Ohio Northern University Law Review

Volume 41 | Issue 3 Article 13

Life on the Mississippi: Reducing the Harmful Effects ofAgricultural Runoff in the Mississippi River Basin

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Ohio Northern University
Law Review

Student Article

Life on the Mississippi: Reducing the Harmful Effects of Agricultural Runoff in the Mississippi River Basin

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> *It is good for steamboating, and good to drink; but it is worthless for all other purposes, except baptizing.*χ
>
> Mark Twain

I. INTRODUCTION

For millennia, the Gulf of Mexico was a pristine and productive ecosystem that supported a wide variety of bird, marine mammal, fish, and crustacean species. Sadly, bad farming and business practices in America's heartland disrupted this ecosystem by releasing enormous quantities of nutrients that traveled by agricultural runoff into hundreds of tributaries in the thirty-one states that drain into the Mississippi River.[1] The Mississippi River, which runs 2,350 miles from Lake Itasca, Minnesota to the Gulf of Mexico, transports these chemicals into the Gulf, where each summer they create a "dead zone" or "hypoxic zone" that stretches thousands of square miles.[2] This hypoxic zone increases in size relative to the amount of

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* Taylor A. Beaty is a 2015 graduate of Ohio Northern University Pettit College of Law. Many thanks to Professor David Raack for his assistance and advice throughout the writing process. Thank you also to the Editor-in-Chief of ONU Law Review, Joshua B. Lanphear, for his wonderful editing suggestions.

χ MARK TWAIN, LIFE ON THE MISSISSIPPI 191 (Harper & Brothers 1917) (1883).

1. *The Mississippi-Atchafalaya River Basin (MARB)*, MISSISSIPPI RIVER GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE, http://water.epa.gov/type/watersheds/named/msbasin/marb.cfm (last visited Aug. 9, 2015).

2. *Id.*

agricultural runoff entering the Mississippi River Basin each year, producing an area devoid of sufficient oxygen for fish and other aquatic life to survive.[3]

The Gulf hypoxic zone generates serious concerns for both the economic and environmental long-term health of the region, as the negative effects of nutrient enrichment have already significantly impacted the region's fishing industries, recreational activities, and tourism. Further, the Gulf is a major source of shrimp, oysters, and commercial fish in the United States, making hypoxia's effect on the fishing industry of particular economic importance for both the region and the entire country.[4] Louisiana, for instance, "hosts one-quarter of America's fishery, one-third of its migratory waterfowl, and one-half of its remaining coastal wetlands."[5] This includes a $2.8 billion fishing industry, roughly twenty-three million recreational fishing trips per year, and "an entire culture" that depends "directly and indirectly on the quality of Gulf waters" for their livelihood.[6]

The good news is that the harmful effects of hypoxia in the Gulf can be reversed if nutrient levels entering the Mississippi River Basin are significantly reduced.[7] Importantly, best management practices, such as decreased nutrient use, wetland creation, and increased vegetation buffers, are reasonably easy to implement and have been shown to reduce nonpoint source nutrient pollution.[8]

Section II of this article reviews the regulation history of runoff into the Gulf of Mexico.[9] Section III discusses the current laws and regulations that shape this issue today.[10] Section IV examines the Gulf hypoxic zone in the news, with a close eye on what scientists and scholars are currently saying about this issue.[11] Section V takes an in-depth look at three of the most promising best management practices currently being utilized to halt and eventually reverse the harmful effects of agricultural runoff in the Mississippi River: reduced nutrient use, wetland creation, and increased vegetation buffers.[12] Next, Section V makes a case study of the successful

3. Oliver A. Houck, *Cooperative Federalism, Nutrients, and the Clean Water Act: Three Cases Revisited*, 44 ENVTL. L. REP. NEWS & ANALYSIS 10426, 10432 (2014).

4. *Id*. at 10431-32.

5. *Id*. at 10431.

6. *Id*. at 10431-32; *NOAA-supported scientists find large Gulf dead zone, but smaller than predicted*, NAT'L OCEANIC AND ATMOSPHERIC ADMIN., U.S. DEP'T OF COMMERCE (July 29, 2013), http://www.noaanews.noaa.gov/stories2013/2013029_deadzone.html.

7. Sarah Zielinski, *Ocean Dead Zones Are Getting Worse Globally Due to Climate Change*, SMITHSONIAN.COM (Nov. 10, 2014), http://www.smithsonianmag.com/science-nature/ocean-dead-zones-are-getting-worse-globally-due-climate-change-180953282/?no-ist.

8. *See infra* note 75 and accompanying text.

9. *See infra* Part II.

10. *See infra* Part III.

11. *See infra* Part IV.

12. *See infra* Part V.

and unsuccessful measures implemented in the Chesapeake Bay region, and explores what regulations and levels of cooperation are needed in the future, as well as what challenges lie ahead.[13] Section VI brings this article to a close, arguing that increased stakeholder engagement, cooperation between local, state, and regional actors, and a continued focus on local and state-led best management practices is essential for the reduction of hypoxia's harmful effects in the Gulf of Mexico.[14]

II. History

In 1948, Congress passed the Federal Water Pollution Control Act ("FWPCA"), marking the beginning of organized federal involvement in the regulation of water quality.[15] Almost twenty-five years later, in 1972, Congress passed the Clean Water Act ("CWA"), which expanded and greatly reorganized the FWPCA.[16] The CWA established a basic regulation structure by which the federal government can regulate pollution discharges into United States waters and regulate surface water quality.[17] While the federal government took the first step toward reducing pollution in waterways of the United States, the CWA acknowledged that state programs were essential to finding successful and sustainable solutions to water quality issues that arise.[18] Specifically, the CWA stated:

> It is the policy of the Congress to recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, to plan the development and use (including restoration, preservation, and enhancement) of land and water resources, and to consult with the Administrator in the exercise of his authority under this chapter.[19]

Thus, in many respects, the CWA delegates responsibility for preventing and reducing pollution to the states.[20] Should a state fail to implement necessary standards to reduce pollution, the Environmental Protection Agency ("EPA") may intervene when it finds "a revised or new standard is necessary to meet the requirements" of the CWA.[21] Under the

13. *See infra* Part V.
14. *See infra* Part VI.
15. *See* Houck, *supra* note 3, at 10427.
16. *See id.*
17. *See id.* at 10428.
18. *See id.* at 10426-27.
19. 33 U.S.C. §1251(b) (LexisNexis 2015); *see* Houck, *supra* note 3, at 10427.
20. § 1251(b).
21. 33 U.S.C. § 1313(c)(4)(B) (LexisNexis 2015).

CWA, the EPA may delegate authority to states to develop programs that issue discharge permits for point source pollution,[22] limiting the amount and type of pollutants facilities may discharge into waters of the United States.[23] However, the CWA does not provide regulatory guidance for pollution that results from nonpoint sources,[24] leaving states to address these issues. Nonpoint solution sources are in many ways more difficult and have traditionally been addressed "through non-regulatory, state-based voluntary approaches, which . . . leaves individual states with the responsibility of developing effective reduction plans."[25] While this seemingly removes any roadblocks to state action, it also produces new challenges for states seeking adequate funding for environmental projects and initiatives.

Independent model studies show the hypoxic zone in the Gulf began to grow in the 1970s.[26] In 1988, in response to growing concerns about the environmental decline in the Gulf and under the authority of the CWA, the EPA created the Gulf of Mexico Program ("GMP"), which began as an intergovernmental program to provide both a community-based support and a partnership through which state agencies and nongovernmental organizations could improve the Gulf environment.[27] The stated goal of the GMP is to:

> protect, restore, and enhance the coastal and marine waters of the Gulf of Mexico and its coastal natural habitats, to sustain living resources, to protect human health and the food supply, and to ensure the recreational use of Gulf shores, beaches, and waters—in ways consistent with the economic well being of the region.[28]

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22. Point sources are defined as, "any discernible . . . pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants may be discharged." *What is Nonpoint Source Pollution?*, EPA, http://water.epa.gov/polwaste/nps/whatis.cfm (last visited Aug. 9, 2015).

23. 33 U.S.C. § 1342 (LexisNexis 2015).

24. Nonpoint sources are defined as, "any source of water pollution that does not meet the legal definition of "point source." *What is Nonpoint Source Pollution?*, *supra* note 22.

