THE IMPACT OF HYPOXIA ON THE LOUISIANA BROWN SHRIMP FISHERY AND THE POTENTIAL FOR THE PUBLIC TRUST DOCTRINE TO SLOW NONPOINT SOURCE POLLUTION

by

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THESIS ABSTRACT

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Seasonal hypoxia in the northern Gulf of Mexico has been mapped extensively and is known to overlap the habitat of the brown shrimp *Farfantepenaeus aztecus* on the Louisiana continental shelf. Yet the impacts of Gulf hypoxia on the profitable brown shrimp fishery in Louisiana remain largely unknown. The problem is primarily attributable to nonpoint source pollution in the Mississippi River, but awareness of the problem has not resulted in an effective policy solution to stem this pollution to date. Using the combination of a quantitative data analysis to look for a correlation between *Farfantepenaeus aztecus* and hypoxic water, a survey mailed to shrimp fishers in Louisiana, and qualitative interviews with shrimp fishers and environmental activists and lawyers in Louisiana, I will examine the potential of a legal tool, the Public Trust doctrine, to slow nonpoint source pollution into the Mississippi River.

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INTRODUCTION

The Problem with Hypoxia in the Northern Gulf of Mexico

The Northern Gulf of Mexico is home to the largest hypoxic area, or "dead zone", in the western Atlantic (Rabalais, Turner, & Scavia, 2002). Hypoxia stems from eutrophication and is clearly linked to human population growth and concurrent increases in nearby agricultural production (Diaz & Rosenberg, 2008; Ibid.). There is consensus within the scientific community that Gulf hypoxia is primarily attributable to agricultural runoff-derived nitrogen, which fuels algal growth along the Texas-Louisiana continental shelf (Bianchi et al., 2010; Diaz & Rosenberg, 2008). Algae and other phytoplankton are stimulated by high levels of nitrogen and phosphorous, which can easily enter waterways from agricultural fields. These nutrients allow phytoplankton colonies to grow to large sizes, or "bloom". The Mississippi and Atchafalaya Rivers combined are responsible for 91% of the nitrogen and 88% of the phosphorous entering the Gulf (Landers, 2008), and estimates of nutrient loading attribute 78% of nitrogen and 66% of phosphorous loading to nonpoint sources (Gulf Hypoxia Action Plan, 2008).

The Mississippi River Basin drains 41% of the contiguous U.S., and almost 60% of that area is cropland (Craig, 2012). While nitrogen pollution declined 21% between 2000 and 2005 (Gulf Hypoxia Action Plan, 2008), the amount of nitrogen entering the Gulf from the Mississippi River tripled between 1970 and 2000 (Goolsby et al., 2001;

Gulf Hypoxia Action Plan, 2008). This large river basin deposits its water and nutrient pollution into the northern Gulf of Mexico, where the excess nutrients initiate and maintain seasonal phytoplankton blooms. As the phytoplankton colonies are consumed by larger organisms or perish, their remains sink to the seafloor where they are consumed by aerobic bacteria, which use oxygen as they respire. Normal (non-bloom) levels of phytoplankton colonies do not lead to hypoxia, but the large increases in their numbers when they bloom translates into increases in phytoplankton-consuming bacteria on the seafloor, which leads to a drawdown of oxygen in the water column. When the water remains stratified due to density differences in the water column, as is typical in the summer months, this process leads to hypoxia (water with a dissolved oxygen content of less than 2 mg/L), and in extreme events anoxia (water with a dissolved oxygen content of ~0 mg/L) because the oxygen is not replaced by water column mixing. This can leave a large area of ocean uninhabitable to most organisms. The Gulf hypoxic zone has been increasing at least since the 1980s, and likely since the 1960s, to a size that averaged 13,600 km^2 between 1993 and 2004, and reached a maximum of 22,000 km^2 in the summer of 2002 (O'Connor and Whitall, 2007; Craig, 2012). Furthermore, sediment core data indicate hypoxia on this scale is not a natural state for the area and has been increasing since the 1950s (Rabalais, Turner, & Scavia, 2002; Rabalais, Turner, & Wisemen Jr., 2002). The Gulf hypoxic zone is so severe it is often referred to as a 'dead zone' by the media and locals.

Most of the Mississippi River no longer passes through filtering wetlands on its way to the delta in Louisiana because of alterations to its course through massive levee building (Rabalais, Turner, & Wisemen Jr., 2002). Instead, the River's water is propelled out of the delta in a fast-moving jet. A jet of water moves quickly and is not slowed by landforms that provide filtering such as wetlands. Another alteration to the system causes the Atchafalaya River to divert one third of Mississippi River water to an outlet 200 km west of the delta (Gulf Hypoxia Action Plan, 2008). This diversion allows more of the Mississippi-Atchafalaya River Basin (MARB) water to persist on the Texas-Louisiana continental shelf where hypoxia forms (the shelf is a relatively shallow piece of underwater land connected to the continent) because the shelf is wider at the Atchafalaya outlet than at the delta (Rabalais, Turner, & Scavia, 2002).

Documentation of Gulf hypoxia first occurred in 1972 and beginning in 1985 the problem has been mapped yearly (Rabalais, Turner, & Scavia, 2002). The Mississippi River Gulf of Mexico Watershed Nutrient Task Force completed their first Action Plan in 2001, in response to the Harmful Algal Bloom and Hypoxia Research Control Act of 1998 (Gulf Hypoxia Action Plan, 2008). The Action Plan was revised in 2008 and includes a goal of reducing Gulf hypoxia to 5000 sq km by the year 2015 (Dale et al., 2010). One overarching principle of the plan is to encourage voluntary actions (Gulf Hypoxia Action Plan, 2008). Unfortunately, the Action Plan goal is no longer attainable because there has not been enough effort to stem nutrient runoff (Dale et al., 2010). The problem clearly impacts the local community and presents a difficult discussion around our valuation of ocean health. The connections between terrestrial systems and ocean systems are no longer thought of as separate, yet our land practices continue to degrade ocean health by placing more value on terrestrial production at the expense of the oceans.

Hypoxia in the Gulf cannot be mitigated without reducing the nutrient load of the Mississippi River (Dale et al., 2010; Gulf Hypoxia Action Plan, 2008; Landers, 2008). If decreases in nutrient inputs are not achieved, the problem is expected to increase with weather pattern changes due to climate change. Climate change is projected to increase worldwide eutrophication processes through mechanisms including warmer waters and increased freshwater inputs to systems (Rabalais et al., 2009). Warmer waters contribute to increased phytoplankton growth through increased growth, metabolism, and respiration rates of phytoplankton and their bacteria decomposers. Increased freshwater to the system can intensify stratification of the water column because the density differences will be more pronounced between freshwater and saltwater.

Hypoxia can affect fisheries by interrupting the typical fish and invertebrate growth and migration patterns exploited by fishers. In the Gulf region of Louisiana, home to several large shrimp fisheries, the effects of hypoxia are beginning to be documented (Zimmerman and Nance, 2001; O'Conner and Whitall, 2007). The local brown shrimp (*Farfantepenaeus aztecus*) fishery overlaps the hypoxic zone spatially and is likely affected by it. The hypoxic zone could impact the fishery in a range a ways from physically blocking shrimp migration patterns to indirect impacts such as decreased growth and reproduction. The shrimp fishery in Louisiana is estimated to be worth $400-$500 million per year (Cowan Jr., Grimes, and Shaw, 2008), and the shoreline of Louisiana and Texas harbor the densest area of brown shrimp within the species' range (Lassuy, 1983). *F. aztecus* individuals migrate from estuaries to the continental shelf as growing juveniles, and the shrimp eventually spawns on the shelf (Lassuy, 1983; Turner & Brody, 1983). The fishing season for brown shrimp tends to overlap the hypoxic zone both in time and in space (Craig, 2012). This overlap may have negative impacts on the fishery through displacement, decreased growth or reproduction, or some combination of these factors that results in a decrease in brown shrimp abundance. The fishery could see positive short-term impacts due to aggregating behavior that allows for more shrimp to be caught in a smaller space (Ibid.), but this may obscure a long-term negative impact on abundance. Unfortunately, few field studies have been undertaken to examine the relationship between *F. aztecus* and dissolved oxygen (Larson, Van Den Avyle, & Bozeman, 1989), and scant studies have linked global fishery declines to hypoxia (Keller et al., 2010). However, a study of the economic impact of hypoxia in North Carolina found it reduced the local shrimp fishery annual harvest by almost 13% (Huang, Smith, and Craig, 2010). Ultimately, effects on fisheries catches from hypoxia may be subject to time lags, which may explain why previous studies have not found a large impact from hypoxia on fisheries (Huang et al., 2012).

Nonpoint Source Pollution and the Legal Vacuum

Agricultural land practices in the Midwestern U.S. are intimately linked to Gulf hypoxia. A large portion of the Midwest is underlain with a type of drainage system commonly called 'tiles'—essentially perforated plastic piping—that drain the landscape and help to shuttle excess nutrients off the land, into waterways, and ultimately into the Gulf via the MARB (Landers, 2008). Further compounding the problem, 80% of the wetlands in the area have been lost through a process of conversion to agricultural fields (Ibid). Wetlands provide a critical filtering service that serves to trap excess nutrients in place. Excess nutrients typically leave agricultural fields in the form of nonpoint source pollution, water-borne pollution that moves in a diffuse manner and does not exit a system through a pipe, and agriculture is the largest contributor of this form of pollution (Crutchfield, Malik, and Letson, 1994). Excess nutrients derive from fertilizer application, which increased twenty-fold between 1945 and 1985 (Puckett, 1994). That increase has slowed in recent years, with nitrogen inputs doubling between 1961 and 1997 (Howarth et al., 2002). If current agricultural practices continue, nitrogen and phosphorous linked eutrophication is estimated to increase by more than two-fold by 2050 (Tilman *et al*., 2001).

Nonpoint source pollution remains the largest regulatory hurdle for the Clean Water Act; 40% of water impairment in the U.S. is attributable to nonpoint source pollution (EPA, 2004). When the Clean Water Act (CWA) was made law, Congress established a national goal of creating fishable and swimmable rivers by 1983, and of eliminating all discharges into waterways by 1985 (Salzman & Thompson Jr., 2010). However, after more than forty-three years, these goals have remained elusive, largely due to nonpoint source (NPS) pollution (Parry, 1998). The Clean Water Act was not implemented with NPS pollution in mind, and merely treats it as an "afterthought" (Andreen, 2004). Unlike the regulation of point source pollution (water-borne pollution conveyed by a pipe or discrete conveyance) the Act leaves the task of NPS pollution regulation up to individual states (Jarrell-King, 2012; Dowd, Press, and Los Huertos, 2008). Furthermore, states receive little to no input from the EPA (which implements most of the CWA) regarding their decision to regulate or not (Salzman and Thompson, 2010). In this legal vacuum, many states choose to not regulate nonpoint source pollution at all while other states only provide for incentive programs that promote best management practices.

A recent engagement with the CWA's Total Maximum Daily Load program has provided some optimism that NPS pollution might finally be regulated (Houck, 2011). When a state's water bodies fail to meet its water quality standards, the CWA requires the state to develop a total maximum daily load (TMDL), or numerical limit, required to achieve its stated water quality standards (Copeland, 2010). Those limits are required to take stock of all sources of pollution to waterways, including NPS pollution. The implementation of the program is currently being wrestled on a local level in the courts (Houck, 2014), and may provide a solution to the problem of NPS pollution, however it is very costly and time consuming to create a TMDL for a waterway.

The Public Trust Doctrine

A completely different legal solution to the nonpoint source pollution and Gulf hypoxia problem can be pursued by using the ancient doctrine of Public Trust. The Public Trust doctrine is a legal doctrine with roots in ancient Roman law, and Spanish and English common law (Wood, 2013). The doctrine maintains some natural resources are held by the government, in a trust, for the benefit of the people, including both current and future generations (Klass & Huang, 2009). In this arrangement, the relevant governing body acts as the trustee of the resources and the people are the beneficiary (Ibid). The Public Trust doctrine, therefore, is a mechanism for the protection of the public's interest in natural resources (Jarrell-King, 2012), including the brown shrimp fishery resource in Louisiana.

The Public Trust doctrine has its more contemporary roots in the protection of waterways for the purposes of navigation, fishing, and commerce, and has increasingly been expanded to include protections for recreation, science, and habitat, although there has not been much development in the doctrine for fish resources (Frank, 2012). Currently, there is some debate among legal scholars as to whether the doctrine is restricted to state law or whether there is a deeper federal Public Trust doctrine as well (Wood, 2013). The doctrine was widely touted in the early 1970s by Joseph Sax, who in his classic paper "The Public Trust Doctrine in Natural Resource Law: Effective Judicial Intervention" outlined how the doctrine could be used as a base for environmental law (1969). However, the passage of a number of landmark environmental laws in the 1970s stifled the motivation for Sax's work until more recently. In the face of growing environmental crises, including hypoxia in the Gulf and the problem of nonpoint source pollution, some legal scholars are beginning to ask whether the Public Trust doctrine might serve as a better tool with which solve these problems.

Putting the Public Trust Doctrine to Work

The Public Trust Doctrine is poised to pick up the slack created by current environmental law. The doctrine has been in the spotlight more recently (see, for instance, PBS NewsHour "Our Children's Trust"), and if it is supported by more case law, it stands to provide an underlayment of environmental protection that current environmental law does not. This is because it is a doctrine rather than statutory law; it stands to provide a base of protection as opposed to protections laid on top of existing land uses. However, while some legal scholars seek to promote the doctrine as a cure-all to pervasive environmental woes (see Wood, 2013), others claim the doctrine is more restricted to state law or to navigational purposes (Frank, 2012). If the doctrine is expanding, it can be used in litigation where other approaches have failed. The problem of Gulf hypoxia, with its stagnant policy recommendations and burnt-out activists, may therefore be a good problem to apply the doctrine to.

Environmental litigation turns on some form of harm done to an environment (for instance by using the Clean Water Act) or to a particular species (by using the Endangered Species Act). The Public Trust doctrine is no different; any case that rests on the doctrine requires some harm done to a natural resource the doctrine protects. If the doctrine is perceived to protect fisheries, for the purposes of fishing, then we can ask whether it can be used to protect the brown shrimp fishery in the Gulf from seasonal hypoxia. This approach will only work if several pieces of the puzzle are in place. The first is harm done. Gulf hypoxia must be shown to have a negative impact on the brown shrimp fishery. Secondly, people who are harmed by a reduced fishery must be able to communicate their harm. If harm to the brown shrimp fishery is supported by scientific research, yet the fishers who exploit the fishery do not recognize the harm, there will be no motivation for litigation. The people impacted must recognize the impact if they are to participate in any litigation. Thirdly, the people impacted must have the capacity to work with the people who can litigate. Coalitions must either exist or be built in order for the two often disparate groups to work together. In the case of the brown shrimp fishery, this means Louisiana shrimp fishers will need to be able to work with environmental activists and lawyers on the issue. Activists can provide a motivating force and organizational capacity to drive a novel approach to the problem. They can also provide the critical link to environmental lawyers who would be required to litigate a case such as this. Finally, the lawyers involved, and to a lesser extent the activists, need to possess an awareness of the Public Trust doctrine for its use. If the doctrine is not part of their toolkit, they will never turn to use it. With these four requirements for the use of the Public Trust doctrine in the case of Gulf hypoxia's impact on the Louisiana brown shrimp fishery in mind, I have explored the potential for the use of the doctrine in a particular case.

CHAPTER II

METHODS

Research Questions

This research aims to gauge the potential for the application of the Public Trust doctrine to the problem of Gulf hypoxia. The doctrine is poised to expand in U.S. law and may provide relief to environmental problems where environmental law has failed. My thesis explores to what degree the four components required for success, as described above, are in place. The overarching research question explored is: Can the Public Trust doctrine be used to lessen the impacts of hypoxia in the Northern Gulf of Mexico on the brown shrimp fishery in Louisiana? In order to explore this question in depth, I first broke it down further into four sub-questions:

1. Is there a correlation between hypoxia and the abundance of brown shrimp in the northern Gulf of Mexico?
2. Do shrimp fishers in Louisiana think hypoxia jeopardizes the brown shrimp fishery?
3. To what extent do coalitions exist between shrimp fishers and environmental activists and lawyers in southeastern Louisiana?
4. Are environmental lawyers and activists in southeastern Louisiana familiar with the Public Trust Doctrine, and do they have motivation to use it?

