Reviving the Dead Zone

Solutions to Benefit Both Gulf Coast Fishers and Midwest Farmers

Technical Appendices

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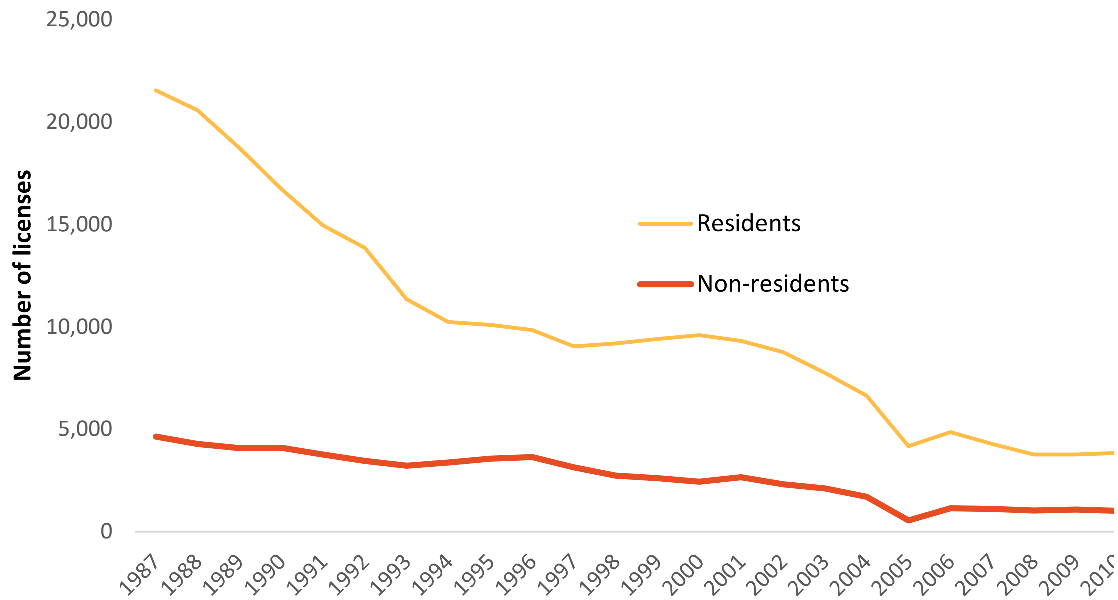
Appendix 1 : Louisiana Shrimp and Fishing Licenses

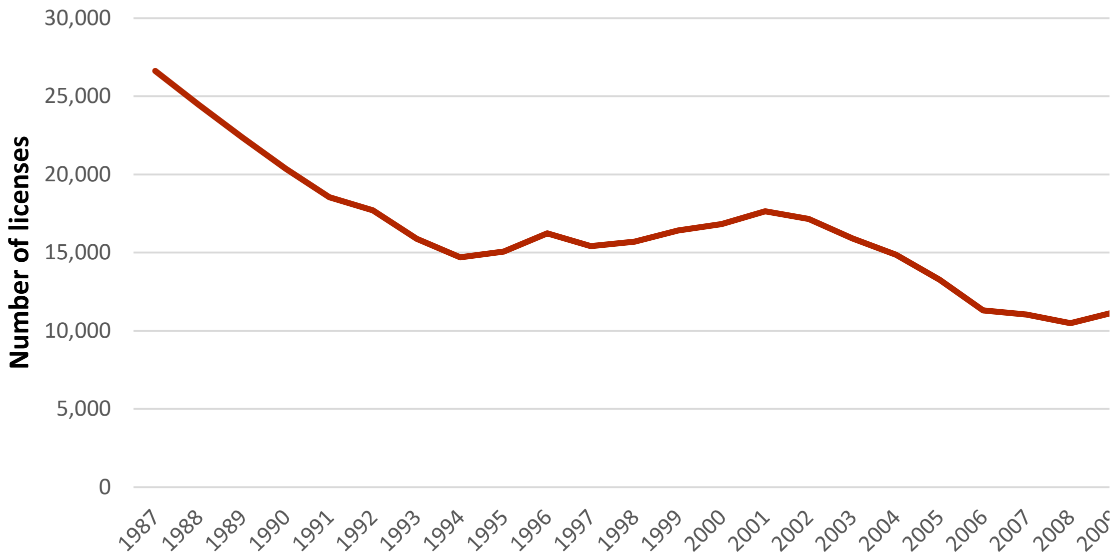
These graphs show the decline in shrimp and commercial fishing licenses in Louisiana from 1987 to 2012 using the most recently available data from the Louisiana Department of Wildlife and Fisheries.

Figure A1.1. Decline in Louisiana Shrimp Trawl Licenses Granted to Louisiana Residents and Non-Residents



Source: LDWF 2019.

Figure A1.2. Decline in Commercial Fishing Licenses Granted to Louisiana Residents



Source: LDWF 2019.