25. Alyse Zadalis, *Kansas Growers and the Environmental Protection Agency: On the Same Side? A Look at Kansas' Implementation of the Surface Water Nutrient Reduction Plan*, 23 KAN. J.L. & PUB. POL'Y 381, 389 (2014).

26. Andy Soos, *The Dead Zone in the Gulf of Mexico*, ENVTL. NEWS NETWORK (June 7, 2010), http://www.enn.com/wildlife/article/41405.

27. *See What is the Gulf of Mexico Program*, EPA, http://www.epa.gov/gmpo/about/whatisgmp.html (last visited Aug. 14, 2015).

28. *See* NUTRIENT ENRICHMENT ACTION AGENDA FOR THE GULF OF MEXICO: FIRST GENERATION—MANAGEMENT COMMITTEE REPORT, EPA i (July 1994), *available at* http://nepis.epa.gov/Exe/ZyNET.exe/20001ODK.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1991+Thru+1994&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C91thru94%5CTxt%5C00000011%5C20001ODK.txt&User

In 1991, the GMP, through the Nutrient Enrichment Issue Committee,[29] began researching the impact of decreased oxygen in the Gulf of Mexico. This data collection culminated in a 1994 Action Agenda that outlined the steps needed in order "to control and substantially reduce the deleterious effects of nutrient enrichment in the Gulf of Mexico."[30] Specifically, this first generation management committee report aspired to serve three purposes: (1) to address and represent public concern about nutrient enrichment in the Gulf of Mexico; (2) to communicate the need for and the impetus for the implementation of joint efforts to reduce the negative effects of nutrient enrichment; and (3) to provide initial data through which to measure success.[31] While this initial report provided analysis of efforts in Alabama, Florida, Louisiana, Mississippi, and Texas, and raised additional awareness through this research, it revealed only slight progress in these states and served only to urge increased nutrient reduction efforts.[32]

In the fall of 1997, and with little progress made toward nutrient reduction, the EPA developed the Mississippi River Gulf of Mexico Watershed Nutrient Task Force ("Task Force") in order to consider additional implementation options.[33] The Task Force is a partnership of five federal agencies, twelve states and the tribes within the Mississippi/Atchafalaya River Basin (MARB), and environmental quality, agricultural, and conservation agencies.[34] The Task Force was specifically established to "coordinat[e] and support[] nutrient management activities from all sources, restor[e] habitats to trap and assimilate nutrients, and support[] other hypoxia related activities in the Mississippi River and Gulf of Mexico watersheds."[35]

On November 13, 1998, Title VI of the Coast Guard Authorization Act of 1998 established a Federal Task Force on Harmful Algal Blooms and Hypoxia to "research . . . the ecology and impacts of freshwater algal blooms; and . . . forecast[] and monitor[] . . . response[s] to freshwater harmful algal blooms in lakes, rivers, estuaries (including their tributaries),

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=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL [hereinafter NUTRIENT ENRICHMENT ACTION AGENDA].

29. The Nutrient Enrichment Issue Committee was renamed the Nutrient Enrichment Focus Team in 1998.

30. *See* NUTRIENT ENRICHMENT ACTION AGENDA, *supra* note 28, at i.

31. *Id.* at iii.

32. *Id.* at 47-56.

33. *Task Force History and Reassessment*, MISSISSIPPI RIVER/GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE, http://water.epa.gov/type/watersheds/named/msbasin/history.cfm (last visited Aug. 10, 2015).

34. MISSISSIPPI RIVER/GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE, http://water.epa.gov/type/watersheds/named/msbasin/index.cfm (last visited Aug. 8, 2015).

35. *Task Force History and Reassessment*, *supra* note 33.

and reservoirs."[36] Importantly, in 2001, and in accordance with the Harmful Algal Blooms and Hypoxia Research Control Act of 1998, the Mississippi River Gulf of Mexico Watershed Nutrient Task Force released an action plan ("2001 Action Plan") with a national strategy to reduce hypoxia in the Gulf of Mexico.[37] The 2001 Action Plan was designed to provide a "basin-wide context for the continued pursuit of both incentive-based, voluntary efforts for nonpoint sources . . . [and] propose[d] an implementation approach" in order to "reduce the 5-year running average areal extent of the Gulf of Mexico hypoxic zone to less than 5,000 square kilometers [about 1,900 square miles]" by the year 2015.[38]

In 2008, the Task Force released a second action plan ("2008 Action Plan") to address progress made from 2001-2007 and to provide a reassessment of critical needs going forward.[39] The 2008 Action Plan found that from 2003-2007 the average size of the Gulf of Mexico hypoxic zone was 14,644 square kilometers (5,600 square miles), which is more than twice the size of the goal set out in the 2001 Action Plan.[40] The 2008 Action Plan applauded significant progress made, such as state creation of Sub-Basin Committees for the Upper Mississippi Basin, the Ohio Basin, and the Lower Mississippi Basin, and increased assistance to agricultural producers through U.S. Department of Agriculture ("USDA") programs for voluntary implementation.[41] Specifically, the report indicated that USDA assistance provided for voluntary implementation of

> an additional 1.4 million acres of wetlands restored, enhanced, or created[,] . . . an additional 2.3 million acres of conservation buffers installed within the Basin during the fiscal years 2000-2006[, and] . . . best management practices . . . applied to 18.3 million acres in the Basin during fiscal years 2000-2006.[42]

Despite these positive steps, the 2008 Action Plan acknowledged that the 5,000 square kilometer (1,900 square mile) Gulf hypoxic zone goal might

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36. *See* Harmful Algal Bloom and Hypoxic Research and Control Act of 1998, 112 Stat. 3447 (1998); *see also* Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014, 128 Stat. 1379 (2014).

37. ACTION PLAN FOR REDUCING, MITIGATING, AND CONTROLLING HYPOXIA IN THE NORTHERN GULF OF MEXICO, MISSISSIPPI RIVER/GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE 1 (Jan. 2001), *available at* http://water.epa.gov/type/watersheds/named/msbasin/upload/2001_04_04_msbasin_actionplan2001.pdf.

38. *Id.* at 4, 9.

39. *See* GULF HYPOXIA ACTION PLAN 2008, EPA (2008), *available at* http://water.epa.gov/type/watersheds/named/msbasin/upload/2008_8_28_msbasin_ghap2008_update082608.pdf.

40. *Id.* at 14.

41. *Id.* at 17.

42. *Id.* at 18.

not be attainable by 2015.[43] However, the report stated that the goal remains reasonable in the context of adaptive management and indicated that in order to reach this goal, nutrient reduction strategy must aim for a 45% reduction in nitrogen and phosphorus load.[44]

In 2013, the Task Force produced a reassessment ("2013 Reassessment") that stated,

> [a]lthough achieving measurable water quality improvements takes time, and more frequent extreme weather events pose challenges, the progress we are making in developing state and federal nutrient reduction strategies, improving access to monitoring data, sponsoring science forums, and coordinating with other Gulf Coast efforts is providing an excellent foundation as we look to the next five years of accelerating our progress.[45]

Thus, with advancements in monitoring technology and greater research efforts since the 2008 Action Plan, scientists have a "more comprehensive understanding of factors regulating hypoxia . . . and better refined . . . approaches to controlling nutrient loads."[46] In regard to the size of the Gulf hypoxic zone, the report noted that the 2013 hypoxic zone measured 15,126 square kilometers (9,399 square miles).[47] As of September 2013, each of the twelve Task Force states were in the process of drafting and executing state nutrient reduction strategies, reflecting the specific water quality issues and implementation methods needed by each state.[48] Ohio, for example, submitted a plan collaborated on by the Ohio Departments of Natural Resources and Agriculture and the Ohio EPA to pursue increased stakeholder engagement and public input in a nutrient reduction strategy.[49] These state initiatives in the 2013 Reassessment demonstrate that progress is in fact being made.