My material for this thesis is comprised from three sources. One source is a quantitative data analysis whereby I utilized publicly available brown shrimp catch and dissolved oxygen content data from the Louisiana continental shelf collected and provided by the National Oceanic and Atmospheric Administration (NOAA) in order to examine whether hypoxia is correlated to brown shrimp abundance in the area. Too few studies have been conducted that study the impacts Gulf hypoxia is having on the brown shrimp fishery, yet this would be a crucial component of any litigation utilizing the Public Trust doctrine, or any other legal tool to show harm done by hypoxia on the fishery. Ultimately, there must be a negative impact to the fishery for litigation with the Public Trust doctrine to work. I undertook this data analysis in order to add to the small number of scientific studies that explore this problem. My analysis uses a combination of data on the abundance of brown shrimp and the severity of hypoxia.

In addition to my quantitative data analysis, I conducted in-depth interviews with both fishers and environmental activists and lawyers in order to better understand whether shrimp fishers in southeastern Louisiana think hypoxia jeopardizes the brown shrimp fishery, to learn to what extent coalitions exist between shrimp fishers and environmental activists and lawyers in area, and if those environmental lawyers and activists are familiar with the Public Trust Doctrine and whether they have motivation to use it. In-depth interviews can provide material for a deep understanding and analysis of respondents' answers as they are allowed to ponder questions at length and discuss topics not specifically addressed by the line of questioning (Weiss, 1995).

In order to fill in the gaps left by in-depth interviews that resulted from the methods of interviewing, I conducted a survey of fishers in Louisiana. The survey specifically addresses the sub-questions regarding whether fishers feel hypoxia jeopardizes the brown shrimp fishery, and regarding coalitions between fishers and environmental activists and lawyers. The survey provided a much larger sample size than in-depth interviewing allowed and it reached a more diverse sample of fishers than I was able to interview.

Brown Shrimp Data Analysis

My quantitative data analysis addressed the research sub-question: Is there a correlation between hypoxia and the abundance of brown shrimp in the northern Gulf of Mexico? The analysis was restricted to the Louisiana continental shelf in the Gulf of Mexico because this is the area where seasonal hypoxia typically exists, and to maintain consistency with the population I interviewed and surveyed. Data consisted of brown shrimp trawl catch individual count numbers, dissolved oxygen content in the bottom of the water column, seafloor depth, salinity in the bottom of the water column, and water temperature in the bottom of the water column. Data were collected using long-term fishery-independent research trawl surveys conducted by the Southeast Area Monitoring and Assessment Program (SEAMAP) of NOAA. All data from SEAMAP are made available to the public online. The surveys have taken place since 1982 and occur year-round.

In addition to looking for a correlation between brown shrimp catch and hypoxia, I looked at differences in two sets of brown shrimp catch. I examined the two variables (brown shrimp catch and dissolved oxygen content) from two different years: a high hypoxia year (2002), and a low hypoxia year (2000) in order to test whether brown shrimp abundance was significantly different in a high hypoxia year compared with a low hypoxia year. The year 2000 had the second-lowest recorded hypoxia in the northern Gulf of Mexico since the hypoxic area has been measured, with an area of 4,400 km^2 (Gulf Hypoxia Action Plan, 2008). The year 2002 had the largest extent of hypoxia since measurements began, with an area of 22,000 km^2 (Ibid) (see figures 2.1 and 2.2). The second-lowest hypoxia year was used rather than the lowest hypoxia year because that year (1988) did not have enough SEAMAP data collected for me to use it in the analysis.

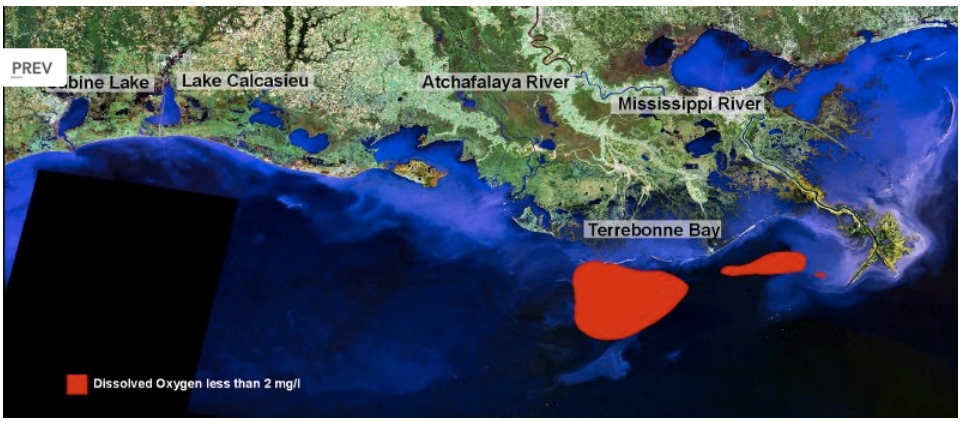


Figure 2.1. Extent of hypoxia in 2000 (from gulfhypoxia.net).

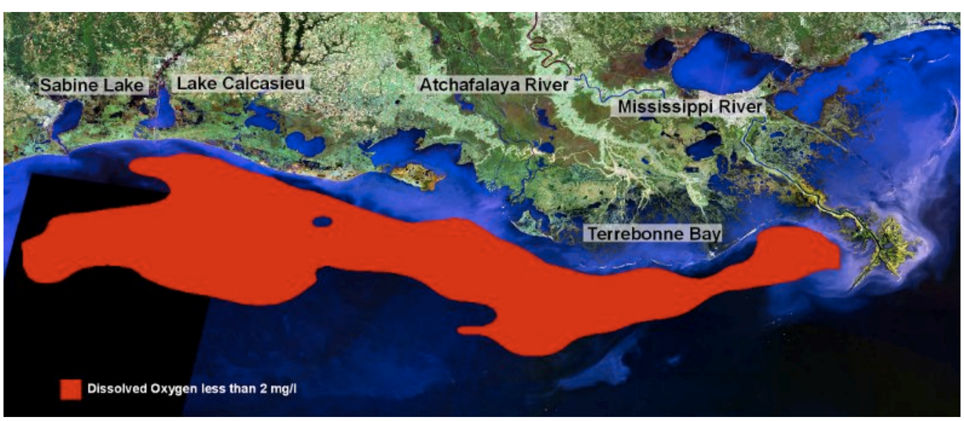
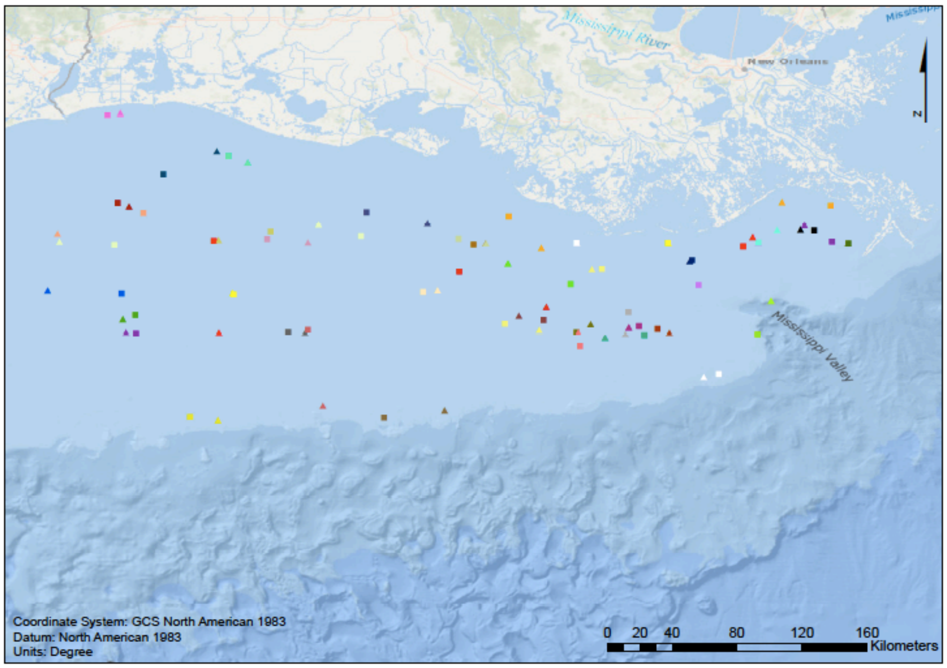


Figure 2.2. Extent of hypoxia in 2002 (from gulfhypoxia.net).

Brown shrimp trawl catch data was compared at forty-six stations in both sample years. Brown shrimp were caught with a 40-foot shrimp trawl net with 1.63 inch mesh openings. Catch was equated from the number of brown shrimp individuals caught in each sample trawl tow. Unfortunately, I was unable to calculate trawl tow area as no flow meter was used, and so am unable to equate number of brown shrimp individuals to volume of water.

Sampling Station Design

Sample stations were paired because individual SEAMAP shrimp trawl stations are not revisited from year to year. Each SEAMAP station is unique and visited only once. In order to compare data from the two sample years, I created station pairs that attempted to mimic a single station with visits in both years. I paired stations by depth and by geographic proximity to achieve site matching as close as possible between the pairs. Ideally pairs would be in the same location, but since this was not possible I first matched depth between pairs in order to control for any oceanographic differences that could be attributable to depth, and then made pairs from the closest stations from the two sample years. Bottom depth differences between paired stations did not exceed three meters at depths of less than eighty-five meters and ten meters at depths greater than eighty-five meters. The differences between depths at station pairs are not significant ($P= 0.93$, $n=46$). Station pairs were labeled with the arbitrary numbers 1-46. This pairing protocol was not successful in finding stations very close together; rather it found the closest station pairs from *all available data* provided by NOAA. The mean distance between station pairs is 18.47 km, the standard deviation is 15.15 km (see figure 2.3). The most closely paired stations (by geographic proximity) are 148 meters apart, the least closely paired stations are 56.88 km apart (see Appendix A).



Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors
Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

Figure 2.3. Sampling station pairs are indicated by color. Station shape corresponds to sample year (triangles indicate 2000, squares indicate 2002).

The data was also restricted to the months of July and August because these are the months when hypoxia is typically most extreme in the northern Gulf of Mexico (Rabalais, Turner, & Scavia, 2002). The data was further restricted to surveys that occurred during daylight hours because there is a large diel difference in the number of shrimp caught by trawl (Craig, Crowder, & Henwood, 2005) (see Appendix B). Complex calculations would be necessary to normalize abundance if data from both day and night were used. Data were further restricted to surveys that took place within the geographic area bounded by NOAA's shrimp statistical zones 13-17, which includes the entire coastline of Louisiana (see figure 2.4). These statistical zones were used to exclude data from Texas, which unlike Louisiana closes its waters to shrimp fishing during the summer months (Ibid). I excluded data from Texas in order to minimize the effects of differences in fishing pressure on brown shrimp abundance due to the two states' differing fishing seasons. Finally, the data was restricted to depths of 0-110 meters because this is the area where the majority of juvenile and adult brown shrimp congregate (Ibid).

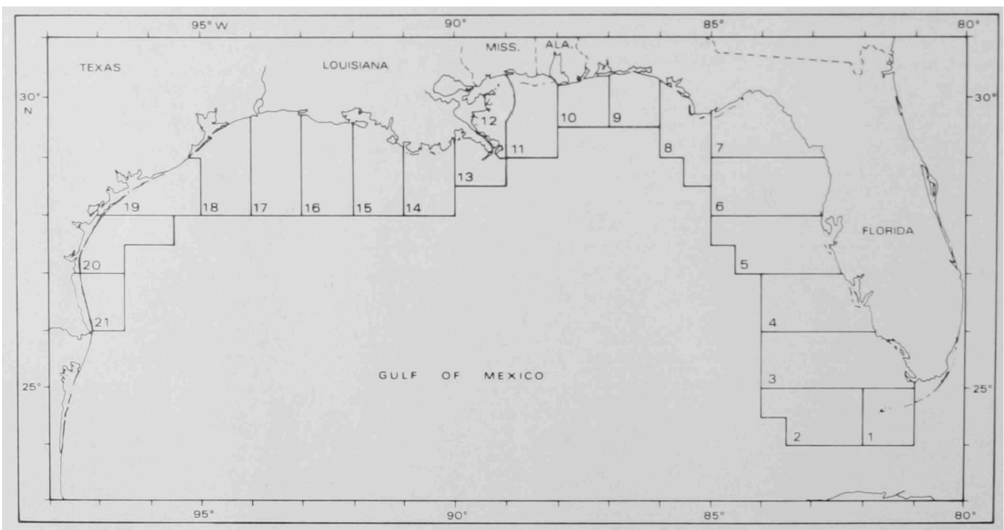


Figure 2.4. Shrimp statistical zones (from Patella).

Physical Variables

All data represent a single sampling event at a particular station. In addition to brown shrimp catch data, data were collected on four physical variables including depth, temperature, salinity, and dissolved oxygen. Each of these physical variables was measured at one meter above the seafloor, where brown shrimp often reside and hypoxia tends to be most severe, using a CTD (conductivity, temperature, and depth) and an "autosal" salinometer for salinity. Several stations (n=27) were missing data for dissolved oxygen, temperature, and salinity measurements during one of the experimental years. Temperature, salinity, and depth data were included in the analysis to examine their relationship with brown shrimp catch and dissolved oxygen content. These variables may be correlated to brown shrimp catch and dissolved oxygen, and by including them I sought to isolate these relationships.

Analyses

This data analysis sought to address the research question: Is there a correlation between hypoxia and the abundance of brown shrimp in the northern Gulf of Mexico? I used a linear regression analysis to determine if a correlation exists. I also used linear regression analyses to look for correlations between dissolved oxygen content and the physical variables temperature, salinity, and depth.

In addition to the linear regression analyses described above, data were analyzed with a paired t-test to determine whether brown shrimp catch means were significantly different in a low and a high hypoxia year. The null hypothesis used states the brown shrimp catch mean in a high hypoxia year (2002) is equal to the brown shrimp catch mean in a low hypoxia year (2000).

Interviews and Survey

During the summer of 2014, I spent two weeks in southeastern Louisiana conducting interviews of shrimp fishers and environmental activists and lawyers in order to answer three of my research sub-questions:

- Do shrimp fishers in Louisiana think hypoxia jeopardizes the brown shrimp fishery?
- To what extent do coalitions exist between shrimp fishers and environmental activists and lawyers in southeastern Louisiana?
- Are environmental lawyers and activists in southeastern Louisiana familiar with the Public Trust Doctrine, and do they have motivation to use it?

My interviews sought to examine the relationships that exist on the ground between shrimp fishers in the area and hypoxia, shrimp fishers and environmental activists and lawyers, and environmental lawyers and the Public Trust doctrine. While I assumed many shrimp fishers in the area had heard of the local dead zone, I wanted to know if they felt threatened by it. I was aware the region is riddled with other problems that can impact the fishery, environmental and other, and may be perceived as bigger threats than hypoxia, and I wanted to learn how shrimp fishers prioritized the threats. Furthermore, shrimp fishers have historically clashed with environmentalists (Harrison, 2010), and I wanted to learn if their relationship with and feelings towards environmentalists has warmed enough for a coalition to emerge. This research approaches the social movement process of framing, as described by Goffman (1974), from a unique perspective because it considers it a tool to build coalitions for the purpose of environmental litigation. This allows me to examine the relationships between shrimp fishers and environmentalists, however, framing is but one component of social movements. I also utilize Swidler's theory of culture as a toolkit (1986) to explore how Cajun culture grapples with the problem of Gulf hypoxia.

I conducted in-depth qualitative interviews using a semi-structured script because they provide a window into the nuance of respondents' daily experience (Weiss, 1995). They give room for respondents to discuss their thoughts and feelings, and they permitted me to ask questions that arose from the interview itself. In-depth interviews allowed me to learn how Cajun shrimp fishers use their cultural identity as a lens to view environmental problems through, and how framing analysis might explain coalitions between fishers and environmentalists. However, an ethnographic study could provide a much more detailed understanding of the everyday experience of respondents than in-depth interviews can, simply by the depth of immersion of the researcher in the community of study (Emerson, Fretz, & Shaw, 2011).