Appendix 2: Method for Estimating Total Fertilizer Nitrogen Applied to Corn and Soybeans and the Amount Lost to the Mississippi and Atchafalaya River Basins

Fertilizer Nitrogen Applications

To estimate fertilizer nitrogen applications in the Mississippi and Atchafalaya River basins (MARB), we compiled annual state-level data from the US Department of Agriculture on fertilizer nitrogen applications to the region's dominant crops, corn and soybeans (NASS 2018).

Data for applications to corn acres were available for 1990 to 2003, 2005, 2010, 2014, 2016, and 2018. Data for applications to soybean acres were available for 1990 to 2002, 2004, 2005, 2012, 2015, 2017, and 2018. We used linear regression analysis (independent variable was year; dependent variable was state-level nitrogen application in tons) to interpolate missing values for time periods with no data between 2003 and 2017.

We compiled data only for states that drain partially or exclusively into the MARB (Table A2.1). To determine whether a state watershed empties into the MARB exclusively, partially, or not at all, we visually evaluated a map of US states and the boundaries of the MARB (Battaglin et al. 2010).

We then estimated total state-level fertilizer nitrogen tons applied annually to corn and soybeans for all states that either exclusively or partially drain into the MARB. We summed the total value of all fertilizer nitrogen applied to all corn and soybeans in all of those states to represent an upper bound estimate. We then summed all of the fertilizer nitrogen applied to all corn and soybeans in just the states that exclusively drain to the MARB as a lower bound. We assumed that actual estimated total fertilizer nitrogen applied annually in the MARB was the midpoint between these upper and lower bounds.

Annual Nitrogen Losses to the Mississippi and Atchafalaya River Basins Waterways

To estimate fertilizer nitrogen applied to corn and soybean acres that is lost to waterways that feed into the MARB, we used published estimates for nitrogen use efficiency (NUE) and loss coefficients (Zhang et al. 2015; NRCS 2012). NUE is the fraction of fertilizer nitrogen applied that is absorbed and used by crops, with the remainder being lost to the environment. The loss coefficient was estimated based on field research observations on the amount of fertilizer nitrogen lost via different pathways (i.e., surface water, groundwater, air) (NRCS 2012). To calculate the amount of fertilizer nitrogen applied that is lost to the environment we multiplied the midpoint estimate of total fertilizer nitrogen applied to corn and soybeans in the MARB by one minus the annual US-based estimate of NUE (Zhang et al. 2015). We then multiplied the annual amount lost to the environment by a coefficient that estimates the share of this lost nitrogen that enters groundwater and surface water (NRCS 2012). This calculation can be summarized in the following equation:

$$N\ lost\ to\ MARB\ waterways_y = N\ applied\ in\ MARB_y * \left(1 - NUE_y\right) * \%\ N\ lost\ to\ water$$

where fertilizer nitrogen (N) lost to MARB in year y is a function of the estimated amount of N applied in the MARB to corn and soybeans (the midpoint estimate), $1 - NUE_y$ presents the share of N that is lost to the environment, and % N lost to water is the estimated share of N lost that enters groundwater and surface water.

Table A2.1. US States Designated as Exclusively or Partially Draining into the Mississippi and Atchafalaya River Basins

State Watersheds Exclusively Draining into MARB	State Watersheds Partially Draining into MARB
Arkansas	Alabama
Illinois	Colorado
Iowa	Georgia
Kansas	Indiana
Missouri	Kentucky
Nebraska	Louisiana
Oklahoma	Minnesota
South Dakota	Mississippi
Tennessee	Montana
	New Mexico
	New York
	North Carolina
	North Dakota
	Ohio
	Pennsylvania
	South Carolina
	Texas
	Virginia
	West Virginia
	Wisconsin
	Wyoming

Note: The states with watersheds that do not drain into the MARB are Arizona, California, Connecticut, Delaware, Florida, Idaho, Maine, Maryland, Massachusetts, Michigan, Nevada, New Hampshire, New Jersey, Oregon, Rhode Island, Utah, Vermont, and Washington.

Source: Battaglin et al. 2010

Appendix 3: Scenarios for Nitrogen Loss Reductions through Agricultural Practices

Table A3.1. Damage Cost Estimates for Reductions in May Total Nitrogen (TN) in the Gulf of Mexico through Changes in Agricultural Practices