In May of 2014, the Task Force announced an important partnership with twelve land grant universities to develop strategies for reducing the water pollution that flows into the Gulf.[50] This partnership, which includes

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43. *See id.* at 21.
44. *See* GULF HYPOXIA ACTION PLAN 2008, *supra* note 39, at 21-22.
45. REASSESSMENT 2013: ASSESSING PROGRESS MADE SINCE 2008, MISSISSIPPI RIVER/GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE iii (2013), *available at* http://water.epa.gov/type/watersheds/named/msbasin/upload/hypoxia_reassessment_508.pdf.
46. *Id.* at v.
47. *See id.* at vi.
48. *See id.* at viii.
49. *See id.* at 7.
50. *See Mississippi River/Gulf of Mexico Watershed Task Force Announces Agreement with 12 Universities to Further Water Pollution Reduction Programs and Goals*, EPA (May 21, 2014),

Purdue University, University of Illinois, University of Arkansas, University of Kentucky, Mississippi State University, Ohio State University, University of Tennessee, University of Missouri, University of Minnesota, University of Wisconsin, Iowa State University, and Louisiana State University, is the first partnership of its kind for the Task Force and non-governmental entities.[51] While there are no formal processes "for sharing university research and ideas across the 12 task force states[,] this new network will bring additional expertise to help reduce nutrient runoff and advise the task force and other national policy makers."[52] This new partnership based on cooperation and collaboration at all levels is an exciting new step toward increased nutrient reduction and, if successful, will pave the way for similar alliances in the future.

III. CURRENT INITIATIVES

In conjunction with the current innovative approach of the Task Force, individual states and tribes are beginning to increase their efforts to aid in public awareness and education of the dangers of agricultural runoff. While these efforts take many forms and are not yet adequate, they are working and they must be increased. The Science Museum of Minnesota, for example, operates an informative and visually appealing website dedicated to the Gulf of Mexico dead zone.[53] This website offers activities, animations, and movies in both English and Spanish that explain what the dead zone is, what causes it, and who it affects.[54] State resources, such as this website, make the problem very easy to understand, interesting to read about, and provide people of all ages with the opportunity to learn about the dead zone.[55]

States are also realizing the financial advantages of joining forces with federal agencies in order to target specific local problems. For example, the State of Iowa and the USDA, which originally paired efforts in August 2001, are working together to address water quality issues caused by excess nitrogen in water in thirty-seven counties in north central Iowa.[56] The Conservation Reserve Enhancement Program ("CREP") uses "federal and

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http://yosemite.epa.gov/opa/admpress.nsf/d0cf6618525a9efb85257359003fb69d/645836a375abee1385257cdf004d41e1!OpenDocument.

51. *Id.*

52. *Id.*

53. *The Gulf of Mexico Dead Zone*, SCIENCE MUSEUM OF MINNESOTA, http://www.smm.org/deadzone/top.html (last visited October 15, 2014).

54. *Id.*

55. *Id.*

56. *Conservation Reserve Enhancement Program*, U.S. DEP'T OF AGRIC. (Aug. 2001), http://www.apfo.usda.gov/FSA/newsReleases?area=newsroom&subject=landing&topic=pfs&newstype=prfactsheet&type=detail&item=pf_20010801_consv_en_crepia01.html.

state resources to safeguard environmentally sensitive land through the Conservation Reserve Program (CRP)."[57] CREP uses "[f]inancial incentives" in the way of annual rental rates to encourage "private landowners to develop and restore wetlands that intercept tile drainage from agricultural watersheds."[58] Moreover, "[l]andowners receive annual land payments for up to 15 years and reimbursement for costs of wetland and buffer establishment[, and] [e]asements to maintain the wetlands and buffers are required for a minimum of 30 years . . . ."[59] Through its integrated approach, CREP provides important financial incentives through the USDA and enables local leadership to work together to implement management practices that best suit their regions.

Regional studies show these partnerships—and the best management practices that they promote—are working to reduce nutrient enrichment in agricultural runoff where they are implemented.[60] Thus, moving forward there must be an intentional effort to increase the application of cooperative practices. The USDA, the CWA, and private donors provide funding for a variety of these projects and should certainly continue to do so, as long as they are able to promote increased public awareness through their efforts. Additionally, state-led education programs must continue to educate farmers, ranchers, concerned citizens, and the general public about the dangers of nutrient enriched agricultural runoff in the Mississippi River Basin.

IV. LITERATURE REVIEW

Many scholars and scientists currently write on the subject of agricultural runoff in the Mississippi River and hypoxia in the Gulf of Mexico, with authors in wide agreement that an increased number of implementation techniques are necessary to address the issue.[61] Additionally, most scientists agree that reduction of nutrients in substantial percentage can only be achieved through the joint implementation of several specific methods.[62] Matt Helmers, PhD, of Iowa State University, says, "[w]e need to see an increase in the rate of implementing practices that lower nutrient export."[63] Further, he states that measures such as cover crops, subsurface drainage bioreactors, and "specialized wetland systems

57. *Id.*
58. *Iowa Conservation Reserve Enhancement Program (CREP)*, WATER RESOURCES BUREAU (last visited Oct. 15, 2014), http://www.iowaagriculture.gov/waterResources/CREP.asp.
59. *Id.*
60. *See id.*
61. *See infra* text accompanying notes 63-68.
62. *See infra* text accompanying notes 64-68.
63. *Hypoxia Issues in the Gulf of Mexico*, SCIENCEDAILY (Oct. 24, 2013), http://www.sciencedaily.com/releases/2013/10/131024101906.htm.

also reduce nutrient export."[64] Similarly, scholars contend that in order to reach a significant decrease in nutrient export of 45%, a combination of nitrogen-management practices and nitrogen-removal practices must be considered and utilized.[65] In fact, merely implementing a nitrogen-management measure, such as improved fertilizer management, is simply not enough change to substantively decrease the harmful effects of nitrogen enrichment.[66] Other scientists specifically

> conclude that a reduction of about 40% of nitrogen loading to the Gulf of Mexico is possible through the implementation of [the following] proven techniques implemented in concert[:] modification of farm practices to make the use of nitrogen from fertilizer, soil, and manure more effective and efficient[;] switching from traditional row crops such as corn and soybeans to alternative cropping systems[;] creation and restoration of major tracts of wetlands and riparian ecosystems located between farmland and streams and rivers . . . [;] flood control in the upper Mississippi River Basin by means of riparian retention of floodwaters, rather than by effort to confine floodwaters to the river channel[;] diversion of floodwaters to backwaters of the Mississippi River delta and coastal wetlands[; and] placement of nitrogen controls on domestic wastewater treatment plants and significant industrial sources[.][67]

Scientists argue that these measures would "enhance water quality . . . wildlife use in the wetlands, forests, and adjacent streams . . . and would not only be more livable, [but] it would also be more economically sound and ultimately more economically sustainable than what it would replace."[68]

Despite much agreement as to the policies and methods that are needed, scientists and scholars espouse differing views as to where public attention concerning the hypoxic zone in the Gulf of Mexico should be focused. While many say attention should largely center on reducing the large amounts of agricultural runoff, others have recently connected increased

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64. *Id.*

65. *See* Eileen McLellan et al., *Reducing Nitrogen Export from the Corn Belt to the Gulf of Mexico: Agricultural Strategies for Remediating Hypoxia*, 51 J. AM. WATER RESOURCES ASS'N 263, 263 (Feb. 2015), *available at* http://onlinelibrary.wiley.com/doi/10.1111/jawr.12246/epdf.

66. *See id*.

67. William J. Mitsch et al., *Reducing Nitrogen Loading to the Gulf of Mexico from the Mississippi River Basin: Strategies to Counter a Persistent Ecological Problem*, 51 BIOSCIENCE 373, 386 (2001), *available at* http://bioscience.oxfordjournals.org/content/51/5/373.full.