I interviewed shrimp fishers (n=8) who reside in southeastern Louisiana because they fish the areas adjacent to the seasonal hypoxic zone. A majority of the fishers I interviewed reside on or very near bayous where they typically moor their boats and access fisheries from what is essentially their back yards. The fishers I interviewed have a variety of connections to the fishery. Some respondents fished only inshore waters, some fished offshore (where the dead zone forms) at the time of interviews, while others had fished offshore in the past but were currently restricted to fishing inshore. Furthermore, some respondents had very little access to wider communities who purchase their catch while others had deep connections to the communities who purchase their catch. These connections range from interactions at farmers markets to access through an online purchasing website. Several respondents serve on fishery council boards or in activist roles as stewards of the fishery. These fishers were more likely to have strong opinions about the dead zone because they engage more with the role of the fishery and the impacts to it. This variety in respondents' relationships with the fishery allowed for a more rounded picture of the fishing community. All shrimp fisher interview respondents had been fishing for many years, most commonly since their youth.

My interview script contained questions focused on the centrality of shrimp fishing to livelihoods and identities, knowledge of the dead zone, concern and attitudes surrounding the dead zone, impacts the dead zone may be having on the brown shrimp fishery, and perspectives on environmental organizations (see Appendix C). These questions began by establishing the connection respondents have to fishing by asking them how long they have actively fished and where they tend to fish. The latter question also established the geographic proximity between the dead zone and where the respondent typically fishes. Questions that discuss the details of respondents' fishing activities allow them to spend time describing their relationship to fishing; this can provide insight into the role fishing plays in their lives. Questions that ask the respondent about the dead zone (for example, whether they have heard of it, and whether they have seen it) sought to take census of how many respondents were aware of the problem. This line of questioning also allowed respondents to express opinions about the problem and their relationships with it. However, if a respondent had not heard of the dead zone, this line of questioning could create some friction in the interviewing process. Questions centered on respondents' attitudes towards environmental organizations sought to explore the connections and discord between the two groups. This line of questioning could distract respondents at times as it sometimes seemed to come out of left field.

The environmental activists and lawyers I interviewed (n=13) also reside and work in southeastern Louisiana. Their proximity to the dead zone dictated this geographic restriction, however, I interviewed one lawyer who resides in Mississippi because he works with a firm housed in New Orleans. Respondents were chosen based on their having some connection to the topic of Gulf hypoxia; their connections to the problem were often based on work they had done or are doing with an employing organization, however some respondents worked on the topic outside of an organization and still others did not work on the topic at all, yet had some knowledge of it. The organizations that respondents were/are typically affiliated are environmental nonprofit organizations. These organizations make their living advocating for environmental health and often litigate environmental problems. The organizations differed in their size and focus, and ranged from small local organizations with a strictly local focus to large national organizations with local branches and a wider focus. This variety allowed for a fuller picture of the diversity of opinion regarding both relationships with the local fishing community and commitment to the Public Trust doctrine.

My interview script contained questions focused on the respondents' involvement with the dead zone, his or her perception of the problem, challenges to reversing the dead zone, knowledge of the Public Trust doctrine, and the potential for differing legal tools to address the problem (see Appendix D). These questions asked the respondents to express their thoughts on the hypoxia problem and how their community has tried to change it. Respondents could be encouraged by these questions to spend a good deal of time pondering past work that has not appeared to have had any impact on the problem. Respondents were also asked to examine their opinions of the utility of the Public Trust doctrine, particularly in the case of the dead zone. This line of questioning allowed for creative thinking on the problem, particularly by respondents who are lawyers.

I made contact with interview respondents by phone or email in most cases. Some respondents were located by websites, others by reference from other respondents. Interviews took place in work spaces, homes, or coffee shop. Interviews lasted from thirty minutes to over one hour, based on how long the respondent wished to talk. All interviews were recorded with a digital recording device after consent to record our conversation was obtained. Interviews followed my script only to the extent I felt it was needed in order to obtain the information I was looking for. Respondents were allowed to wander in the conversation and they often touched on topics outside of the interview script, but interviews followed a similar format for the most part.

I developed the Louisiana fisher survey in order to expand on the interviews I conducted with shrimp fishers. More people can be reached through a survey, and while their answers to questions are more limited than in interviews by necessity of the format, the sheer number of respondents reached can provide a fuller picture of the range of opinions held by the community. My shrimp fisher interview sample was small (n=8) and did not include any non-Cajun respondents, yet Asians own 75% of the vessels larger than 50 feet in Louisiana (Burrage, 2009), many of whom are Vietnamese speakers. Additionally, the survey allowed me to hear the opinions of more offshore fishers, who by nature of where they fish are more likely to feel a negative impact from the dead zone.

The survey was conducted within a fishing organization that has members across the state of Louisiana. The survey was administered through the online platform SurveyMonkey in English, and distributed to members as paper copies in both English and Vietnamese. The survey response rate was 34.2%. The survey utilized a purposive sampling method, used within a certain group, in order to establish opinions within a known group of fishers (Petty et al., 2012). This range of opinion can then be applied to other similar fishers who maintain membership within a fishing advocacy organization. This approach was useful for my research because the shrimp fishers who are members of a fishing advocacy organization are most likely to be interested in forming coalitions with environmental activists and lawyers; they are already participating in a type of activism that seeks to strengthen their position as fishers.

The survey consisted of sixteen questions, all of which were optional for respondents to complete. Respondents could move on to a new question without first answering the previous question; in this way the respondent could choose to skip questions in the survey entirely. The survey included questions that established the number of years respondents had been fishing, the species they fish for, where they normally fish, their knowledge of the dead zone, its impacts to the fishery, how they first heard of the dead zone, knowledge of how the dead zone forms, a ranking question designed to establish levels of concern for a degree of problems affecting the fishery, and several open-ended questions that allowed respondents to discuss their thoughts on the dead zone and it's impact in the future (see Appendix E). This line of questioning was similar to that of my shrimp fisher interview script, but it allows for a quantitative analysis of the results. It can also enhance my results from the shrimp fisher interviews because the survey can illuminate questions from a different perspective and gives respondents a different format within which to respond. If a particular respondent is unlikely to respond with depth to an in-person interview, that person may be more likely to respond with depth to the more private and anonymous survey. However, because the survey is administered in private and anonymously, respondents may tend to be less honest than during in-person interviews, and move through questions without giving them much thought. Furthermore, a survey does not provide the rich detail that the interview format brings out.

CHAPTER III

SEAMAP DATA ANALYSIS

Results

For this data analysis, I used the shrimp species *Farfantepenaeus aztecus*, commonly called brown shrimp, to explore the impacts of severe hypoxia in the northern Gulf of Mexico. I sought to answer the research question: Is there a correlation between hypoxia and the abundance of brown shrimp in the northern Gulf of Mexico? My research question addresses the potential impact of hypoxia on an important fishery in Louisiana, which can play a critical role in any litigation that uses the Public Trust doctrine to mitigate nonpoint source pollution.

Depth

Bottom depths at sampling stations ranged from 5.5 meters to 108.3 meters. This depth range reflects the area where brown shrimp are typically fished for and where they are found in high abundance (Craig, Crowder, & Henwood, 2005). 82.6% of the stations in both years had depths of less than 40 m and only 10.9% of stations had depths greater than 50 m in both years (see figure 3.1).

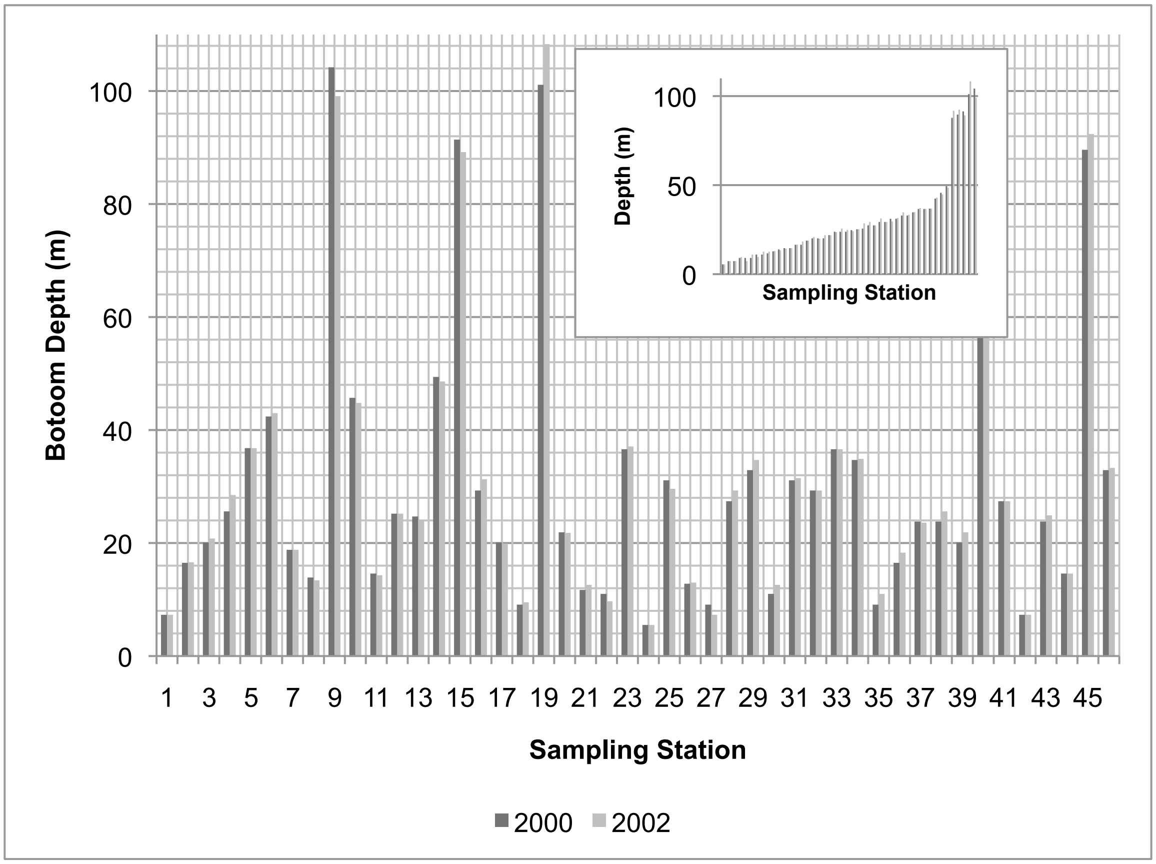


Figure 3.1. Bottom depths at sampling stations. Inset shows range of depths sampled.

Temperature

Bottom temperature at sampling stations ranged from 17.96 C to 30.12 C. The mean bottom temperature in 2000 at the sampling stations was 25.03 C, the standard deviation was 3.34 C. The mean bottom temperature in 2002 at the sampling stations was 26.78 C, the standard deviation was 2.06 C. Data were missing from four stations in 2000 and five stations in 2002. In the year 2000, 90.5% of stations reported bottom temperatures above 20 C. In the year 2002, 90.2% of stations reported bottom temperatures above 25 C (see figure 3.2). Temperatures were distributed across stations and did not exhibit a pattern connected to station location. A linear regression analysis shows temperature is closely correlated to bottom depth, with an R^2 value of 0.688 (see figure 3.3).

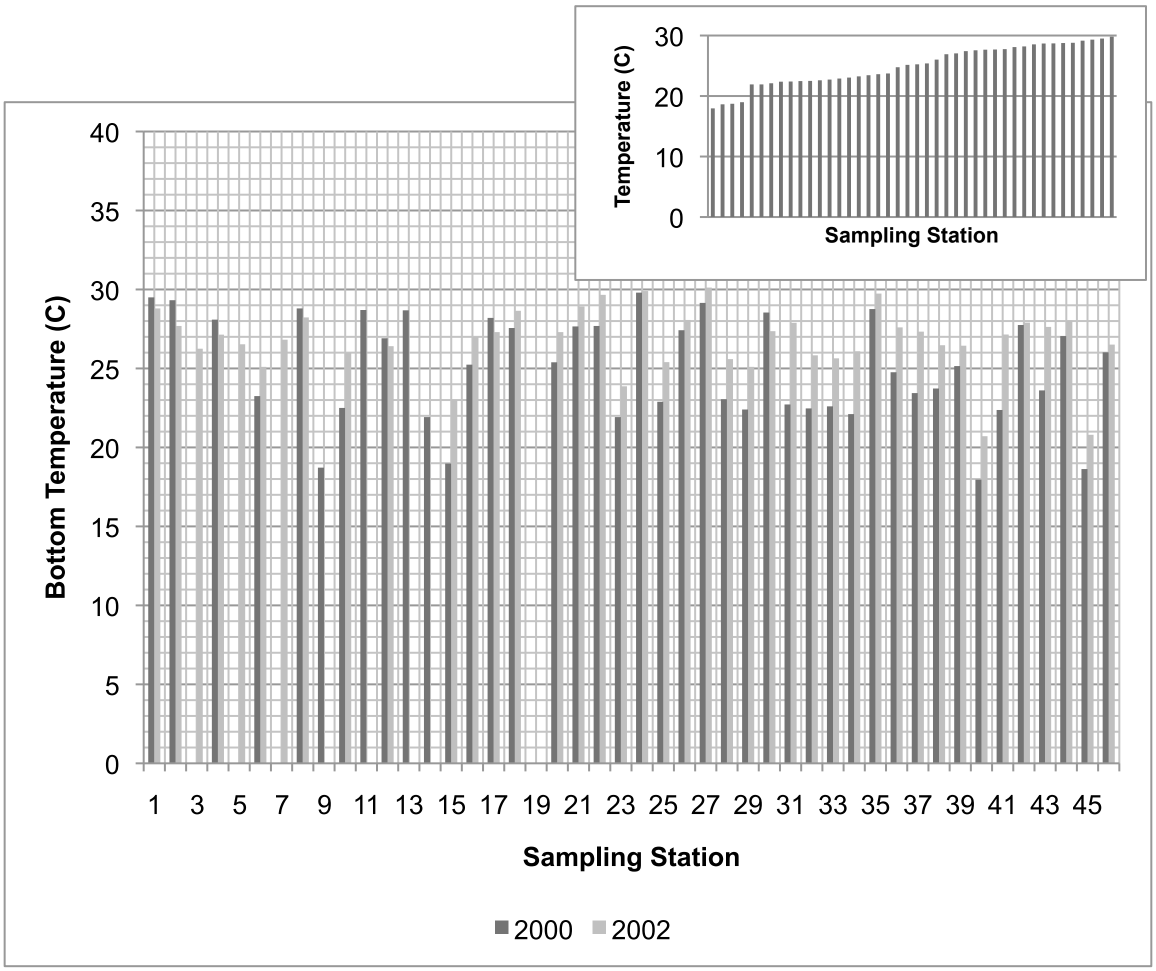


Figure 3.2. Bottom temperatures at sampling stations. Inset shows range ordered in 2000.

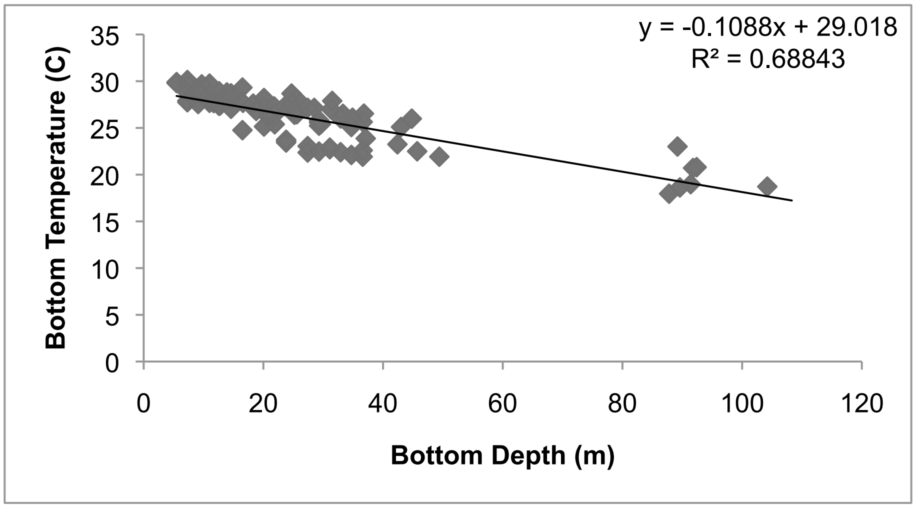


Figure 3.3. Linear regression analysis of bottom temperature and bottom depth at each station, 2000 & 2002 combined data.