	Damage Costs (Billions of 2010 Dollars)			Total Annual Damage Costs Averted, 2010 Dollars	Total Annual Damage Costs Averted, 2018 Dollars
	Baseline Costs	New Costs Following Changes in Agricultural Practices	Difference in Costs (New Costs – Baseline)		
Scenario 1: Average annual damage costs averted with 6.3% May TN load reduction					
Low	0.48	0.45	0.03	30,000,000	34,300,000
Medium	1.29	1.17	0.12	120,000,000	138,196,800
High	2.09	1.94	0.15	150,000,000	172,746,000
Note: May TN reductions in this scenario are based on widespread adoption of targeted conservation practices in the MARB (Rabotyagov et al. 2014).					
Scenario 2: Average annual damage cost averted with 14.7% May TN load reduction					
Low	0.48	0.41	0.07	70,000,000	80,614,800
Medium	1.29	1.06	0.23	230,000,000	264,877,200
High	2.09	1.78	0.31	310,000,000	357,008,400
Note: May TN reductions in this scenario are based on implementation of cover crops on 99% of cultivated acres with slope of less than 5% in the Upper Mississippi and Ohio-Tennessee river basins (Kling et al. 2014).					
Scenario 3: Average annual damage cost averted with 20% May TN load reduction					
Low	0.48	0.39	0.10	96,000,000	110,557,440
Medium	1.29	1.00	0.29	292,000,000	336,278,880
High	2.09	1.67	0.42	420,000,000	483,688,800
Note: May TN reductions in this scenario are based on expansion of suite of farm bill programs that increase cover cropping; implementation of nutrient management; restoration of floodplains, wetlands, and forests; and other practices across the MARB (Tallis et al. 2019).					
Scenario 4: Average annual damage cost averted with 33% May TN load reduction in stream nitrogen loads in the Upper Mississippi River Basin					
Low	0.48	0.32	0.16	159,000,000	183,110,760
Medium	1.29	0.84	0.45	454,000,000	522,844,560
High	2.09	1.40	0.69	690,000,000	794,631,600
Note: This scenario is based on treatment of 35.2 million acres with erosion control practices plus nutrient management practices (NRCS 2012).					

Scenario 5: Average annual damage cost averted with 45% May TN load reduction					
Low	0.48	0.28	0.20	197,000,000	226,873,080
Medium	1.29	0.74	0.55	554,000,000	638,008,560
High	2.09	1.23	0.86	860,000,000	990,410,400
Note: This scenario is based on expansion of suite of farm bill programs that increase cover cropping; implementation of nutrient management; restoration of floodplains, wetlands, and forests; and other practices (Tallis et al. 2019).					

Notes: Low, medium, and high damage costs values were calculated using the low, medium, and high nitrogen damage factors from Sobota et al. 2015. In all scenarios, current and reduced damage cost values were calculated as averages based on 1980 to 2017 Gulf nitrogen loading data produced by the US Geological Survey (Lee, Norman, and Reutter 2018). 2010 dollar estimates were adjusted using the Bureau of Labor Statistics CPI Inflation Calculator, available online at https://www.bls.gov/data/inflation_calculator.htm.

Detailed Description of Scenarios 1 through 5

- Scenario 1: Water erosion control and improved fertilizer nitrogen management on cropland across the MARB (Rabotyagov et al. 2014). Practices to improve water erosion on farmland included terracing, contour cropping, strip cropping, riparian buffers, filter strips, and improvements to irrigation water conveyance and application. Improved fertilizer management practices included reduced application rates, moving nutrient applications from fall to spring, and implementation of application methods to reduce field losses. Adoption of such practices on approximately 44 million acres of cropland was estimated to reduce May TN loading by 6.3 percent, while reducing the dead zone five-year average areal extent by 21 percent.
- Scenario 2: Widespread adoption of cover crops on cropland across the MARB (Kling et al. 2014). In this scenario cover crops are implemented on approximately 32 million acres of farmland in two major MARB tributaries that empty into the Gulf of Mexico. In this scenario May TN loading is reduced by 14.7 percent, reducing the dead zone areal extent by 47 percent and bringing its size to near the short-term goal of the Gulf Hypoxia Task Force (EPA 2017).
- Scenario 3: Widespread adoption of cover cropping, nutrient management plans, conservation tillage, improved subsurface tile management, installation of waterway buffers, perennial crop planting, or land retirement on cropland in the MARB (Tallis et al. 2019). In this scenario a 20 percent reduction in annual nitrogen export from the Ohio and Upper Mississippi River basins - two watersheds which deliver a disproportionate share of nutrients to the Gulf - could be achieved if these practices are adopted on 46.7 million acres in the watershed. For simplicity, we assume that this 20 percent reduction would translate into an equivalent reduction in May TN loading in the Gulf of Mexico. This 20 percent reduction also corresponds to the Mississippi River/Gulf Hypoxia Task Force short term reduction goal.
- Scenario 4: Widespread adoption of erosion control and nutrient management practices on cropland in the MARB (NRCS 2012). In this scenario a 33 percent reduction in average May nitrogen loading is accomplished through treating 35 million acres in the MARB with erosion control and nutrient management practices. These practices are adopted on cropland that is particularly vulnerable to nutrient and soil losses. Because cost data were not available for this scenario, we estimated them using data practice costs, adjusted to 2010 dollars, of implementing various nitrogen-reduction practices in US agriculture (Doering et al. 1999).
- Scenario 5: Widespread adoption of cover cropping, nutrient management plans, conservation tillage, improved subsurface tile management, installation of waterway buffers, perennial crop planting, or land retirement on cropland in the MARB (Tallis et al. 2019). A 45% reduction in Gulf May TN nitrogen loading would be aligned with achieving the Mississippi River/Gulf Hypoxia Task Force long term reduction target in nitrogen export from the Ohio and Upper Mississippi River basins, two watersheds which deliver a disproportionate share of nutrients to the Gulf. This reduction is partially achieved by implementing the same practices on the same land as in scenario 3 from Tallis et al. 2019.

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