68. *Id.*

hypoxic zones worldwide with climate change.[69] In light of new data suggesting that global temperatures continue to rise, several scientists recently expressed deep concern that "[c]limate change will drive expansion of dead zones, and has likely contributed to the observed spread of dead zones over recent decades."[70] In *Global Change Biology*, Andrew Altieri of the Smithsonian Tropical Research Institute in Panama and Keryn Gedan of the University of Maryland, College Park, and the Smithsonian Environmental Research Center in Maryland state, "[c]limate change can have a variety of direct and indirect effects on ocean ecosystems, and the exacerbation of dead zones may be one of the most severe."[71]

However, Patrick J. Michaels, a former president of the American Association of State Climatologists and a contributing author of the United Nations Inter-governmental Panel on Climate Change, disagrees with this approach.[72] "Given that dead zones maximize during the summer's hottest temperatures," Michaels concedes, "there is surely *some* component from warming."[73] However, he insists "the more obvious answer" and the one that should be focused on "is that the massive flushing of nitrates into the world's nearshore regions is changing a minor (and possibly undetectable) amplification into a stinking roar."[74] Only by acknowledging that the real ecological problem of nutrient enrichment in the Gulf of Mexico can "be significantly reduced with relatively simple measures," will noticeable progress be made toward decreasing the size of the hypoxic zone.[75] After noting the serious nature of these recent statements implicating climate change in the increasing size of hypoxia worldwide, Sarah Zielinski, an award-winning science writer and editor shares the good news: "the dead zone problem can be tackled by reducing nutrient pollution."[76]

V. Analysis

A. The Science of Hypoxia

Hypoxia typically occurs in estuaries and coastal waters when oxygen levels are abnormally low.[77] Hypoxia can result from a variety of factors

69. *See infra* text accompanying notes 70-76.
70. *See* Zielinski, *supra* note 7.
71. *Id.*
72. *See* Patrick J. Michaels, *Climate, Agriculture, and the Dead Zone*, CATO INSTITUTE (Nov. 11, 2014 3:37 PM), http://www.cato.org/blog/climate-agriculture-dead-zone.
73. *Id.*
74. *Id.*
75. *Id.*
76. *See* Zielinski, *supra* note 7.
77. *Hypoxia 101*, MISSISSIPPI RIVER GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE, http://water.epa.gov/type/watersheds/named/msbasin/hypoxia101.cfm (last visited Aug. 9, 2014) (saying

such as "excess nutrients, primarily nitrogen and phosphorus, and waterbody stratification due to saline or temperature gradients."[78] These nutrients come from a variety of sources, including fertilizers from agriculture, golf courses, suburban lawns, erosion of soil, discharges from sewage treatment plants, and atmospheric nitrogen.[79] Agricultural runoff is the leading cause of "water quality impacts on surveyed rivers and lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of surveyed estuaries and ground water."[80] Therefore, this article will specifically focus on fertilizer runoff from agricultural land, as it is the largest contributor of nutrient enrichment.

Agricultural runoff is especially dangerous because these nutrients promote rapid algae growth, and as the "dead algae decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water."[81] Again, as nitrogen and phosphorous are powerful nutrient-rich fertilizers, they "energize aquatic vegetation the same way they energize terrestrial crops, only more acutely."[82] While hypoxia is a natural occurrence in various aquatic environments, frequently in deep ocean basins, hypoxia is now occurring increasingly in estuaries and shallow coastal waters as a direct result of the growing human nutrient input.[83] In the Gulf of Mexico, the hypoxic zone forms every summer from excess nutrients in agricultural runoff that travel down the Mississippi River.[84] Once it makes its way to the Gulf, this nutrient rich freshwater is less dense and remains on top of the more dense saline saturated water already in the Gulf.[85] These different layers of stratification prevent the nutrient rich freshwater from mixing with the oxygen-depleted water on the floor of the Gulf.[86]

Every summer, researchers measure the size of the hypoxic zone and use that measurement as a significant "indicator of how much progress is being made to reduce nutrient inputs into the Gulf of Mexico."[87] As of June 17, 2015, the hypoxic zone was estimated at approximately 5,483 square miles, roughly the same size that it has averaged over the last several

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that "[h]ypoxic waters have dissolved oxygen concentrations of less than 2-3 ppm.") [hereinafter *Hypoxia 101*].

78. *Id.*

79. *Id.*

80. *Water: Polluted Runoff*, EPA, http://water.epa.gov/polwaste/nps/agriculture.cfm (last visited Aug. 7, 2015).

81. *Hypoxia 101*, *supra* note 77.

82. *Houck*, supra note 3, at 10430.

83. *See Hypoxia 101*, supra note 77.

84. *Id*.

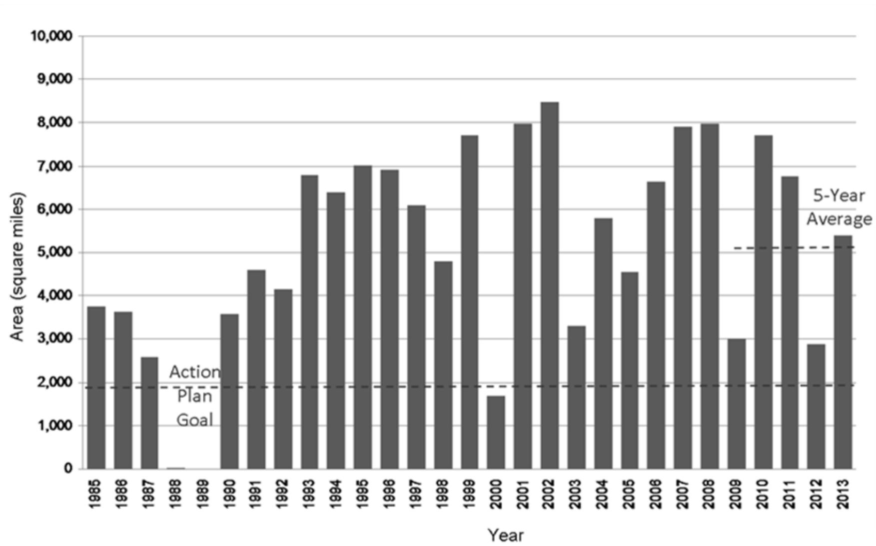
85. *Id*.

86. *Id*.

87. *Northern Gulf of Mexico Hypoxic Zone*, MISSISSIPPI RIVER GULF OF MEXICO WATERSHED NUTRIENT TASK FORCE, http://water.epa.gov/type/watersheds/named/msbasin/zone.cfm (last visited Aug. 13, 2015).

years.[88] Interestingly, as depicted in Table 1, the size of the 2013 hypoxic zone was about double that of the 2012 hypoxic zone measurements.[89] Researchers find these differences correlate strongly to weather patterns, as they attribute the small size of the hypoxic zone in 2012 to the summer drought conditions in the Mississippi River Basin that resulted in "greatly reduced nutrient outputs into the Gulf of Mexico."[90] Similarly, years with floods affecting the Mississippi River Basin can result in an increase in the size of the hypoxic zone.

Table 1: This graph shows hypoxic trends from 1985-2013, the Action Plan Goal set by the Task Force, and the five-year average from 2009-2013.[91]



B. Different Approaches Analyzed

1. Introduction

A variety of proposed solutions to the problem of agricultural runoff in waterways leading to the Gulf of Mexico exist. Some of these proposed solutions have been discussed at great length or even implemented in other

88. *Id*.
89. *Id*.
90. *Id*.
91. *Scientists find large Gulf dead zone, but smaller than predicted*, PHYS.ORG, phys.org/news/2013-07-scientists-large-gulf-dead-zone.html (last visited Aug. 3, 2015).

regions of the United States to improve water quality. In the efforts to discover the optimal methods for addressing this problem, cooperation at the local, state, regional, and national levels is of the upmost importance.

Notably, agricultural companies can contribute private funds to research effective methods for reducing harmful agricultural runoff. For example, in 2008, Monsanto, a major St. Louis-based agricultural company, pledged five million dollars to back a three-year study conducted by The Nature Conservancy, which aimed to reduce nutrient runoff into the Mississippi River.[92] Through this study, the Mississippi River Watershed Partnership ("MRWP"), farmers, and conservation groups collaborated on ways to reduce harmful runoff into the Mississippi River Basin and developed best management practices to both monitor and reduce this runoff.[93] The Nature Conservancy partnered with local organizations and agricultural producers in the Root River in Minnesota, the Pecatonica River in Wisconsin, the Boone River in Iowa, and the Mackinaw River in Illinois to formulate precision conservation including the use of cover crops, strip tillage, bioreactors, no-till farming, and installing grass waterways.[94] Most importantly, the results were very encouraging. "For example, in the Root River watershed, short-term results show that the new conservation practices can reduce the amount of nitrates entering the watershed by 53,520 pounds per year. In the Boone River watershed, the results can show a reduction of approximately 76,000 pounds per year."[95] For its continued efforts to reduce agricultural runoff, Monsanto won the 2013 Gulf Guardian award by the Gulf of Mexico Program, an award "given to business, community groups, individuals and agencies that are taking positive steps to help keep the Gulf healthy, beautiful and productive."[96] The MRWP illustrates the significant benefits of cooperation at all levels and highlights a possible solution to the funding question faced by local organizations or states looking to implement similar programs.