Salinity

Bottom salinity at sampling stations ranged from 17.53 ppt, in 2002, to 39.03 ppt in 2000, however, the range on 2000 was much smaller than in 2002 (see figure 3.4). The mean bottom salinity in 2000 at the sampling stations was 35.79 ppt, the standard deviation was 1.12 ppt. The mean bottom salinity in 2002 at the sampling stations was 33.63 ppt, the standard deviation was 4.88 ppt. Freshwater runoff from the MARB was considerably lower than average in 2000 (Rabalais, Turner, & Scavia, 2002), which may explain the higher salinities seen at sampling stations in that year. Reduced freshwater inputs are associated with both smaller nutrient loading and higher salinities. 83.3% and 76.2% of bottom salinities were above 35 ppt in the years 2000 and 2002, respectively. Data were missing for four stations in both years (different stations, not pairs).

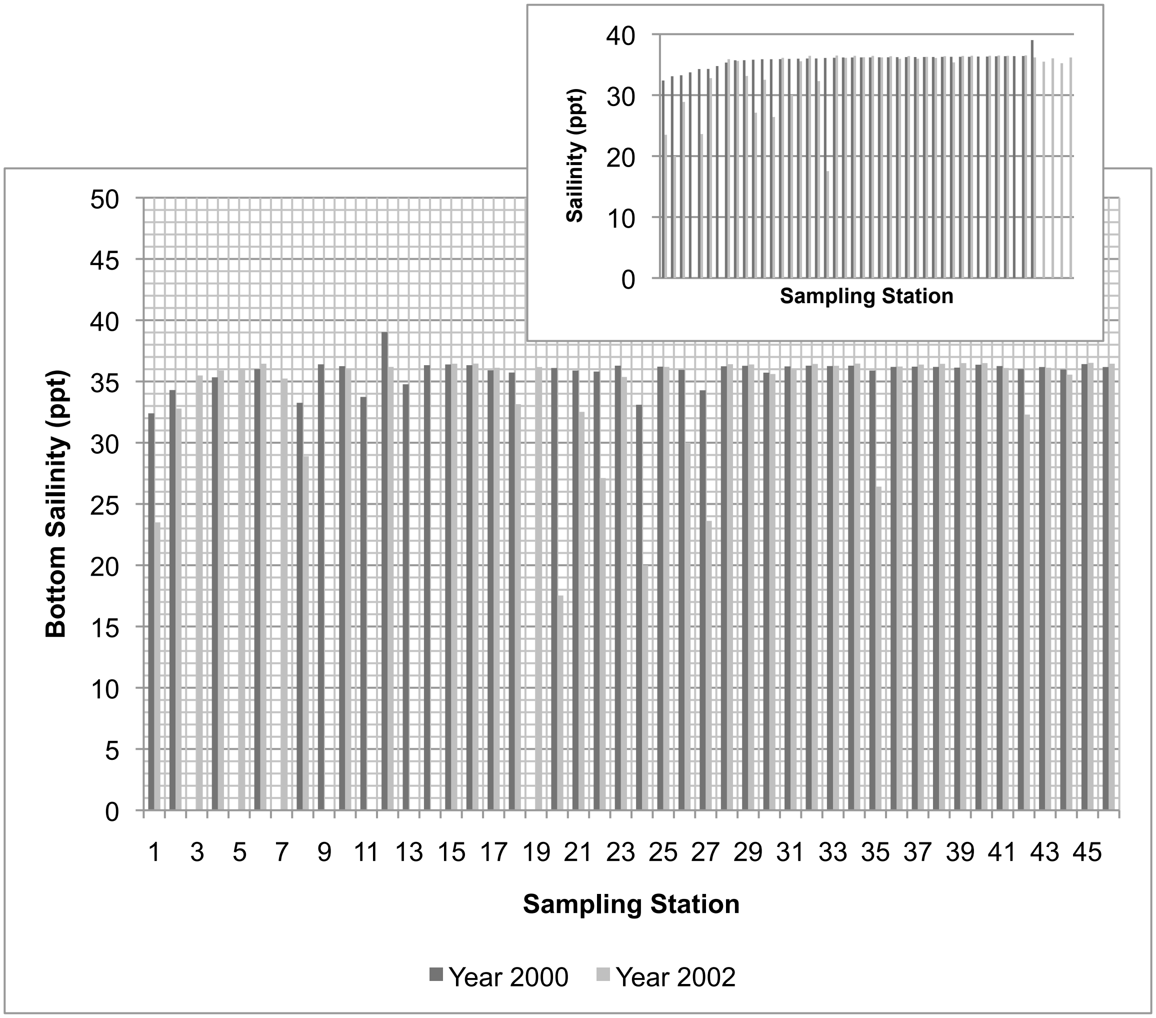


Figure 3.4. Bottom salinities at sampling stations. Inset shows range ordered in 2000.

Dissolved Oxygen

Dissolved oxygen content ranged from 0 ppm, or anoxic conditions, to 5 ppm in the year 2000, and from 0.1 to 7.2 ppm in the year 2002 (see figure 3.5). The mean bottom dissolved oxygen content in 2000 at the sampling stations was 2.91 ppm, the standard deviation was 1.43 ppm. The mean bottom dissolved oxygen content in 2002 at the sampling stations was 3.34 ppm, the standard deviation was 1.96 ppm. Both years had thirteen stations with dissolved oxygen content of < 2.0 ppm, or hypoxic conditions.

The year 2000 had five stations with missing data, and the year 2002 had four stations with missing data.

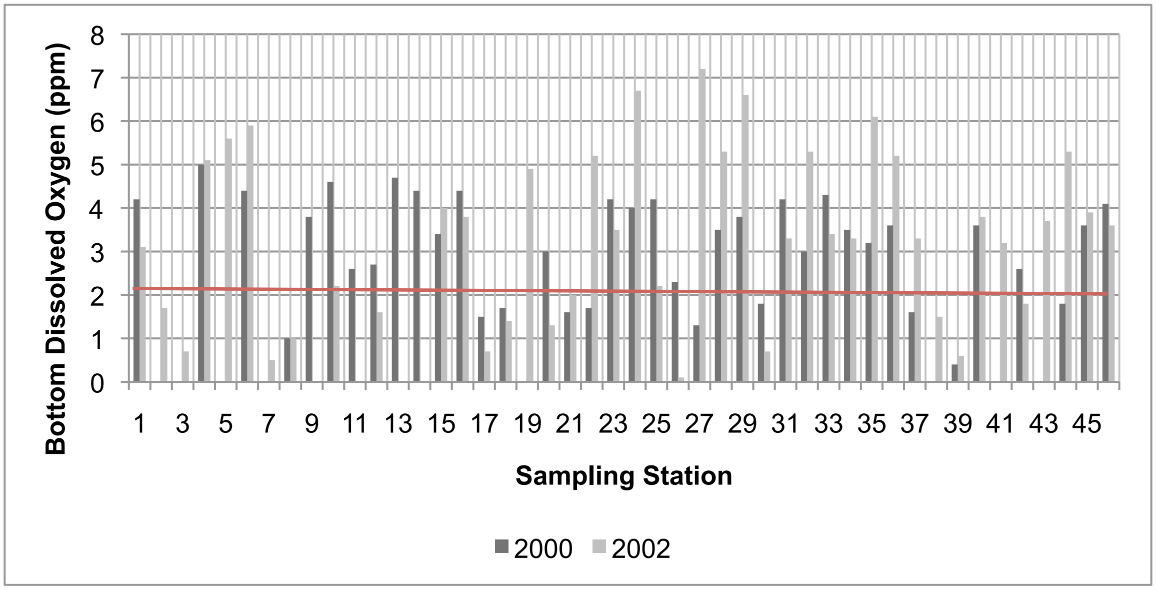


Figure 3.5. Bottom dissolved oxygen at sampling stations. Orange line at 2 ppm indicates boundary of hypoxic conditions. (Data was unavailable for stations 2, 3, 5, 7, and 19 in year 2000. Data was unavailable for stations 9, 11, 13, and 14 in year 2002.)

Linear regression analyses show bottom dissolved oxygen content is not correlated to bottom temperatures (see figure 3.6), bottom salinities (see figure 3.7), or bottom depths (see figure 3.8).

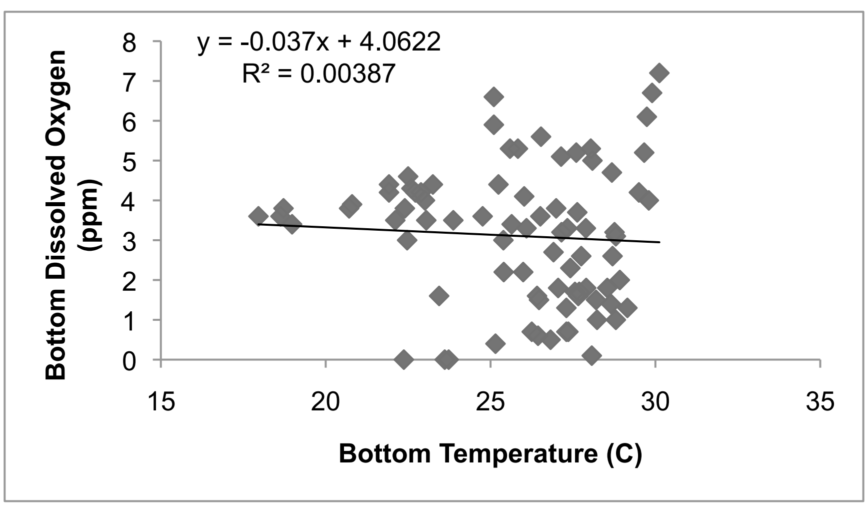


Figure 3.6. Linear regression analysis of bottom dissolved oxygen and bottom temperature at each station, 2000 & 2002 combined data.

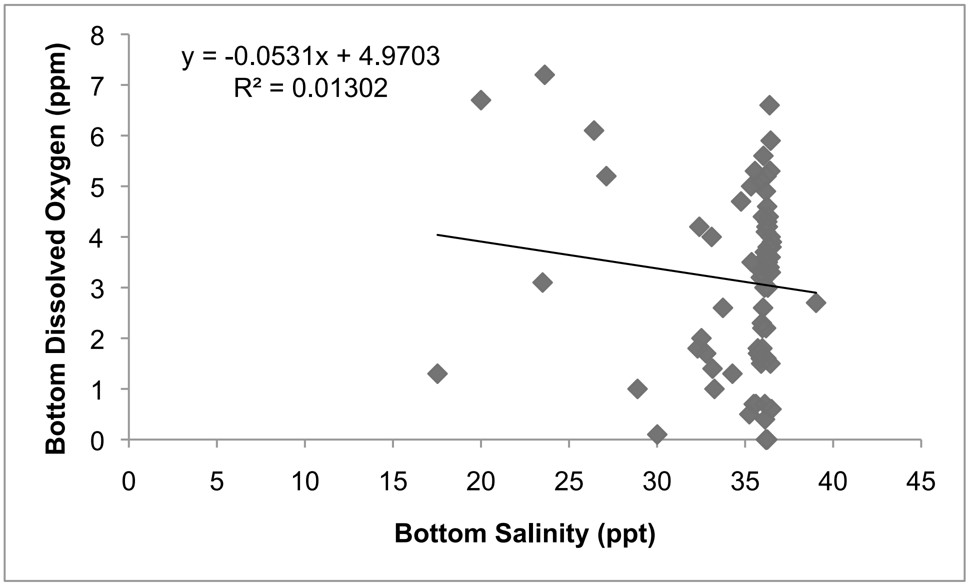


Figure 3.7. Linear regression analysis of bottom dissolved oxygen and bottom salinity at each station, 2000 & 2002 combined data.

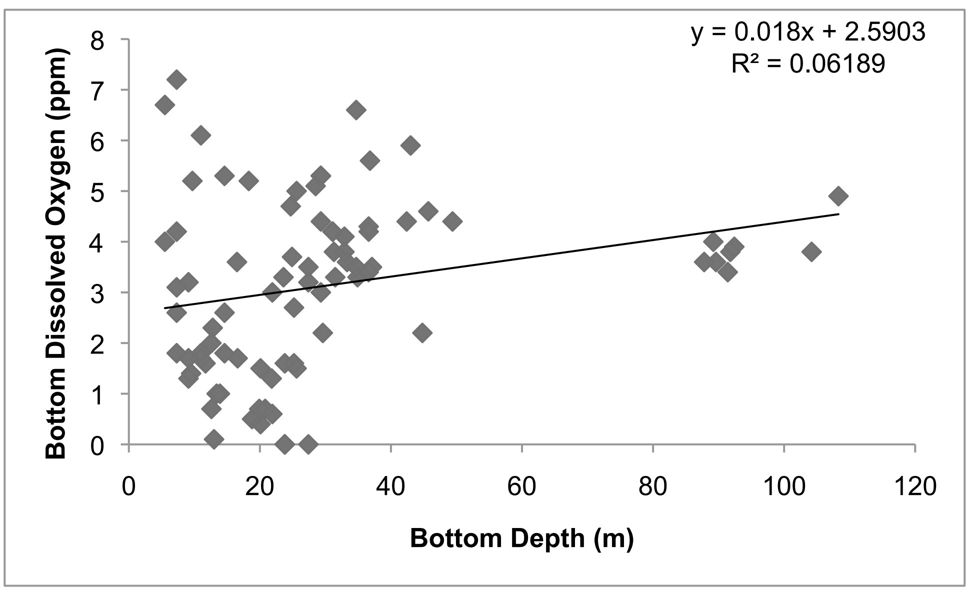


Figure 3.8. Linear regression analysis of bottom dissolved oxygen and bottom depth at each station, 2000 & 2002 combined data.

Brown Shrimp Individual Counts

Brown shrimp individual counts ranged from 0 to 411 at individual stations (see figures 3.9 and 3.10). Twenty-three stations reported brown shrimp caught in the year 2000, with the remaining twenty-three stations reporting 0 brown shrimp caught. Thirty-four stations reported brown shrimp caught in the year 2002, with the remaining twelve stations reporting 0 brown shrimp caught. I tested my research question (Is there a correlation between hypoxia and the abundance of brown shrimp in the northern Gulf of Mexico?) with a linear regression analysis (see figure 3.11 and 3.12) and a paired t-test. The linear regression analysis shows no correlation between brown shrimp count and bottom dissolved oxygen, both when all data is included (figure 3.11), and when zero count data is removed (figure 3.12). Furthermore, brown shrimp count means were binned by dissolved oxygen ranges for both years independently and both years combined in order to better visualize the data (see figures 3.13, 3.14, and 3.15). The low hypoxia year, 2000, resulted in a considerably higher shrimp count mean in the 2.0 to 2.9 ppm DO bin (mean = 142). Almost no shrimp were found below 2.0 ppm DO. The high hypoxia year, 2002, resulted in lower means (none over 35) that are more spread out across the DO bins. However, the large number of zeros for brown shrimp counts may skew this data. The paired t-test was used to test the null hypothesis: Brown shrimp mean in a high hypoxia year (2002) is equal to the brown shrimp mean in a low hypoxia year (2000). While the mean brown shrimp count was higher in the low hypoxia year, I failed to reject my null hypothesis with this data analysis ($P= 0.87$, $n= 46$) (see pairwise difference table, Appendix F).

