costs of Implementing the Phosphorus Management Tool on the Eastern Shore of Maryland," 2014. https://mda.maryland.gov/Documents/pmt-analysis.pdf

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[62] See note 6.

[63] Casey, J.A. and colleagues, "Industrial Food Animal Production and Community Health," Current Environmental Health Reports, 2015. https://www.ncbi.nlm.nih.gov/pubmed/26231503

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[66] Accomack County Planning Commission, "2020 Annual Poultry Report."

[67] Ibid. And County of Accomack Planning and Zoning Staff, "2019 Annual Poultry Report," February 26, 2019. Link: https://www.co.accomack.va.us/home/showdocument?id=11067

[68] CAST public reports, including both "regulated developed" and "non-regulated developed."

[69] https://cast.chesapeakebay.net/

[70] https://www.chesapeakeprogress.com/clean-water/watershed-implementation-plans

[71] For example, the ammonia emissions factors for broilers in the 2014 and draft 2017 NEIs only account for emissions from broiler confinements, and not from manure storage or land application. In addition, the 2014 and 2017 NEIs appear to omit layers with wet manure management systems, and the 2014 NEI omitted several other categories of livestock waste.

[72] See, e.g., EIP 2018 at 6-7.

[73] Based on data provided by KCI Technologies to EIP.

[74] Jordan Baker et al., "Modeling and Measurements of ammonia from Poultry Operations: Their Emissions, Transport, and Deposition in the Chesapeake Bay, 706 Sci. Total Environ. Article 135290 (March 2020,

available online Nov. 24, 2019)." Link:
https://www.sciencedirect.com/science/article/pii/S0048969719352829

[75] This was calculated by dividing the delivered nitrogen load coming from the atmospheric deposition of poultry ammonia emissions on land and non-tidal water (8.3 million pounds) by the delivered nitrogen load coming from all atmospheric deposition on land and non-tidal water (71.5 million pounds).

[76] According to EPA staff, the 2018 watershed model runs used ammonia emissions estimates from the 2011 National Emissions Inventory (NEI). Future runs will start to incorporate more recent emissions estimates from the 2017 NEI. Personal communication with Jesse Bash, staff scientist with EPA's National Exposure Research Laboratory (Oct. 24, 2019).

[77] U.S. EPA, 2011 National Emissions Inventory, version 2, Technical Support Document, Table 3-33 (Aug. 2015).

[78] D. Wood et al., A summary of ammonia emission factors and quality criteria for commercial poultry production in North America, 115 Atmospheric Environment 236 (Aug. 2015).

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[82] EIP 2018, Table 7.

[83] Production-based results for New York could not be calculated because New York broiler production statistics are not available from the USDA.

[84] For New York, we calculated the ratio of the state's 2017 broiler inventory to its 2007 broiler inventory
[85] U.S. Department of Agriculture, Quick Stats, https://quickstats.nass.usda.gov/. The Quick Stats website provides access to both survey and census datasets.

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[87] Jordan Baker et al., "Modeling and Measurements of ammonia from Poultry Operations: Their Emissions, Transport, and Deposition in the Chesapeake Bay, 706 Sci. Total Environ. Article 135290 (March 2020, available online Nov. 24, 2019)." Link:
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[88] Subsequent NEIs in 2014 and 2017 only estimated ammonia emissions from confinements, and not from manure storage or land application. For broilers in Maryland, the 2017 confinement emissions factors is 0.26 g NH_3 per bird per day. This is almost identical to the emissions factor for confinements in the 2011 NEI (0.27 g/bird-d).

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