While numerous methods to reduce harmful agricultural runoff exist, the following subsections discuss three of the most promising to date: reduction in agricultural chemical use, wetland creation, and vegetation buffer creation.

92. *Mississippi River/Groups to target ag runoff in river*, PIONEER PRESS (Dec. 9, 2008 12:35 AM), http://www.twincities.com/alllistings/ci_11171993.

93. *Mississippi River Watershed Partnership – Reducing Runoff*, MONSANTO, http://www.monsanto.com/improvingagriculture/pages/mississippi-river-water-shed-project.aspx (last visited Aug. 13, 2015).

94. *Id.*

95. *Id.*

96. *Id.*

2. Reduction in Agricultural Chemical Use

Directly proposing a reduction in the number of agricultural fertilizers and pesticides used every year provides the most direct solution to the harmful effects of the Gulf of Mexico Dead Zone. Instituting a reduction in agricultural chemicals can be accomplished through either voluntary or mandatory means, or a combination of both. However, if this issue is to be approached from the standpoint of cooperation on all levels, then a voluntary route is certainly preferred.

Improved management of fertilizers and pesticides lies at the heart of this issue and the responsibility of management "rests with the farmer, the supplier of the nutrients . . . and the crop consultants."[97] Applying nitrogen at the proper rate and time significantly decreases nitrogen loss, as compared to excessive application at improper times.[98] New techniques of testing nitrogen levels in the soil will greatly aid farmers in determining precisely the time and amount of nitrogen application.[99]

Increased education of farmers and ranchers, explaining the benefits of proper chemical application, is the preferable way to reduce agricultural chemical use. Thus, state-led education programs should be substantially expanded as improved technology continues to provide convincing data that there is a proper time and a proper level of fertilizers to apply. These education efforts would voluntarily bring farmers and ranchers into the reduced chemical use discussion. The alternative to voluntary education and implementation would likely include mandatory nitrogen permits and credit systems that, while certainly effective, could create long-term relationship issues and resentment among local actors.[100]

3. Wetland Creation

Wetlands operate as transition zones between terrestrial and aquatic systems and are among the most productive ecosystems in the world, having even been compared to rain forests and coral reefs.[101] As wetlands can be created in many possible locations, they provide great versatility to conservation planning. Wetlands located in watersheds are fed primarily by runoff through flooding streams, "allow[ing] for seasonal floodwaters to deposit sediments and chemicals in the wetland and for the water to seep back into the stream."[102] In performing this function of filtering out

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97. Mitsch, *supra* note 67, at 382.
98. *Id.*
99. *See id.* at 383.
100. *See Hypoxia Issues in the Gulf of Mexico*, *supra* note 63.
101. *Wetlands*, ENCYCLOPEDIA.COM, http://www.encyclopedia.com/topic/wetlands.aspx (last visited Aug. 13, 2015).
102. Mitsch, *supra* note 67.

inorganic nutrients, these wetlands save local and state governments large amounts of money that otherwise would be spent purifying and treating the water.[103]

Wetlands are particularly critical in the Corn Belt, where many farms use underground tile drains to carry high concentrations of nitrates directly into streams and rivers. Strategically constructed wetlands intercept runoff and remove nitrates and herbicides from this farm drainage, drastically improving the water quality of agricultural runoff before it begins its journey down to the Gulf of Mexico.[104] These systems, prevalent in Illinois, Iowa, and Ohio, "essentially use wetlands as a first line of treatment to remove the highest concentrations of nitrates."[105]

According to studies along the Illinois River, "floodplain wetlands can remove about 0.24 tons of nitrate per acre."[106] Further, Iowa's Conservation Reserve Enhancement Program, the combined effort of state and federal agencies and local conservation districts, found:

> such strategically placed wetlands remove 40-70 percent of nitrates (and over 90 percent of herbicides) from farm drainage. This pollution trapping not only improves the quality of local waters and the Gulf of Mexico downstream, but the wetlands provide prime habitat for birds and wildlife, opening up recreational opportunities . . . The Conservancy's research suggests that a wetland area equal to about 6% of the tiled farm field removes about 50% of the nitrates draining off the field.[107]

Wetland construction offers additional benefits beyond the reduction of nutrients found in agricultural runoff. Wetlands also provide flood mitigation, shoreline erosion protection, increase wildlife, aesthetic appreciation, and recreational enjoyment, and are home to a wide variety and considerable quantity of food for many animal species.[108] Numerous bird species enjoy shelter and nesting in wetlands, so increased wetland creation would facilitate the growth of certain bird species. For instance, the Ohio Department of Natural Resources estimates that 75% of all

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103. NATIONAL MANAGEMENT MEASURES TO PROTECT AND RESTORE WETLANDS AND RIPARIAN AREAS FOR THE ABATEMENT OF NONPOINT SOURCE POLLUTION, EPA 41 (2005), *available at* http://nepis.epa.gov/Exe/ZyPDF.cgi/20005FGX.PDF?Dockey=20005FGX.PDF.

104. Sandra Postel, *Stronger Efforts Needed to Reduce Nitrate Pollution in Mississippi River Basin*, NAT'L GEOGRAPHIC (Nov. 1, 2013),http://voices.nationalgeographic.com/2013/11/01/stronger-efforts-needed-to-reduce-nitrate-pollution-in-mississippi-river-basin/.

105. Mitsch, *supra* note 67, at 378.

106. Postel, *supra* note 104.

107. *Id.*

108. *See Wetlands*, *supra* note 101.

waterfowl in Ohio breed exclusively in wetlands.[109] These wetlands are vital to Ohio's economy by supporting the fishing, hunting, and wildlife watching industry.[110] Furthermore, wetlands provide a vast array of recreational options for those looking to enjoy the outdoors, from bird watching to kayaking.

4. Vegetation Buffer Creation

Vegetation buffers are uncultivated "strips of land with permanent vegetation designed to intercept stormwater runoff and minimize soil erosion."[111] These vegetation buffers are typically set at a specified width around the perimeter of farmed fields, intercepting the soil particles and sediments that carry fertilizer pollutants from cultivated fields toward streams. Similarly, the "[s]oil microbes and grass in buffer stripes . . . can facilitate the transformation and uptake of these pollutants, thus protecting surface water resources."[112] According to the Minnesota Department of Natural Resources, vegetation buffers can remove "50 percent or more of nutrients and pesticides, 60 percent or more of some pathogens, and 75 percent or more of sediment."[113]

In addition to improving water quality, these vegetation buffers protect streams by reducing bank erosion and providing shaded environments along stream banks, which moderates water temperature, aids cold-water fish species, and provides rich sources of food, nesting, and shelter for many wildlife species.[114] Furthermore, by greatly slowing down the erosion process, vegetation buffers preserve expensive farmland that is rich for cultivation.[115]

While vegetation buffers aid water quality preservation by trapping nitrates and phosphates before they travel underground or run into waterways, they also benefit farmers as well. These buffer strips aid farmers by reducing flood damage to crops, by slowing erosion and other sediment loss, and by lowering ditch maintenance costs.[116] They also serve practical purposes by removing troublesome end rows that are difficult to

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109. *Ohio's WILD Wetlands!*, OHIO DEP'T OF NATURAL RES. (2007), *available at* http://wildlife.ohiodnr.gov/portals/wildlife/pdfs/education/WetlandBook.pdf.

110. *Id.*

111. VEGETATION BUFFER STRIPS IN AGRICULTURAL AREAS, DNR WATERS (Nov. 2007), *available at* http://files.dnr.state.mn.us/publications/waters/buffer_strips.pdf.

112. *Id.*

113. *Id.*

114. *Id.*

115. RIPARIAN BUFFERS, N.C.STATE UNIV., (last visited Aug. 11, 2015), *available at* http://www.bae.ncsu.edu/programs/extension/wqg/sri/riparian5.pdf.