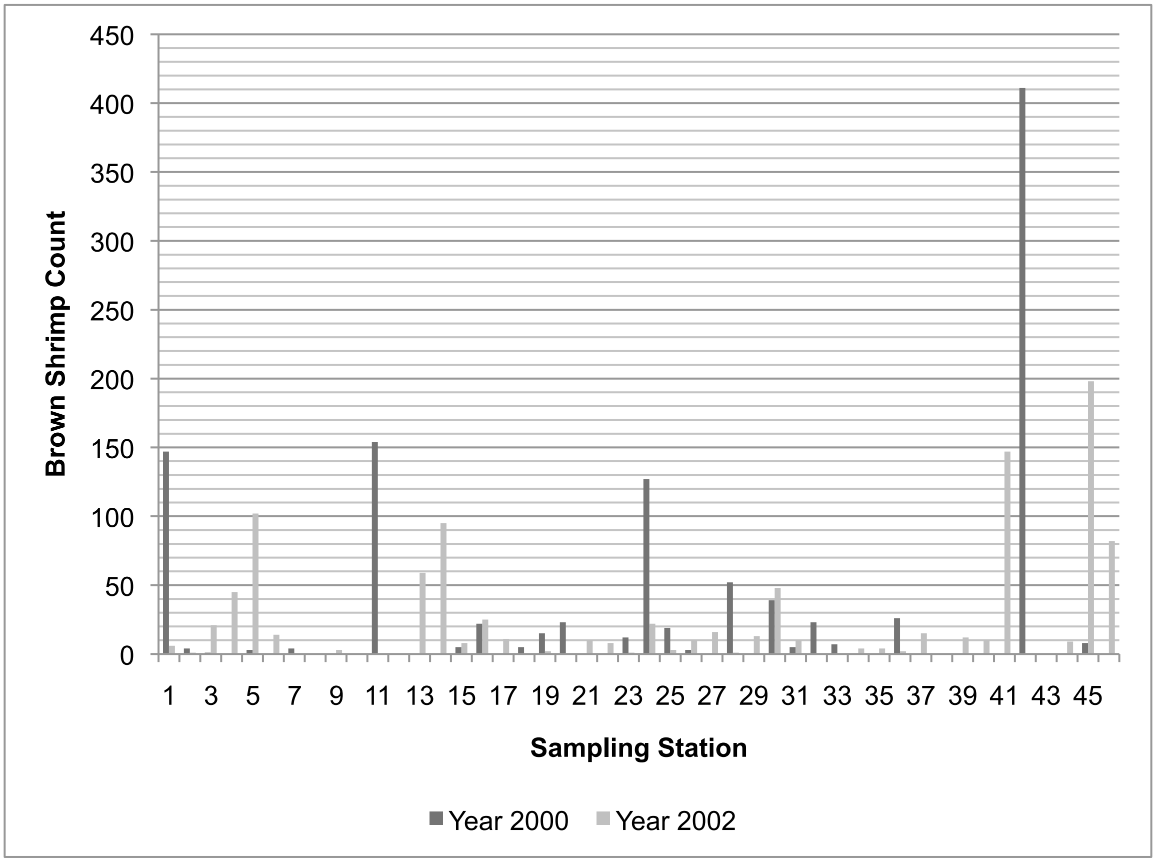


Figure 3.9. Brown shrimp count at sampling stations.

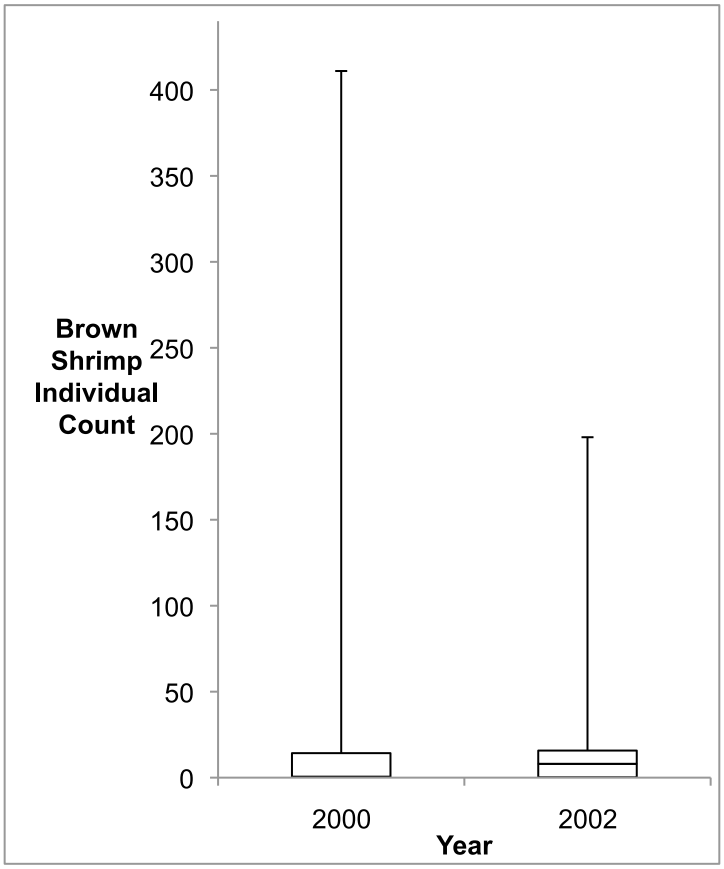


Figure 3.10. Box-and-whiskers plot showing brown shrimp individual count quartiles in the years 2000 and 2002. Whisker ends are maximums and minimums.

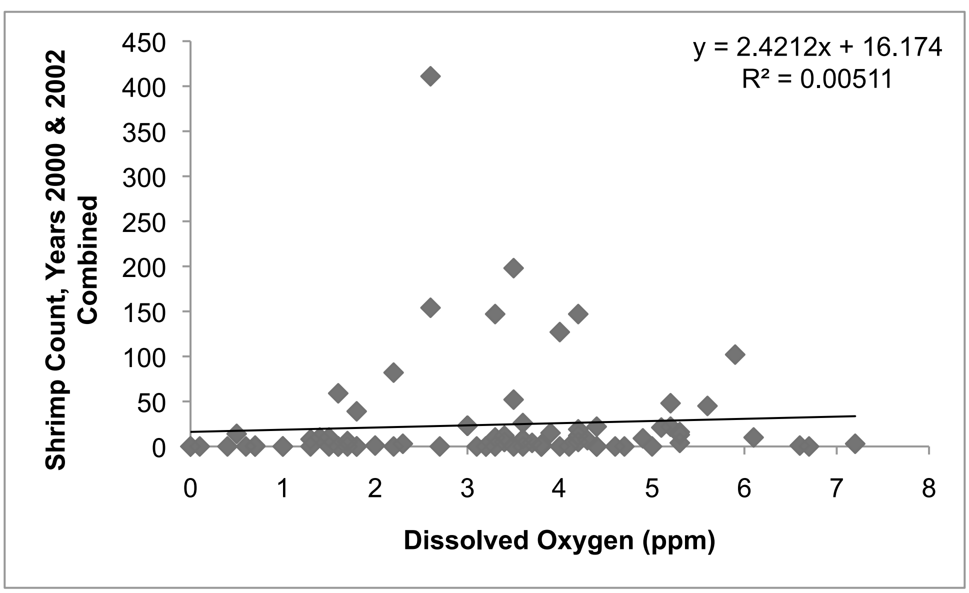


Figure 3.11. Linear regression brown shrimp count and dissolved oxygen at each station, 2000 & 2002 combined data. Zero data included.

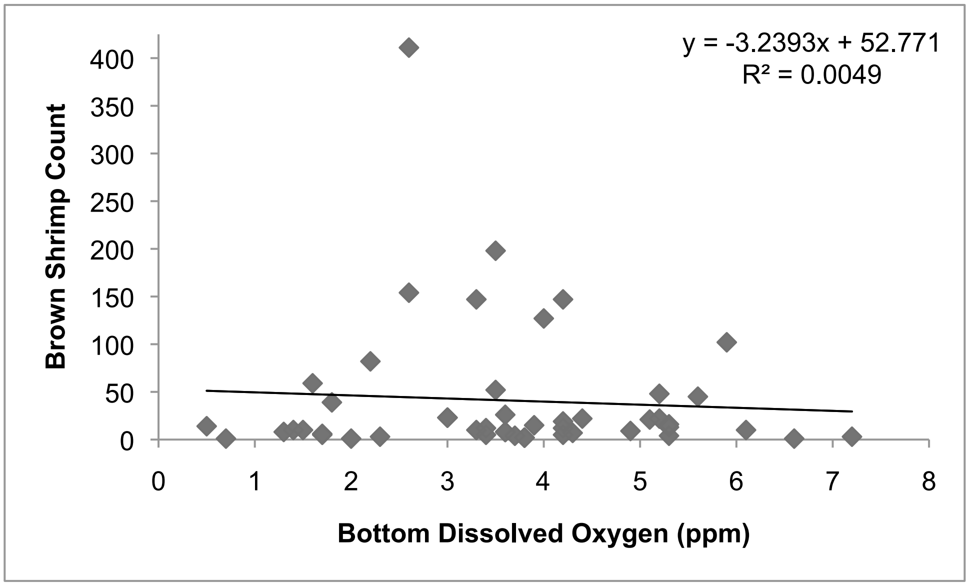


Figure 3.12. Linear regression brown shrimp count and dissolved oxygen at each station, 2000 & 2002 combined data. Restricted to presence data.

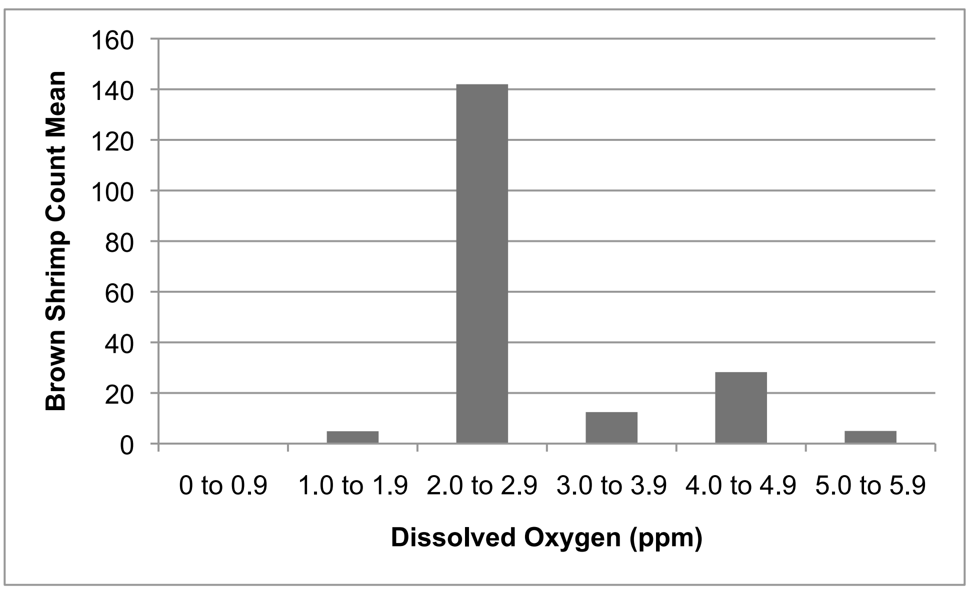


Figure 3.13. Brown shrimp count means and bottom dissolved oxygen, year 2000.

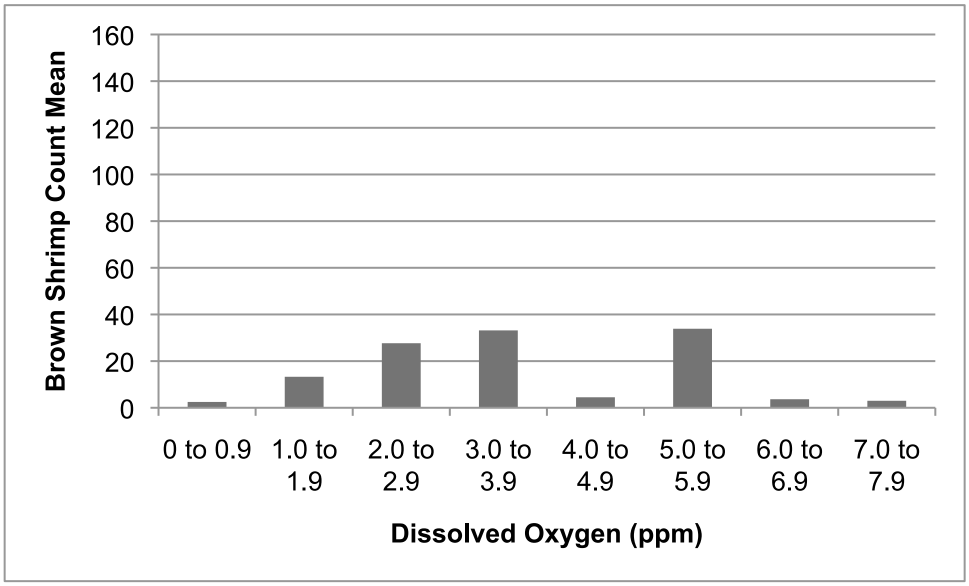


Figure 3.14. Brown shrimp count means and bottom dissolved oxygen, year 2002.

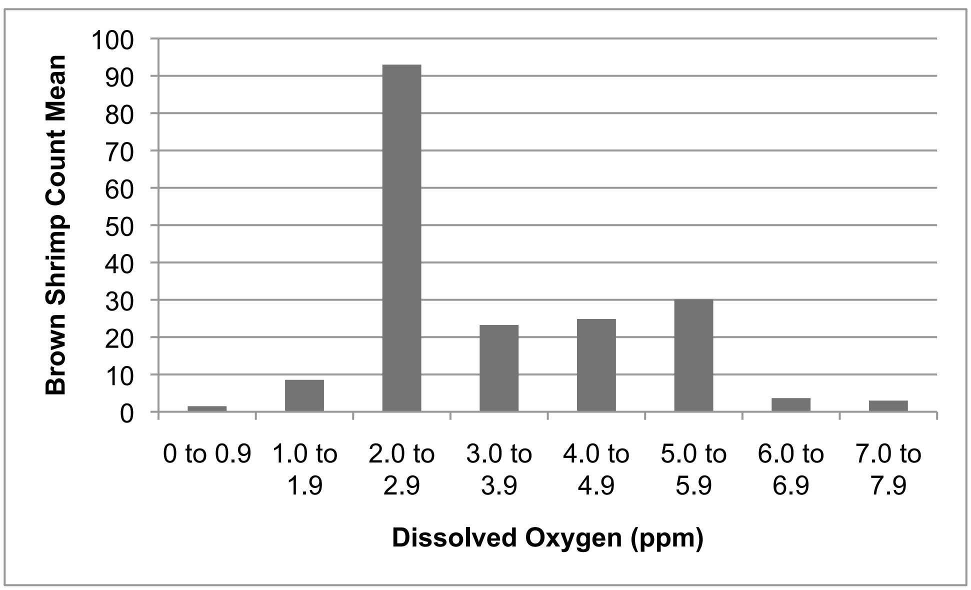


Figure 3.15. Brown shrimp count means and bottom dissolved oxygen, years 2000 & 2002 combined.

Discussion

This data analysis addressed the research question: Is there a correlation between hypoxia and the abundance of brown shrimp in the northern Gulf of Mexico? I examined whether brown shrimp catch means were significantly different in a low and a high hypoxia year, and I looked for correlations between brown shrimp catch and dissolved oxygen content, between bottom temperature and bottom depth, and between bottom dissolved oxygen and temperature, salinity, and depth. My results fail to find a correlation between brown shrimp abundance and bottom dissolved oxygen, or a significant difference in mean brown shrimp counts between the two experimental years, but they also fail to find a correlation between dissolved oxygen and the other physical variables. My results do find a correlation between bottom depth and bottom temperature, and they show very few brown shrimp individuals in water with <2.0 ppm dissolved oxygen.

The linear regression analysis of bottom depth and temperature showed a strong correlation (69% of variation). This result is in line with typical oceanographic patterns. The linear regression analysis of brown shrimp count and bottom dissolved oxygen did not show a significant correlation, with a result that accounts for only 0.5% of the difference in shrimp count. Interestingly, this result occurred both when the zero count data was included and when it was excluded, but the slope of the line is positive in the former scenario and negative in the latter. This tells us the large amount of zero data—due to the patchy distribution of brown shrimp—is not likely obscuring a correlation. The problem with the distribution of brown shrimp in this kind of analysis is a problem with the open ocean: organisms are often distributed in patches due to the large size of the ocean and so it can be difficult to isolate effects of phenomenon such as hypoxia on organisms. Another problem associated with scale is that of my dissolved oxygen content samples. While 2002 had a much larger hypoxic zone than 2000 in the Gulf overall, the sampling stations I used had lower overall dissolved oxygen in the year 2000 (mean 2.91 ppm) than in the year 2002 (mean 3.34 ppm). This may be an effect of local dissolved oxygen as contrasted with that of a larger scale, as is mapped annually in the Gulf, and may have an impact on my brown shrimp individual count numbers.

In addition to the linear analysis described, the paired t-test resulted in no significant difference between the brown shrimp counts in high and low hypoxic years. While these results are telling us hypoxia is not having much of an impact on the abundance of *Farfantepenaeus aztecus* in the Gulf, there are many factors, physical and other, that were not controlled for. Physical factors that may influence brown shrimp abundance include temperature, salinity (Zein-Eldin and Aldrich, 1965), and depth (Turner & Brody, 1983). Dissolved oxygen may also be correlated to other physical factors, yet my results do not find any correlation between dissolved oxygen and temperature, salinity, or depth. This helps me separate dissolved oxygen from the other physical variables because it is not predicted by them. The availability of nursery habitat can also influence brown shrimp abundance. *Farfantepenaeus aztecus* uses wetland habitat for its nursery grounds (Ibid), and this inland habitat is rapidly diminishing (Rabalais, Turner, & Wisemen Jr., 2002). An indirect effect on abundance may also result if the seasonal hypoxic zone acts as a physical barrier, stopping or slowing the migration of juveniles from their nursery habitat to the offshore spawning grounds (Diaz & Solow, 1999).