116. *See* VEGETATION BUFFER STRIPS IN AGRICULTURAL AREAS, *supra* note 111.

harvest, providing additional turn room for farmers to maneuver their large machinery, and supplying general access paths to other fields.[117]

As vegetation buffers are successful in purifying water before it enters streams, creeks, or rivers, some states have enacted statutes requiring construction of these buffers. In Minnesota, for example,

> permanent strips of perennial vegetation shall be 16-1/2 feet in width measured outward from the top edge of the constructed channel . . . . Agricultural practices, other than those required for the maintenance of a permanent growth of perennial vegetation, are not permitted on any portion of the property acquired for perennial vegetation.[118]

A study specifically looking at Wisconsin vegetation buffers admitted that the effect of historical land use on modern channels leads to higher phosphorus levels, but concluded "in most watersheds, a large proportion (approximately 70 %) of these pollutants can be eliminated from streams with buffers."[119] Thus, state-led vegetation buffer implementation policies are widely considered a major step in the right direction and a necessary best management practice.

5. Practical Considerations

Although wetland and vegetation buffer creation are two of the most effective ways to reduce nutrient levels in waterways flowing to the Gulf, some potential practical constraints exist. Public sentiment provides the first potential obstacle. For years, wetlands were seen as wasted space and simply a nuisance that bred disease-ridden mosquitos. In fact, in the 1800s, swampland was essentially given away to those who would drain it and make it useful. However, researchers have relatively recently begun to understand the ecological functions associated with wetlands and their societal significance. Thus, through science and education, the public is starting to see the many "benefits that wetlands provide [in the way of] water-quality improvement, flood attenuation, esthetics, and recreational opportunities."[120] Despite these improvements, progress is slow and greater education is still needed.

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117. *See id.*

118. MINN. STAT. § 103E.021 (2014).

119. M. Diebel et al., *Landscape Planning for Agricultural Nonpoint Source Pollution Reduction III: Assessing Phosphorus and Sediment Reduction Potential*, 43 ENVTL. MGMT. 69, 69 (2009).

120. Mary E. Kentula, *Restoration, Creation, and Recovery of Wetlands*, U.S. GEOLOGICAL SURVEY, (last visited Nov. 10, 2014), http://water.usgs.gov/nwsum/WSP2425/restoration.html (last visited Nov. 10, 2014).

Funding for creation of these best management practices is certainly a potentially large obstacle, but one that can be successfully conquered. An exciting example of success comes from CREP, which provides funding assistance for farmers and ranchers looking to set land aside for wetland creation to intercept tile drainage from agricultural watersheds.[121] Landowners who voluntarily participate in this program receive compensation for costs associated with wetland and buffer establishment and annual land payments for up to fifteen years.[122] As this process unfolds locally, program managers work with each landowner so their individual operations are not negatively affected.

Similarly, organizations realize this funding must come from joint cooperation in order to sustain long-term improvements in water quality. Of immense importance is the enthusiastic support that wetland and buffer creation receives from outdoorsmen and duck hunting organizations. For example, Duck Commander, a prominent name in the hunting industry, recently joined over 150 other companies located in Louisiana to sign a letter urging Congress to support restoration of the Mississippi River Delta's endangered wetlands.[123] Certainly awareness of this issue is gaining momentum, with the added benefit that private funds and pressure will follow in support of wetland and vegetation buffer creation, restoration, and maintenance.

While reduction of agricultural chemicals, wetland creation, and vegetation buffer creation can all be effective in small part on their own, they must be implemented together to target agricultural runoff. Even if farmers and ranchers use best management practices by implementing one of the above methods, unexpected heavy rainfall or other environmental factors may still cause harmful chemicals to enter waterways and flow downstream toward the Gulf of Mexico.[124] Thus, these methods must be implemented jointly in order to see positive results such as those reported by the Mississippi River Watershed Partnership.[125]

C. Chesapeake Bay Case Study

The Chesapeake Bay is the largest estuary in the United States, measuring roughly 200 miles long with a watershed of almost 64,000 square

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121. *See Conservation Reserve Enhancement Program*, *supra* note 56.

122. *See id*.

123. *Duck Commander Champions Support For Mississippi River Delta*, WATERFOWLER.COM, http://waterfowler.com/duck_hunting/duck-commander-champions-support-mississippi-river-delta/ (last visited Aug. 10, 2015).

124. *What are farmers and ranchers doing to reduce fertilizer and pesticide use?*, BESTFOODFACTS.ORG (Oct. 17, 2011), http://www.bestfoodfacts.org/food-for-thought/reduce_fertilizerpesticide.

125. *See id.*

miles.[126] During the 20th century, the Bay's fish and shellfish populations decreased, signaling an overall deterioration in the health of the Bay.[127] Scientists and environmental experts blamed this deterioration on increased levels of agricultural runoff, population growth, and sewage treatment plant discharges fed chiefly from the Susquehanna and Potomac Rivers.[128] The EPA estimates that about 60% of the nutrients that reach the Bay come from nonpoint sources, the largest of which is agricultural runoff.[129] As in the Gulf of Mexico, these nutrients promoted increased algae growth that directly lead to the creation of a dead zone in Chesapeake Bay.

While researchers originally believed that hypoxia in the Chesapeake Bay steadily worsened every summer since the 1950s and 1960s,[130] a 2011 study conducted by The Johns Hopkins University and the University of Maryland Center for Environmental Science discovered this dead zone "leveled off in deep channels of the bay during the 1980s and has been declining ever since."[131] In recent years, researchers recorded early summer spikes in the dead zone size, leading them to speculate that reducing nutrients in the bay was not improving bay health; however, this 2011 study directly addressed these fears by finding these significant increases were due to "changes in climate forces like wind, sea levels and the salinity of the water."[132] As such, continued nutrient reduction remains the most important component to achieving improvements in the Chesapeake Bay.

The finding that the size of the dead zone leveled off in the 1980s is of particular significance because the Chesapeake Bay Program began targeted efforts to reduce nutrient pollution in the Bay during this time period.[133] State and federal efforts combined "to reduce the flow of algae-feeding into the Bay. For example, farmers were encouraged to plant natural barriers . . . to keep fertilizer out of waterways that feed the Chesapeake."[134] The program promoted increased nutrient management practices through which "fertilizers are applied to farmland in amounts carefully calculated to meet

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126. *See Chesapeake Bay cleaner says report*, SCHOOL OF SUSTAINABILITY (Nov. 8, 2011), http://www.school-of-sustainability.com/chesapeake-bay-cleaner-says-report/ [hereinafter SCHOOL OF SUSTAINABILITY]; *see also Chesapeake Bay*, EPA, http://www.epa.gov/oaqps001/gr8water/xbrochure/chesapea.html (last visited Aug. 11, 2014).

127. *See* SCHOOL OF SUSTAINABILITY, *supra* note 126.

128. *See Chesapeake Bay*, supra note 126.

129. *Id*.

130. *Dead Zones: A Common Symptom of Nutrient Pollution*, NOAA'S STATE OF THE COAST, http://stateofthecoast.noaa.gov/hypoxia/dead_zone.html (last visited Aug. 10, 2015).

131. *See* SCHOOL OF SUSTAINABILITY, *supra* note 126.

132. *Id.*

133. *Id*.

134. *Id.*

the needs of the crops. This practice reduces the runoff and leaching of nutrients that result from overuse of fertilizers."[135]

Planting underwater bay grasses, vegetation buffer creation, and wetland restoration and creation are critical to increased wildlife health and a significant component to the overall health of the Chesapeake Bay ecosystem. This is a considerable concern for the Bay, as the "fishing industry holds tremendous commercial, cultural and historic value[, so . . . m]anaging the fisheries for blue crabs, oysters, striped bass, shad and menhaden" is of particular importance to restoring the region's health.[136] However, due to funding cuts, the large-scale planting of these underwater grasses in the Bay is now a rarity.[137]

Vegetation buffer creation has been marginally successful in the region, with a slight decrease in planting of these areas from 2010-2013.[138] Pennsylvania, for example, planted 138.7 miles of forest buffers in 2013, and since 2000 the state has restored 58% of vegetation buffer miles located in the Bay watershed.[139] Recently, the Chesapeake Bay Program committed to creating or restoring 14,400 additional miles of forest buffers between 2010 and 2025, averaging out to about 900 miles per year.[140]

Wetland creation and restoration has met great success in the region, primarily through land purchases and conservation easements. "Between 2010 and 2013, 6,098 acres of wetlands were established, rehabilitated or reestablished on agricultural lands in the Chesapeake Bay Watershed."[141] This wetland construction is extremely encouraging and signaled the beginning of increased restoration and creation efforts adopted by the Chesapeake Bay Program in 2014, which pledged "to create or reestablish 85,000 acres of tidal and non-tidal wetlands by 2025."[142]

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135. *Chesapeake Bay*, *supra* note 126.

136. *Restoration and Protection Efforts*, CHESAPEAKE BAY PROGRAM, http://www.chesapeakebay.net/track/restoration (last visited Aug. 7, 2015).

137. *See Planting Underwater Bay Grasses*, CHESAPEAKE BAY PROGRAM, http://www.chesapeakebay.net/indicators/indicator/planting_bay_grasses (last visited Aug. 7, 2015). Both funding and capacity for bay grass planting need to be increased dramatically to meet the goals set by the Bay Program. To date, "[t]he National Oceanic and Atmospheric Administration's Chesapeake Bay Office and U.S. Army Corps of Engineers Engineer Research and Development Center have funded almost all of the large-scale plantings in the region. Neither agency has been able to increase the funding enough to meet the annual planting need." *Id.*

138. *See Planting Forest Buffers*, CHESAPEAKE BAY PROGRAM, http://www.chesapeakebay.net/indicators/indicator/planting_forest_buffers (last visited Aug. 7, 2015).

139. *Id*.

140. *Id*.

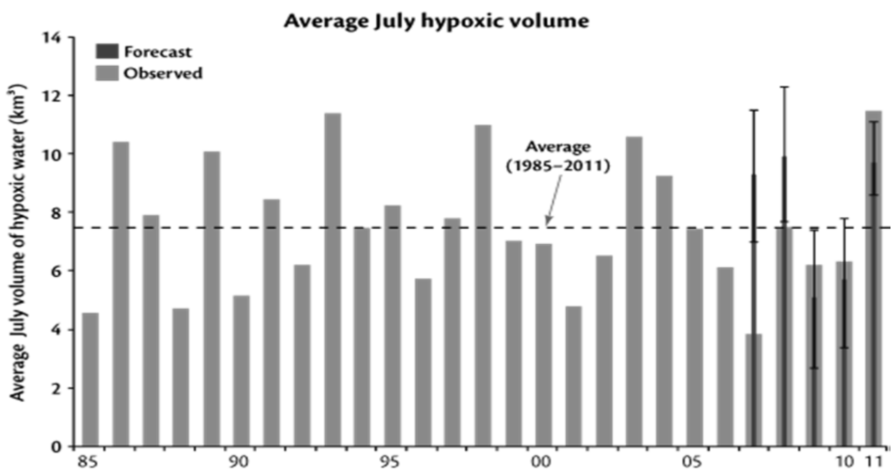
141. *See Restoring Wetlands on Agricultural Lands*, CHESAPEAKE BAY PROGRAM, http://www.chesapeakebay.net/indicators/indicator/restoring_wetlands (last visited Aug. 11, 2015).

142. *See id.*

> This goal is based on the wetland restoration targets outlined in the Watershed Implementation Plans (WIPs) that will help jurisdictions meet the goals of the

In 2010, the EPA established the Chesapeake Bay Total Maximum Daily Load ("TMDL"), which sets limits on the amount of nitrogen, phosphorus, and sediments allowed to enter the Bay each year.[143] Through TMDLs, the Chesapeake Bay Program estimates that nitrogen loads to the Bay will be reduced by 75.09 million pounds: from 282.66 million pounds in 2009 to 207.57 million pounds by 2025.[144]

Table 2: This graph shows average July hypoxic volume each year in the Chesapeake Bay from 1985-2011.[145]



Bay's "pollution diet," or Total Maximum Daily Load (TMDL). Under this target, 83,000 acres of tidal and non-tidal wetlands should be created or reestablished on agricultural lands.

Id.

143. *See Restoration and Protection Efforts*, *supra* note 136.

144. *Reducing Nitrogen Pollution*, CHESAPEAKE BAY PROGRAM, http://www.chesapeakebay.net/indicators/indicator/reducing_nitrogen_pollution (last visited August 13, 2014). For specific information and videos about the reduction of nitrogen by source, jurisdiction, and total load, see *id.*

145. *See ecocheck: How healthy is your ecosystem?*, INTEGRATION & APPLICATION NETWORK, http://ian.umces.edu/ecocheck/summer-review/chesapeake-bay/2011/indicators/hypoxia/ (last visited Nov. 20, 2014).

In June 2011, scientists forecasted that the 2011 July hypoxic volume would be 9.7 km^3, based on January to May total nitrogen loads. The observed July hypoxic volume was 11.47 km^3, which is higher than the forecasted number and also above the forecasted range of 8.6 to 11.1 km^3. The average hypoxic volume for 2011 is the highest on record (since monitoring began in 1985), slightly higher than the previous record of 11.38 km^3 in 1993.

Id. For more information, visit the University of Michigan's School of Natural Resources & Environment, available at http://snre.umich.edu/.

However, some argue that "[d]espite comprehensive modeling and monitoring programs, the complex hydrodynamics, biogeochemistry, and varying inputs from a large watershed have led to uncertainty about the response of Bay hypoxia to management actions."[146] Yet other researchers claim:

> long-term nutrient monitoring and modeling is key to tracking how nutrient conditions are changing in response to floods and droughts and nutrient management actions . . . . Understanding the sources and transport of nutrients is key to developing effective nutrient management strategies needed to reduce the size of hypoxia zones in the Gulf, Bay and other U.S. waters where hypoxia is an ongoing problem.[147]

In furthering this goal of monitoring, the U.S. Geological Survey operates more than 3,000 real-time stream gages and collects water quality data at numerous long-term stations throughout the Mississippi River basin and the Chesapeake Bay to track how nutrient loads are changing over time.[148]

While the long-term effects of these toxins in the Chesapeake Bay are largely unknown, similar to the Gulf of Mexico, their impact on the commercial fishing industry and overall health of the Bay is immediate.[149] Yet, efforts to reduce nutrient enrichment in the region are showing steady progress that is encouraging for other regions also currently dealing with hypoxia issues.[150] The Gulf of Mexico in particular can benefit from the efforts in the Chesapeake Bay by observing the success of cooperative programs and realizing that an increased focus on best management practices, such as reduced chemical use, wetland creation, and vegetation buffer creation, implemented together produce the most significant results. The Gulf can also benefit from recent studies and emerging monitoring technology that shows best management practices are substantially impacting nonpoint source pollution, particularly agricultural runoff.[151] The

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146. Rebecca R. Murphy & William P. Ball, *Analysis of Chesapeake Bay Hypoxia and Stratification*, JOHNS HOPKINS WATER MAGAZINE (Aug. 10, 2010), http://water.jhu.edu/magazine/analysis-of-chesapeake-bay-hypoxia-and-stratification/.

147. *Scientists anticipating smaller hypoxia levels this summer in Chesapeake Bay*, UNIV. OF MD. CTR. FOR ENVTL. SCI., http://www.umces.edu/story/2013/jun/18/scientists-anticipating-smaller-hypoxia-levels-summer-chesapeake-bay (last visited Oct. 17, 2014).

148. *Id.*

149. *See* Houck, *supra* note 3, at 10431-32.

150. *See generally supra* text accompanying notes 133-148.

151. *See infra* text accompanying notes 161-163.

slow progress of these efforts in the Bay can be hastened in the Gulf if greater focus is placed on local and state-led initiatives, with the increased education of farmers and ranchers as to the short-term and long-term benefits of best management practices.