These results do show very few brown shrimp are found in water with less than 2.0 ppm dissolved oxygen, which supports laboratory experiments and previous field experiments. Brown shrimp aggregate on the edge of the hypoxic zone in the northern Gulf of Mexico (Craig, 2012), and are known to have the capability to detect and avoid water with as little as 1 mg/L dissolved oxygen (Wannamaker and Rice 2000). Their habit of remaining in waters with very low dissolved oxygen content, near the hypoxic edge, may have an impact on their abundance. For instance, high densities of shrimp may negatively affect growth rates (Rozas and Minello, 2011). This amassing of brown shrimp likely has implications for trophic interactions; the shrimp may be able to utilize an increase in prey, or may themselves be subject to higher rates of predation or fishery effort. These effects combined with avoidance behavior may determine population level effects of hypoxia on mobile species (Craig and Crowder, 2005). Aggregating behavior is one more layer to the hypoxia interaction puzzle that may be difficult to untangle.

In addition to physical factors, brown shrimp are subject to fishing pressure in Louisiana, including during the time period the sampling took place. The Texas offshore fishery is closed from May to July (Zimmerman & Nance, 2000), which is why I restricted this data analysis to Louisiana. However, the added factor of fishing may confound the results. Factors such as coastal development, tourism, recreational fishing, and shipping can also obscure the impacts of hypoxia on fisheries (Chesney & Baltz, 2001).

This data analysis used a station pairing protocol that matched stations as best possible given the available data, however, no two station pairs were in the exact same location. Depths were more closely matched than geographic coordinates in an attempt to minimize any variation attributable to depth difference. The geographic difference between the stations could have a confounding effect on the results. A further experiment would negate this problem by sampling at repeat random locations. Additionally, the data used was obtained from NOAA, and it is possible the data itself has problems, as I cannot vouch for the fidelity of the data collection. Finally, a serious flaw in this data is my inability to normalize trawl catch data by volume sampled. This confounds my ability to find accurate shrimp abundance numbers and may be skewing my results. Any future sampling should utilize a flow meter to facilitate volume calculations.

The low hypoxia year, 2000, still had a considerable zone of hypoxic water. This could provide a further confounding factor. The year 1988 saw almost no hypoxia (Gulf Hypoxia Action Plan, 2008), and so would serve as a good baseline/low hypoxia year, however the data collected in that year does not provide a good match to the station data from 2002, the high hypoxia year used in this analysis. The size of the hypoxic zone in the year 2000 was just below the 2008 Gulf Hypoxia Action Plan's stated goal of 5,000 km^2, at 4,400 km^2, and so can provide a baseline for the Plan itself (Ibid).

One of the benefits of studying a species in the wild is the ability to examine population dynamics such as abundance, however, a laboratory experiment could separate some of the potentially confounding variables out. Wannamaker and Rice suggest this cannot provide data on how populations behave when interacting with hypoxia (2000), yet further laboratory experiments could be used to determine if hypoxia has direct physiological effects on individual brown shrimp.

Previous studies have used fisheries landing data in an attempt to link hypoxia size to fisheries declines in the Gulf. Zimmerman and Nance found brown shrimp catch in Louisiana offshore waters was very small during a period of expanding hypoxia from 1992 to 1998, but they could not attribute the decline solely to hypoxia (2000). O'Connor and Whitall extended that study and found a significant correlation between fishery total landings in Texas and Louisiana combined and hypoxia area for 1985-2004 (2007). However, Chesney and Baltz failed to find a relationship between brown shrimp abundance and hypoxia by using fisheries landing data, and they assert the large size of the basin provides sufficient refuge from hypoxia to obscure its effects on abundance (2001). Fisheries landing data is ultimately unable to separate other environmental factors from hypoxia itself.

The goal of this data analysis was to relate variations in shrimp catch (fisheries independent) to variations in dissolved oxygen and size of hypoxic zone, which is why I used a low and high hypoxia year. While I did not expect to find many shrimp in hypoxic water, I wanted to determine whether the overall size of the yearly hypoxic zone has an impact on the abundance of *Farfantepenaeus aztecus*. To do this I used random samples. However, it was impossible in this test to determine effects due solely to the size of the hypoxic zone. Further tests would need to isolate the factor of dissolved oxygen from other factors, and some effort would still need to be made to separate hypoxia from variables it is linked to itself, such as salinity and temperature. Altered salinity and temperatures may affect juvenile brown shrimp growth and production

(Adamack et al., 2012), and these changes may be happening due to a number of factors, including climate change and hypoxia induced range shifts (Craig, 2012). A laboratory experiment would best isolate hypoxic conditions from the other physical variables.

CHAPTER IV

INTERVIEWS & SURVEY: RESULTS & DISCUSSION

- Do shrimp fishers in Louisiana think hypoxia jeopardizes the brown shrimp fishery?
- To what extent do coalitions exist between shrimp fishers and environmental activists and lawyers in southeastern Louisiana?
- Are environmental lawyers and activists in southeastern Louisiana familiar with the Public Trust Doctrine, and do they have motivation to use it?

My interviews with shrimp fishers and the survey I distributed among fishers both addressed a sub-question of my research question that asks if shrimp fishers think hypoxia jeopardizes the brown shrimp fishery. If shrimp fishers think hypoxia is indeed jeopardizing the fishery, they may be interested in utilizing a tool such as the Public Trust Doctrine to slow nonpoint source pollution, but if they are unaware of an impact, they will not have any reason to litigate.

My interviews with environmental activists and lawyers aimed to address two sub-questions embedded within my larger research question. Firstly, I wanted to determine whether coalitions might already exist or be built between Louisiana shrimp fishers and environmental activists and lawyers in the area. If Louisiana shrimp fishers are motivated to litigate to slow Gulf hypoxia, by using the Public Trust doctrine or any other legal means, they will need to first have built coalitions with the people who have experience in environmental litigation, or at the very least they will need a foundation of trust. Lawyers specialize and so an environmental lawyer would be the right kind of lawyer for this job, and environmental activists provide foundational and community support to environmental advocacy. My interviews with shrimp fishers also sought an answer to this sub-question.

Secondly, I wanted to determine whether environmental lawyers and activists in the area are familiar with the Public Trust doctrine, and if so, if they view it as a useful tool for litigation aimed at slowing Gulf hypoxia. If the experts in the field do not think the doctrine is a useful tool, then it is very unlikely anyone will propose using it. Furthermore, the overall sentiment towards the problem, by the lawyers and activists, can provide insight into their levels of motivation to litigate with any legal tool, particularly one that they may feel would be difficult to use.

Who's Heard of Gulf Hypoxia?

My interviews with shrimp fishers in southeastern Louisiana and the survey I conducted of fishers in Louisiana both asked respondents about the dead zone by beginning with whether respondents are familiar with it. I wanted to know what percentage of shrimp fishers in the area know of its existence. This knowledge has to be the foundation for any litigation over the problem. Before I could begin to determine if shrimp fishers think the dead zone jeopardizes the brown shrimp fishery, I first needed to determine if a significant number of them even know about the problem. My interview and survey research resulted in very different percentages: seven out of the eight (87.5%)

shrimp fishers I interviewed told me they had heard of it, yet only 56% of survey respondents who actively fish for shrimp said they had heard of it. This discrepancy could be a result of my small interview sample size, and because the shrimp fishers I interviewed included two people who are active in fishing advocacy organizations and so are likely to exhibit a higher degree of awareness of problems the fishery faces by virtue of their activism. The survey result percentage of shrimp fishers who have heard of the dead zone, just over half, is therefore more reliable.

In order to include only shrimp fishers in the survey results (distinguished from fishers who catch or harvest organisms other than shrimp), I separated out respondents who are active shrimp fishers. This allowed me to compare results between interview respondents and survey respondents. Of the total survey respondents (n=214), 116 met my active shrimp fisher criteria, which consisted of fishing for shrimp (either brown or white, or both), having fished for shrimp for more than three years, and spending more than one month per year fishing for shrimp. A large majority of these respondents replied they fish for shrimp at least five months out of every year. Of those shrimp fisher respondents *who have heard of the dead zone*, 47.3% fish in inshore waters only, where the dead zone is not found.

Active shrimp fisher respondents, who said they are aware of the dead zone, were also asked if they have ever seen the dead zone in order to establish a percentage who have had some sort of physical contact with it (see figure 4.1). 44% of these respondents said they have seen the dead zone themselves. If they answered in the positive, they were then asked how many times they had seen it. The majority of whom said they have seen it between one and seven times, however, 11% of respondents answered they have seen it on more than twenty occasions. Additionally, active shrimp fishers, who have heard of the dead zone, were asked whether or not they have ever fished near it. 45% responded that they have indeed fished near the dead zone (see figure 4.3).

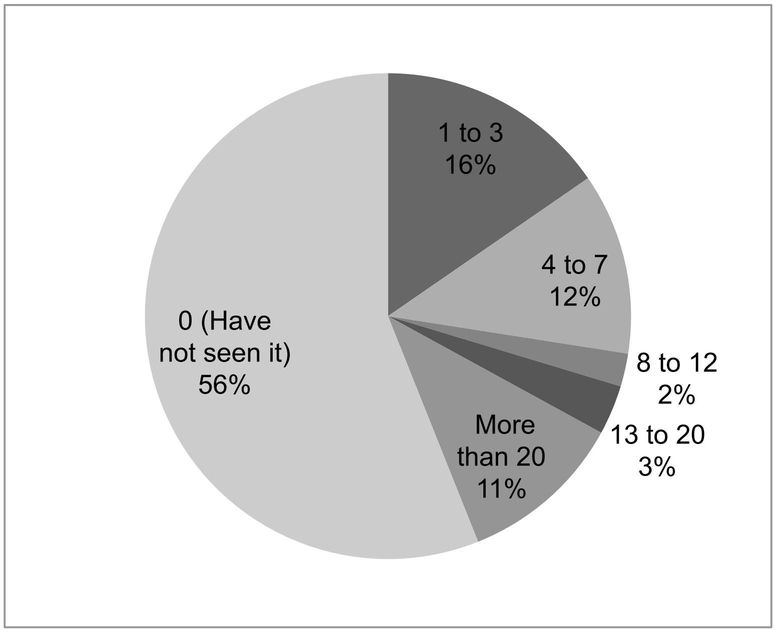


Figure 4.1. Number of times shrimp fishers have seen the dead zone.

I also asked survey respondents who are aware of the dead zone how they first heard of it (see figure 4.2). In this manner I sought to learn more about the source of community awareness of the problem. The range of responses included news source, friends or relatives, other fishers, fishing associations, or other (with room for the respondent to elaborate). The responses given for the category “other” included responses that respondents learned about it from direct experience while attempting to fish in it, the state fish and wildlife department, and a local marine laboratory that researches Gulf hypoxia (Louisiana Universities Marine Consortium, or LUMCON). Of those who have heard of the dead zone, 56% answered they first heard about it from a "news source". The remaining 44% responded with an almost equal combination of "fishing association", "friend or relative", or "other fisher". A smaller percentage, 6%, responded with the write-in answers described above.

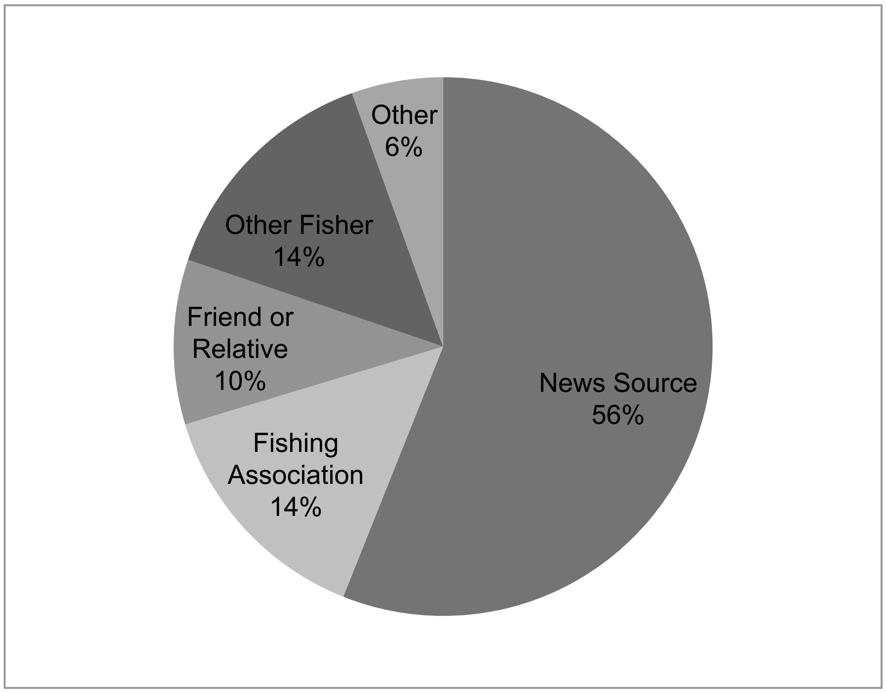


Figure 4.2. Active shrimp fishers' source of awareness of the dead zone.

After I established what percentage of shrimp fishers have at minimum heard of the dead zone, I asked respondents about the finer details of Gulf hypoxia in order to learn how deep their knowledge of the problem runs. The scientific explanation of the problem can be quite technical, and I was curious to what degree shrimp fishers know details of the science behind Gulf hypoxia. I asked respondents if they know how the dead zone forms each year. Within the survey, 64% of active shrimp fisher respondents, who said they have heard of the dead zone, answered yes, they know why it forms every year (see figure 4.3).

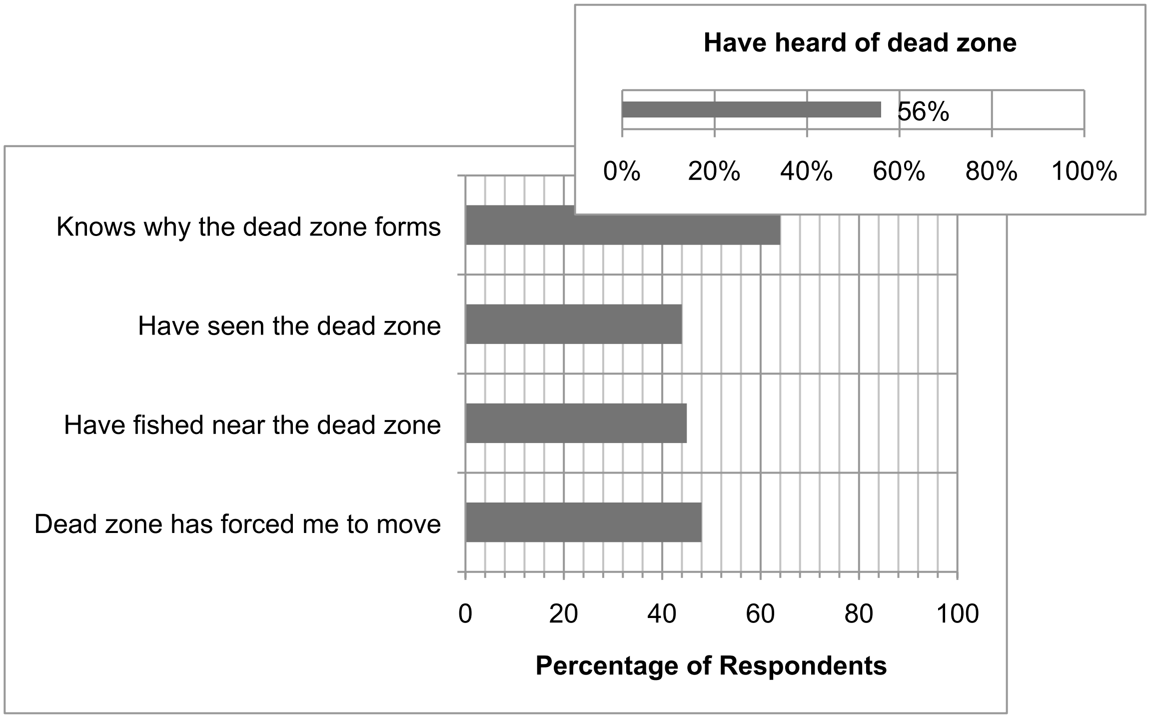


Figure 4.3. Summary of shrimp fisher survey responses. All answers outside of inset are from respondents who answered yes, they have of the dead zone.

Among the shrimp fishers I interviewed, most of the respondents exhibited knowledge of the formation processes responsible for the problem, although that knowledge was not always consistent and respondents displayed a range of confidence in their understanding. For instance, Jim (all names are pseudonyms), a shrimp fisher from Chalmette who heads up a local fishing advocacy organization, explained,

> I'm familiar with how it moves, how it travels…we know what it's caused from: all the runoff. And it changes every year, especially when you have the years of low turbidity, it gets worse. It just hangs out, with nothing to break it up, no oxygen.

While Nathan, a shrimp fisher from the Pointe aux Chenes tribe, told me “I think they say on the news there’s overflow from the farms in the north. I don’t know if that’s what it is or not.” He also mentioned his news outlet notified him the problem arises “from the spraying of their crops and all that stuff.” John, a shrimp fisher who sells at farmers markets in New Orleans, understands the connections between nutrients from the Mississippi River, differing water temperatures, algae growth, and hypoxia. He described the relationships,

> You have the main hypoxia zone that everyone talks about that’s getting bigger cause it’s coming from the Mississippi River from all the nutrients and stuff coming out of the river from farming and what have you, and all that comes out and blends with the warmer water and when it does that you have this explosion of algae and it takes all the oxygen out of the water.

Some interview respondents clearly have a fairly technical understanding of the causes of Gulf hypoxia and a grasp of the oceanographic concepts that explain it. Interview respondents also expressed awareness that Gulf hypoxia changes in size from year to year. For instance, Nathan told me: “it’s getting bigger, I don’t know if it’s enlarging or something.”

Respondents’ scientific grasp of the problem was at times misinformed. Gulf hypoxia is largely driven by nutrient pollution (Dale et al., 2010), but interview respondents occasionally confused pesticide runoff with fertilizer runoff. Richard, a fisher with a larger boat and a thriving internet wholesale business, lumped the two pollutants together when he said “It’s not only fertilizers we have problems with, but people who fertilize their lawns, or use pesticides on their lawns.” While a range of scientific understanding is expected from a large, diverse fishing community, my research shows a slight majority of the shrimp fishing community is informed of the problem and how it comes to be each year. This is in contrast with the perception the environmental activist and lawyer community holds of the shrimp fishing community, as evidenced by my interview results.

While a majority of activist/lawyer respondents identified shrimp fishers as the most likely group to be negatively impacted by Gulf hypoxia, many exhibited a belief that the problem is almost invisible, and not well known among the fishing community. Jack, a legal scholar at a local university, does not know of shrimp fishers who are vocal on the issue. He said,

> I'm not sure that they're that aware of it. Especially not compared to the oil spill. They were very vocal, and still are vocal about the impacts of that oil spill. But you don't really hear them talk about the dead zone except maybe in passing and that type of thing. They don't really tend to understand what impacts it might be having on them.

And Peter, an activist in Baton Rouge who works on river health, said "The only people in Louisiana that really talk about it are academics, it's not a day-to-day, I think, concern of the people who are actually affected by it."

However, Paul, a policy scholar and activist, does know of shrimp fishers who talk about the issue. He reminded me, "There's awareness among both commercial fishers and recreational fishers—over the last decade or more, back to the beginning of this process—those groups have not been the most active, but they have been periodically active." Disagreements of this nature, between the group most impacted by the problem, and the group that can facilitate environmental litigation, may stand in the way of coalition building.

The study of social movements can provide a useful lens to examine a potential coalition between shrimp fishers and environmental activists and lawyers in Louisiana through. While the lack of a social movement built around Gulf hypoxia does not preclude litigation over it, some social movement processes may be critical to any coalition between the two groups. One such process is framing, which allows the actors to see the problem from a similar perspective. Framing recognizes events are mediated by our culture, and can be used by leaders and activists within social movements to mobilize grievances (Snow & Soule, 2010). A coalition between the two groups, then, could be facilitated by framing the problem in a manner that assigns blame to the lack of regulation of nonpoint source pollution and thus points the groups towards litigation.

A question then arises: who will best serve as the coalition's leaders and mobilize grievances? Leaders can emerge from the shrimp fishing community or from the environmental activist community. However, if the environmental activist community remains ignorant of the degree to which the shrimp fishing community is even aware of the dead zone, it is unlikely leaders will emerge from this group. Furthermore, the shrimp fishing community may not harbor enough trust of environmental activists to facilitate leaders from within. The shrimp fishing community, therefore, is better positioned to provide leaders for a coalition between the two groups. The challenge will be for them to effectively message their grievances with Gulf hypoxia and nonpoint source pollution in the Mississippi, but this is one area where a coalition could be fruitful.

Environmental activists are good at messaging and some local groups are already familiar with framing the problems associated with Gulf hypoxia and can inform the process.

Trust between the two groups will also be a critical component to an effective coalition. Common ground is the foundation of trust, yet common ground alone is not enough. History can dampen enthusiasm for trust, and may be a problem for shrimp fishers due to past clashes with environmentalists, for instance during the turtle excluder device episode (Harrison, 2010). My shrimp fisher interview results show the tenuousness of any relationship between them and environmental activists, but many respondents indicated they are open to coalition building and explained they delineated between types of environmental activists. I asked respondents to discuss the people who actively work on the dead zone issue, and whether they have any commonalities. This line of questioning allowed respondents to talk about their relationships with (if any), and feelings towards environmentalists. John sees a threat from groups he considers radical, and told me, “You got the extremists—the PETA type people—that feel like you shouldn’t be out there killing anything, and they don’t realize that everything out there is food.” Joe, an ex-fisher who now runs a fishing advocacy organization (a different organization than Jim’s), also views environmentalists as uncompromising. He said, “Their idea is, lets go back to when we reintroduce the river to the wetlands—we’ll blow up the levees and everyone’s got to move!” Jim, however, separates environmentalists into different factions. One faction he calls “Neo-Nazi environmentalists” and says they “want everything.” Another faction he told me, “Some of these environmental groups that really want to reach out and don’t want to just blame, but want to see if there’s a solution, can we do something." Jim also emphasized strategic alliances when he told me "you gotta be really careful who you support."

Shrimp fisher interview respondents also discussed coalition building when I asked them if they had common interests with people interested in addressing the dead zone. The relationships they discussed were both between fishers and environmentalists and scientists, and among different fishing groups such as recreational fishers and commercial fishers. Richard described the lack of coalitions between scientists and fishers, "There's not a whole lot of communication between them. I mean they do stories in the paper on a regular basis, but I don't see like meetings or outreach or anything like that." However, John described a different scenario when he said, "In the situation with the dead zone, or incidents with the oil companies, people start getting back together and beating their heads together trying to find middle ground they can go on." Joe shared the sentiment: "Maybe next year we'll be killing one another over another issue, but this is serious; this puts us all out of business." And Jim described the on and off again animosity among fishers as "I want to catch more than you, but I don't want you to go out of business either."

Meanwhile, activist and lawyer respondents held a variety of opinions on whether coalitions could be built with shrimp fishers. Shelly, a prominent scientist who also advocates for a solution to Gulf hypoxia, illustrated how scientists and fishers often do not think in the same terms when she told me, "I mean they're just reflecting on their almost immediate day or week's catch. Not thinking long term." Both Stacey, an activist who works on environmental justice issues in Cancer Alley, and Paul told me resource users are not well connected to activists and do not harbor great deal of trust in them.

Paul explained, “I’ve tried to stay to stay engaged with the resource users. I can’t speak for everybody, you know a lot of the fishing groups are not very trustful of environmental groups.” And Peter, a Riverkeeper who works out of Baton Rouge, claimed activists and shrimp fishers are not communicating over the issue at all when he told me, “People who are focused on the hypoxic zone have for decades not been successful in engaging the commercial fishing population in really doing anything about it.” However, Jerry, an environmental lawyer who has many shrimp fisher clients, told me the more politically active shrimp fishers are interested in building coalitions. He said, “You got your [fisher] policy groups, the nonprofits, right? They’re very aware, and also want to be aligned, to the extent it’s in their interests, with the environmental groups.”

These conversations demonstrate the need for increased trust and communication between the two groups if a coalition is to be built. Organizations concerned with mitigating Gulf hypoxia already exist in Louisiana, yet these organizations are not typically aligned with the shrimp fishing community. A coalition between the two groups can become a wholly new organization. Rao, Morrill, and Zald explain new organizations can be initiated by the framing process within social movements through the erosion and buildup of beliefs (2000). A recent example can be seen in the “Cowboy Indian Alliance”, which was formed in opposition to the Keystone XL pipeline. The organization is made up of iconic opponents who can be seen to represent environmentalists (Indians) and natural resource extractors (cowboys and farmers). The alliance represents two groups who rarely form coalitions and are typically seen as at odds with each other in an attempt to show unified opposition to an environmental threat.

Because framing is a collective process, as described by Benford and Snow, both groups need to clearly understand how the other views the problem, in addition to agreeing on the basic underlying problem (2000). The misconception of what shrimp fishers know and think about Gulf hypoxia, by activists and lawyers, may dampen their enthusiasm to frame Gulf hypoxia as a threat; they are less likely to frame the issue if they think fishers will not be receptive to the framing. However, the coalition-building work would seem less challenging if they were to recognize that fishers' awareness represents an ongoing collective framing they are heedless of. The two communities have been at odds in the past, and so any grounds for agreement will allow them to work together more readily on Gulf hypoxia mitigation actions.

Why Doesn't Anyone Care?

Within my interviews of environmental activists and lawyers, many respondents expressed fatigue and pessimism associated with Gulf hypoxia even though they are aware of the problem, and are even occasionally engaged with it. This can be compared to a similar response from shrimp fisher respondents in both my interviews and the survey, and the perception activists and lawyers have of shrimp fishers.

When I asked activists and lawyers who they thought Gulf hypoxia impacted most, in order to learn how they see the problem's impacts, respondents often brought in a discussion of fatigue and priorities. Sometimes this was assigned to shrimp fishers, other times it was clear both groups are fatigued and more concerned with other local problems. Some respondents claimed that those who are affected by Gulf hypoxia, including both shrimp fishers and environmental activists, are detached from the problem. For instance, Stacey told me, “I think we were always conscious of the dead zone; the dead zone’s always been something we talked about and are concerned about,” but she thinks of the issue as something that happens in the background of more pressing problems. And Peter said “I think people adjust to it,” asserting fishers have moved on to other problems. Furthermore, many respondents explained that other problems in the area are bigger and more of a focus for locals. Peter thinks this is “Because the dead zone is a big picture thing that they’ve heard of, but it’s been there forever and there’s nothing they can do about it.” Philip, the policy coordinator for an environmental advocacy nonprofit, sees the impacts from other problems and a lack of discussion around the dead zone by shrimp fishers as intertwined. He explained,

> So it’s not something necessarily that I’ve seen on the tips of the tongues of the shrimpers just because there’s so many other things that if they’re going to complain about stuff, the dead zone has been going on for a while and it’s something they deal with as opposed to something that’s a more immediate impact.

Brian, an environmental lawyer who works in southern Mississippi and has many clients who are shrimp fishers, also blamed a lack of interest on the part of his clients on the many other problems they must deal with, which are often less predictable. He told me there is “widespread cognizance of the dead zone in fact, that it’s there,” but because “you can’t do anything about it, people are going to turn their attention to something they can do something about.”

When I asked them about the impacts the dead zone might be having on the fishery, shrimp fisher respondents repeatedly told me other problems they contend with often seem more important. Fishers in the area face numerous challenges to a fishing way of life that includes both anthropogenic and natural causes. Challenges include hurricanes, which can damage infrastructure, boats, and oyster beds; oil spills, which are always sudden events they cannot plan for; low shrimp prices due to imports; high diesel prices; the local loss of wetlands; and freshwater diversion plans. John illustrated, "To me [oil spills are] a much bigger threat than a dead zone, cause that's your nursery area." And Jim explained his logic,

> Other problems are more pressing because they're putting you out of business quicker than the dead zone is. Some of the people in the fishing organizations, we have conversations about it, but it's not a priority cause the other problems are more pressing. The bottom line is, whoever's going to shoot you in the leg, you gotta stop first.

Joe, while indicating hypoxia is an ongoing problem, explained fishers have become numb to it and told me "Whichever fire is burning the hottest right now is where I'm at. I tell people we live in disaster central. We're always battling the dead zone."

Respondents also expressed a variety of opinions regarding concern over hypoxia within their fishing communities. Tom, an ex-fisher who now runs a shrimp-processing warehouse, explained how interest in the hypoxic zone is often positively correlated to its size, "I think [interest] peaks from year to year. You'll get a year where the dead zone is the size of a small state and it will become a big topic in the news." John thinks other fishers are paying attention to the changing size of the hypoxic zone, generating awareness because “they notice that it’s growing from time to time.” However, Tom does not think fishers were very concerned with Gulf hypoxia because he feels it is not impacting the areas where the majority of fishers work. And Richard thinks shrimp fishers do not worry about hypoxia; he claimed, “It’s more of a scientist based type thing.” But James, a fisher from the Pointe aux Chenes tribe, said other fishers he knows talk about the dead zone.

In order to explore how shrimp fishers perceive the interaction of Gulf hypoxia with the fishery, I asked them whether they thought it was having an impact or not. Several shrimp fisher respondents claimed Gulf hypoxia is or has impacted their fishing in some manner. This can be compared with results from the survey (see figure 4.3). John explained how it has forced him to drive further when fishing, thus increasing his fuel costs,

> What you’ll find is you’ll go out and you’ll be looking for fish, or shrimp or whatever, and you’ll get to an area and it’s like a desert: there’s nothing there. So you’ll have to just use your wits and either go further out or come closer in, to get around it.

He told me more boats are forced to work a smaller area as well, because the hypoxic area reduces the total fishable area. Jim described a similar scenario,

> Where we were producing there was [no shrimp], so you gotta go east or west or south or north, to get away from it, and where it impacts us is it takes that [area] out of production. Any one wave or any one concentration of shrimp you take out of my potential harvest hurts.

Joe illustrated the direct impact of the hypoxic zone on shrimp fishing,

> 19-20 feet under the boat we were catching shrimp, doing pretty good . . . and you get just a little bit further out, maybe just 1 or 2 feet, which is maybe quarter of a mile, nothing! Not a fish, not a crab, nothing. And it was like that all the way out!

Other respondents were less certain Gulf hypoxia is negatively affecting their fishing. Nathan, for example, said “I don’t know if it’s a threat or not.” And Richard even thinks the hypoxic zone may be benefitting his harvest because the organisms he fishes for are constricted to a smaller area, making it easier for him to catch them.

My survey results support the claims of the shrimp fishers, activists and lawyers I interviewed. I asked survey respondents to rank potential threats to their fishing livelihoods, in order of severity in order to learn how big or small of a priority Gulf hypoxia is for them (see figure 4.4). Categories included “worst threat ever,” “severe threat,” “mild threat,” and “N/A,” in order of largest to smallest threat. Threats included turtle excluder devices (TEDs), diesel prices, the dead zone, hurricanes, wetland loss, freshwater diversions, imports, and oil spills. Respondents were allowed to rank multiple threats in one category. Turtle excluder devices are devices that props trawl nets open in order to let trapped sea turtles out. Shrimp fishers notoriously opposed turtle excluder devices when they were mandated for use in trawl nets (Harrison, 2010). Diesel prices are directly linked to fishers’ profits, as the higher the diesel price, the more a fisher will have to pay to fish. Hurricanes can negatively impact fishers by damaging infrastructure used to fish. Wetland loss is southern Louisiana has resulted in a reduction of inland brackish nursery and fishing grounds (Dale et al., 2010). Freshwater diversions were brought to my attention by many of my fisher interview respondents, who clearly saw them as a potential threat to nursery grounds and as a possible source of inland dead zones. Imports of cheap shrimp from Asia and Latin America has caused a crisis within the industry since the late 1990s (Harrison, 2010), and is linked to reduced prices paid to local shrimp fishers. Oil spills can affect fishers by closing an area to fishing and causing a loss of confidence in their consumers that reduces demand, as happened after the BP Deepwater Horizon tragedy.

Survey respondents ranked imports as their worst threat most often, at 21%, and oil spills close by at 18%. Freshwater diversions were ranked as the worst threat 13% of the time, wetland loss 10%, the dead zone, hurricanes, and TEDs were ranked worst threat only 9% of the time, and only diesel prices and write-in responses ranked below the dead zone at 7% and 4%, respectively. This ranking used response data from active shrimp fisher respondents.