D. Initiatives Needed and Future Outlook

While a healthy and bright future is well within reach for the Mississippi River Basin, many challenges lie ahead. First, funding may be an ongoing problem, especially for state initiatives that generally rely upon the support of state taxpayers and strong public opinions. Partnerships such as the Mississippi River Gulf of Mexico Watershed Nutrient Task Force and the Conservation Reserve Enhancement Program provide local, state, and even regional actors with the ability to implement changes through the significantly larger budget of the federal government through the USDA and the CWA.[152] Additionally, increased public awareness also increases public support and private fund donations. Monsanto's five million dollar partnership with The Nature Conservancy, which directly supported the Mississippi River Watershed Partnership, farmers and ranchers, and conservation groups, serves as a prime example of how important this private monetary support is for nutrient reduction efforts moving forward.[153]

The continued education of farmers and ranchers is crucial to the success of these initiatives. The support of farmers, despite the strong potential for initial mistrust of additional regulations on cultivating processes, encourages voluntary participation in implementing best management practices during daily agricultural operations. Education is the key to helping farmers and ranchers understand the numerous personal and environmental benefits that result from implementation of these conservation techniques.

The most efficient way to combat this large-scale problem of agricultural runoff is through the combined efforts of local, state, regional, and federal actors. Local and state actors have an intimate grasp on issues particular to their geographical areas, such as farming practices, topography, and public sentiment. Thus, local and state actors should continue to lead the way in implementing best management practices such as chemical use reduction, wetland creation, and vegetation buffer creation along the waterways in the Mississippi River Basin. In addition, by creating vegetation buffers, farmers and ranchers have the unique opportunity to minimize the environmental impacts of pesticides, while working to preserve the longevity of their land for themselves and future generations.

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152. *See supra* text accompanying notes 56-59.
153. *See supra* text accompanying notes 92-96.

While federal initiatives have the advantage of larger budgets and greater uniformity, I believe strong local voices are needed in order to ensure that the creation of these wetlands and vegetation buffers is handled with a particular eye to the specific needs of each region. If not handled properly, or if local citizens, primarily local farmers and ranchers, feel as though they are being told what they must do on their land, these initiatives will fall short of their intended goals. Implementation of these methods with cooperation creates a mutually beneficial arrangement for all parties involved, including the environment.

In light of both the regional considerations and the local nuances presented, this issue is currently, and properly, being addressed with a watershed approach.[154] A "watershed" approach is "a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically-defined geographic areas, taking into consideration both ground and surface water flow."[155] This approach is exceedingly beneficial because it sheds light on local and regional economic realities within the context of environmental sensitivity while remaining true to the watershed objectives.[156] "Establishing [these] environmental indicators helps guide activities toward solving those high priority problems and measuring success in making real world improvements rather than simply fulfilling programmatic requirements."[157] Thus, nutrient reduction in the Mississippi River Basin should continue through a watershed approach.

As discussed above, the exciting new partnership between the Task Force and the twelve land grant universities will achieve a new level of local, state, regional, and federal cooperation.[158] While this type of alliance is the first of its kind for the Task Force and non-governmental entities,[159] continued success is likely because it accounts for the interests of many within the framework of the region as a whole.

> The most important lesson learned is that an effective watershed management program requires many participants working in concert, with input from key stakeholders, including farmers and others affected by water quality

154. *Benefits Derived from Taking a Watershed Approach*, EPA, http://www.epa.gov/owow/watershed/framework/ch5.html (last visited Aug. 13, 2015).

155. *What is a Watershed Approach?*, EPA, http://www.epa.gov/owow/watershed/framework/ch2.html (last visited Aug. 13, 2015).

156. *See Benefits Derived from Taking a Watershed Approach*, *supra* note 154.

157. *Id.*

158. *See supra* notes 50-52 and accompanying text.

159. *See Mississippi River/Gulf of Mexico Watershed Task Force Announces Agreement with 12 Universities to Further Water Pollution Reduction Programs and Goals*, *supra* note 50.

> concern and the action proposed to address it. Conservation practices that managers recommend must be based on solid science and economics and must have the potential to achieve water quality goals of stakeholders.[160]

Innovative technological developments further aid these cooperative efforts and provide additional opportunities to refine best management practices already in practice on a large scale.[161] On November 4, 2014, for example, the U.S. Geological Survey announced the use of new sensor technology in the Mississippi River Basin.[162] This technology detects rapid changes in nitrate concentration levels every hour that were nearly impossible to detect with traditional monitoring methods, adding more depth to both the study of what must currently be done to reduce nitrate runoff and the future projections of chemical impacts in waterways throughout the United States.[163] Undoubtedly, this will aid analysis of nitrate levels and effects, serve to further educate discussions by providing insight into where these nitrate pulses originate, and forecast their arrival in the Gulf of Mexico. As science continues to identify what is needed,

> farmers, agency personnel, and the private and nonprofit sectors must work together to get those practices on the ground in the right places and ensure that they are properly managed and maintained. This requires that all parties understand what farmers can and will accept and that practices be tailored to meet those demands while still achieving water quality goals. It also is critical that education, technical assistance, and financial assistance be consistent, well organized, and highly coordinated. Finally, correcting water quality problems and protecting water resources at the watershed scale are on-going processes that will require effective support and adaptive management to achieve true, long-lasting sustainability.[164]

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160. Deanna L. Osmond et al., *Synthesizing the Experience of the 13 National Institute of Food and Agriculture-Conservation Effects Assessment Project Watershed Studies: Present and Future*, *in* HOW TO BUILD BETTER AGRICULTURAL CONSERVATION PROGRAMS TO PROTECT WATER QUALITY:THE NATIONAL INSTITUTE OF FOOD AND AGRICULTURE–CONSERVATION EFFECTS ASSESSMENT PROJECT EXPERIENCE 151, 166-67 (Osmond, Meals, Hoag & Arabi eds., 2012), *available at* http://www.swcs.org/documents/filelibrary/conservation_programs_to_protect_water_quality/Chapter8_F663E50742ED2.pdf.

161. *See Technical Announcement: Tracking the Nitrate Pulse to the Gulf of Mexico*, USGS NEWSROOM (Nov. 4, 2014 11:36 AM), http://www.usgs.gov/newsroom/article.asp?ID=4046#.VgeoModPI2n.

162. *Id*.

163. *Id*.

164. Osmond, *supra* note 160.

This kind of collaboration structure and regulatory scheme, which combines new research with the state-led implementation of reduced chemical use, wetland creation, and vegetation buffer creation, is needed for the Gulf restoration to truly be a success.

As much must yet be accomplished in the Mississippi River Basin, it is tempting to resolve the issue with federally mandated standards for all waters that fall under the authority of the CWA. If nutrient enrichment is not decreased through a joint implementation of the above methods, thus allowing the hypoxic zone in the Gulf of Mexico to grow in the coming years, fertilizer and pesticide limits and discharge permits will likely become mandatory through government policy.[165] However, these restrictions would be met with much opposition and scar the long-term relationship benefits of a cooperative process. Instead, the "EPA should continue to encourage states to develop and implement nutrient reduction plans but should institute a timeline with teeth to impose consequences on states that are slow to comply[,] . . . giv[ing] those states an incentive to press the difficult-to-solve issue of nonpoint source pollution within their own boundaries."[166] This should be done by states with an increased focus on expanded stakeholder engagement and cooperation between local, state, and regional actors. A "spur to action" is needed, but the focus should still be on local and state-led initiatives, as the implementation of best management practices is relatively simple and has been shown to be effective at reducing nonpoint source nutrient pollution.[167]

VI. CONCLUSION

Poor farming practices and business practices in the heartland of America have contributed greatly to nutrient enrichment in the Mississippi River Basin, creating a dead zone that stretches thousands of square miles each summer.[168] In order to effectively reduce the nitrate and phosphate runoff into the Mississippi River, local, state, regional, and federal actors must work together to educate and implement best management practices with farmers and ranchers, local businesses, and conservation and watershed management professionals.[169] Through implementation of these practices, a significant number of additional wetlands and vegetation buffers should be created and restored throughout the Midwest, especially in Ohio and along the Upper Mississippi region.[170] These best management practices must

165. *See Hypoxia Issues in the Gulf of Mexico*, *supra* note 63.
166. Zadalis, *supra* note 25, at 400.
167. *See id.*
168. *See supra* text accompanying notes 1-3.
169. *See supra* text accompanying note 164.
170. *See supra* Parts V.B.3-4.

also be implemented with reduced agricultural chemical use in order to significantly decrease the amount of nutrients that enter the Mississippi River Basin each year, and in turn, the size of the hypoxic zone in the Gulf of Mexico.[171]

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171. *See supra* text accompanying notes 65-67.