Survey respondents occasionally provided write-in answers to the questions "Please explain how the dead zone has impacted your fishing", and "What do you think will be happening with the dead zone in 10 years?". Their answers show that at minimum, some shrimp fishers feel the dead zone is having an impact on the fishery, or is likely to in the future, even though the majority feel other problems are more pressing.

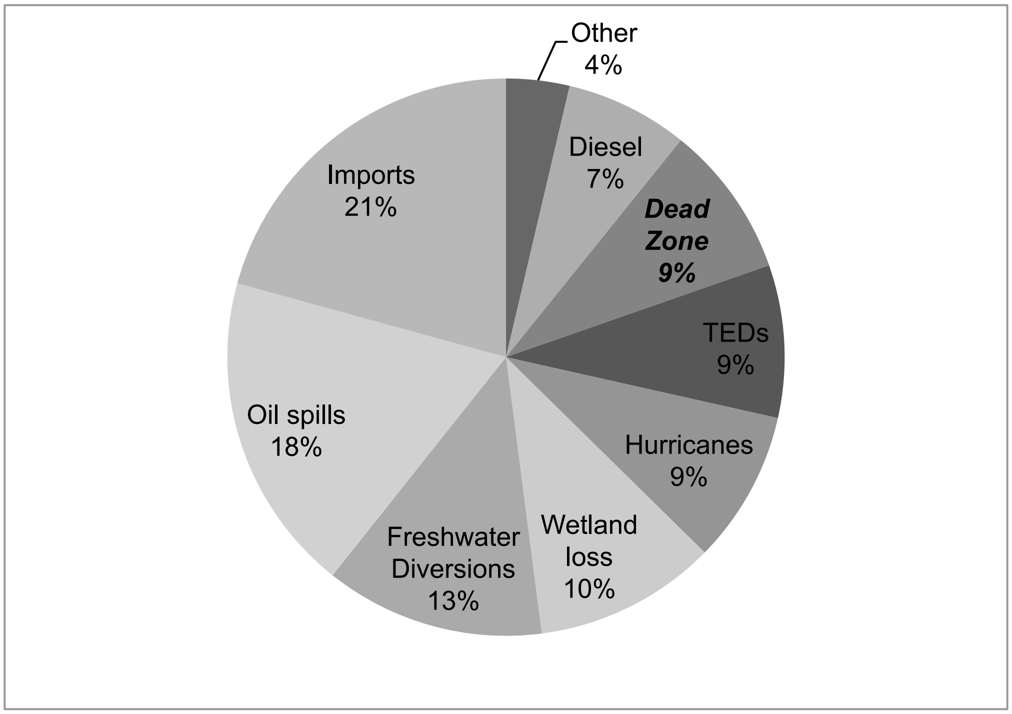


Figure 4.4. Worst threats to fishing livelihood according to shrimp fishers in Louisiana.

Common answers such as "You have to either stop fishing or travel further at greater expense to fish" illustrate an obvious impact to their fishing when the dead zone's location forces them to travel further than they normally would to reach suitable fishing grounds, thus causing them to spend more money on diesel to get there. Respondents also frequently described diminished shrimp harvests as a result of the dead zone when they wrote in answers such as "decrease in the number of shrimp" or "there seems to be less shrimp and growth" in response to the first question. Another possible impact resulting from the physicality of the dead zone is exemplified by the response "It tends to put the boats all working in a smaller area". Responses to the second question regarding the future may begin to explain fatigue and pessimism; respondents often wrote in answers to the question that show they either believe the problem will worsen, or they do not know what the future holds. For instance, one respondent said "I'm scared this will worsen", and many respondents answered with a simple "I don't know".

In order to better understand how physical contact with the dead zone might impact whether survey respondents feel it is having some impact on their fishing, I performed a cross tab analysis on the questions "Have you ever seen the dead zone yourself?", and "Has the dead zone impacted your fishing in any way?". This analysis was restricted to active shrimp fisher respondents. Of the respondents who have seen the dead zone themselves, 83.3% said the dead zone has impacted their fishing in some way, yet of the respondents who have not seen the dead zone, only 34.8% said the dead zone has impacted their fishing in some way (see figure 4.5). Having seen the dead zone thus may influence whether a shrimp fisher feels it is having an impact on his or her fishing.

	Yes, I have seen the dead zone	No, I have not seen the dead zone
Yes, the dead zone has impacted my fishing	35	16
No, or not sure, the dead zone has not impacted my fishing	7	30

Figure 4.5. Cross tab analysis of two survey questions, numbers indicate number of respondents.

Shrimp fishers I interviewed often described a strong belief that Mother Nature will repair anthropogenic problems. This topic always came up seemingly unbidden, as respondents pondered environmental problems. Sometimes this manifested explicitly, other times it was described in terms of non-human organisms' abilities to navigate their environments. For instance, John said, “I’ve found most critters don’t go where the water’s not right,” while Jim told me, “Mother Nature is fixing man-made problems. That’s all we can hope for: Mother Nature to fix man’s problems.” Joe also told me he thinks the shrimp he fishes for have a better understanding of their environment than we humans do. This latter comment reveals a trust in Mother Nature that is mediated through the fisher’s intimate relationship with the organisms she or he fishes for.

The eagerness with which shrimp fishers identify other problems as more pressing evinces a numbing to the problem that may be shared by environmental activists and lawyers. While not all shrimp fishers are aware of the problem, the slight majority who are aware of it expressed feelings of fatigue and pessimism towards the dead zone during our interviews. Gulf hypoxia is a problem that has persisted on the landscape for over three decades and is fairly reliable: it returns almost every year in the spring or summer, and then disappears as the weather cools and storms mix the water (Bianchi et al., 2010). Shrimp fishers know the area where it typically resides, and what they need to do to avoid it. This is in sharp contrast to uncertain events such as oil spills, hurricanes, and fluctuating diesel prices. However, shrimp fishers also identify other problems, such as imports and wetland loss, which are also predictable, as a bigger threat than hypoxia. Cajun culture, of which a majority of shrimp fishers in the region are a part of, places a strong reliance on the concept of Mother Nature, as evidenced by fisher interview respondents’ near constant reference to it. For instance, Don, a shrimp fisher from a village south of New Orleans exclaimed, “My opinion is Mother Nature is working” after he had described the myriad problems his fishing business faces in the wake of the Deepwater Horizon oil spill. And Joe said, “Mother Nature is a wonderful thing, it always lets a little door out." Cajuns' emotional connections to nature are strengthened by their contact with their environment through activities that include hunting and fishing, both of which are part of the Cajun cultural fabric (Harrison, 2012). Emotional affinity towards nature is reinforced by positive experiences in nature, according to Kals, Schumacher, and Montada (1999). This emotional affinity, furthermore, is part of the Cajun cultural toolkit, which Swidler explains encompasses the symbols, world-views, and rituals people use to solve problems (1986). Cajuns' emotional affinity for nature is expressed in part by their belief in Mother Nature. In this case, Mother Nature is a cultural tool within the their toolkit that can help them regain control over their environment and may provide answers to difficult environmental problems during a time of deep pessimism. Kals and Montada contend people are compelled to act in a protective manner towards the environment by an emotional connection to nature (1995). While Cajun culture's embrace of Mother Nature exemplifies an emotional connection to nature that can be utilized to encourage Cajun shrimp fishers to act in pro-environmental ways, my research indicates it is encouraging inaction on their part. Shrimp fisher respondents conveyed they are relying on Mother Nature to solve problems they feel they are powerless to control, yet other research indicates the opposite response could result from their belief in Mother Nature. This reliance may prove to work as a barrier to mobilizing shrimp fishers' grievances with Gulf hypoxia; if Mother Nature is expected to right anthropogenic wrongs, there may be little incentive for action on the part of Cajun shrimp fishers.

A reliance on Mother Nature, however, cannot explain the weariness with which activists and lawyers approach Gulf hypoxia (or the fatigue and pessimism of the non-

Cajun shrimp fishing community). Many of these respondents exhibited pessimism that the problem of Gulf hypoxia is solvable, and they often identified a lack of political will as a major hurdle to change. Jerry identified the problem of one state working alone, with no political will when he claimed, "The political will will never be there; it's got to be a federal solution because Louisiana can't tell another state what to do." Bob, an oceanographer-cum-activist, believes the problem must be dealt with, yet he thinks it is a "wicked problem." Some respondents claimed political will problems rest squarely on Louisiana. Some told me the state had even intervened in Chesapeake Bay's Total Maximum Daily Load program, which they felt clearly put Louisiana's cards on the table against nutrient reductions. David, a different Riverkeeper who works out of Baton Rouge, claimed, "The tricky thing is being in Louisiana. There is only so much we can do about the nutrients up in the middle of the country. It's always a challenge to figure out what our role is."

Other respondents focused on the complexity inherent in dealing with so many states at once. For instance, Philip told me, "The feds have the states—that's another complication that the Clean Water Act is federalist, so each of the states, 48 of the 50, have primacy over their limitations for clean water." And Brian explained, "Well anything that crosses state lines, you have a similar set of difficult policy issues which have interacted with the political climate over the last twenty-five years to produce an inability to do anything very effective."

Activist and lawyer respondents often mentioned the lack of regulation on nonpoint source pollution as a major obstacle to mitigating Gulf hypoxia. Brian described the problem as a lack of legal handles with which to litigate, and he feels the

Clean Water Act is out of date and environmental law stagnant. And Philip reminded me, "Agriculture is pretty much exempt from the biggest tool that we have for water pollution, which is the Clean Water Act." Randy, an environmental activist who is currently focused on environmental justice issues in the New Orleans area, explained how a lack of regulation translates into a lack of incentive. He said, "Right now there's no incentive to not put it in the river or stream. So there needs to be some kind of really strict regulatory process to address that. And I don't see that happening."

What's Wrong with the Public Trust Doctrine?

Environmental activists and lawyers often identified the lack of regulation on nonpoint source pollution as a major barrier to mitigating Gulf hypoxia. This unregulated state does not provide a familiar legal tool with which to litigate the problem. They also often identified complexity as a barrier, particularly the large number of states that contribute to the problem, which complicates any legal approach to the problem. While a high degree of cooperation between a large number of agencies and states is required to address water quality in the Mississippi River, agreement on a solution to stem nonpoint source pollution has largely been elusive (Chase, 2011). Additionally, a lack of political will was frequently identified as a barrier to legal action. These three barriers contribute to a lack of interest in mitigating Gulf hypoxia and the general sense of fatigue and pessimism among environmental activists and lawyers in the area.

Every lawyer, and many of the environmental activists, I spoke with were familiar with the Public Trust doctrine. However, not a single respondent thought the doctrine could be used with much effect in the case of Gulf hypoxia. One respondent framed his knowledge of the doctrine as something activists dreamed about when they weren't busy using more immediate tools. However, several respondents thought the doctrine would become a more enticing option the worse the problem gets and the more desperate fishers become. For instance, Peter said, "I think the further along it gets, and the more desperate they get I think solutions like that will probably get more utilized cause they're not going to have any other way to address their circumstance." Jack agreed that a bigger problem could mean legal action would work when he said, "Of course, if it got to a point where it was so damaging, and so obviously detrimental to large groups of people, then I think you'd see some legal action and you'd see things stick." Others claimed the Public Trust doctrine approach would still face the complications arising from multiple states having jurisdiction over waters fueling Gulf hypoxia. For instance, Philip told me, "I haven't really looked much into public trust issues, and then you know, I don't know how that exactly would translate for interstate waters."

Some respondents, however, thought a federal Public Trust doctrine could be used in this case, and the question then turned on whether or not there really is a federal Public Trust doctrine. Brian is certain any success with the doctrine would be at the federal level. And Jerry is confident there is a basis for a federal Public Trust doctrine, yet when pressed he could not articulate why he felt that, "I have to believe that there is—this is just belief, airy belief—that there is a foundation for that in federal law, common law probably. I don't know why I think that. Common sense?" Jerry summed up what many other respondents had told me when he said,

> It's an interesting idea, one that I find a little off, a little too difficult, too abstract, and there are other hooks. Why would you pick the vaguest, most problematic one to try to prove, in a difficult case to start with, that there is such a beast as a Public Trust in the federal government when there are specific statutes you could apply better? As a legal strategy I likely wouldn't go there unless it was the only thing left.

Ultimately, respondents were more willing to discuss legal tools other than the Public Trust doctrine. Many respondents were adamant that numerical standards were needed, which is a route to creating a TMDL system. Brian claimed, "It's hard to deal with problems that cross jurisdictions without having very concrete enforceable limits." And Philip suggested Louisiana should sue upstream states for physical impairment when he said, "I would like to see Louisiana's attorney general file suit against upriver states, because under the Clean Water Act you can't cause or contribute to a downstream impairment, and it's kind of a poster child." Louise, an environmental lawyer and law instructor, is interested in a legal concept that might be considered more radical than the Public Trust doctrine, but which she feels would provide more ecological protections. She explained, "We don't have a right of nature. It's something I'd like to change. I think if the courts could, let's sue on ecological concerns."

When activist and lawyer respondents discussed the Public Trust doctrine with me, it was clear the doctrine is not currently viewed as a reasonable tool to use to mitigate Gulf hypoxia. Respondents were aware of the doctrine, and in some cases viewed it as a pipe dream, but they were quick to find barriers to using it. They were clearly more comfortable discussing legal tools they had more experience with, such as the creation of a TMDL program for the Mississippi River that would enforce numerical standards for nitrogen and phosphorous. However, several respondents felt the bigger the problem gets the more likely they would be to consider a fringe legal tool such as the Public Trust doctrine. Overall, respondents were clear that the doctrine would need a lot more understanding for them to be comfortable with it. This may be a result of environmental law's focus on environmental statutes. Many environmental lawyers are simply not familiar enough with the Public Trust doctrine to consider its use.

One aspect of the Public Trust doctrine that further complicates its usage in the case of Gulf hypoxia is the extent to which the legal community believes in a federal Public Trust doctrine. Each state is unique in the degree to which it embraces the doctrine, and the tools it uses to recognize it (Klass & Huang, 2009). The doctrine can take the form of a Constitutional restriction on legislative power, or judge-made common law that can be overturned by legislatures, or some variation between. Due to the large number of states that contribute to Gulf hypoxia, any approach at mitigation using the doctrine would need to utilize a federal Public Trust doctrine because the impact of the problem is not felt in the states that are the largest contributors to the problem. However, just as my interview respondents were uncertain whether there actually is a federal doctrine or not, many scholars disagree on this point. Frank claims the question of a federal Public Trust doctrine is regarded as more or less settled, the answer being Public Trust doctrine resides in state law (2012), yet Chase asserts the doctrine is considered a federal common law that helps to govern national waterways (2011). Additionally, Craig tells us the federal Public Trust doctrine affirmation comes from the historic Illinois Central case of 1892, and that because a federal Public Trust doctrine underlies all state versions of the doctrine, any variance from the federal doctrine by a state's Public Trust doctrine can be seen as an expansion of the federal doctrine (2007). Wood, moreover, firmly believes the Public Trust doctrine has Constitutional foundations, and she argues it is a fundamental attribute of sovereignty itself, and as such it needs not be explicitly described in the U.S. Constitution (and those of other democratic nations) in order to be considered a part of the Constitution (2013). Another major hurdle for the doctrine is its adversarial relationship with property rights. It elevates public property over private property rights (Klass & Huang, 2009), which can be a hard sell in the U.S. Both the uncertain nature of a federally recognized Public Trust doctrine, and the potential it holds to diminish private property rights, reduce its allure as a solution for Gulf hypoxia for the time being.

CHAPTER V

CONCLUSION

By breaking my larger research question into several smaller questions, I was able to combine three different methods into one coherent picture addressing the feasibility of using the Public Trust doctrine in the case of the brown shrimp fishery in the northern Gulf of Mexico. In order for the Public Trust doctrine to be a useful tool, there must be a clear negative impact by hypoxia on the brown shrimp fishery. Furthermore, the people who utilize the fishery must have knowledge of that impact. Finally, there must be enough knowledge of the Public Trust doctrine in the community with resources to litigate to enable the use of the doctrine. The doctrine is unlikely to be useful in this case without any one of these components in place.

This research did not find a significant impact from Gulf hypoxia on the abundance of brown shrimp. However, prior research has begun to document some impacts, which could be used in a Public Trust doctrine case. Any effect of hypoxia on the brown shrimp is still too small to register as a high priority for the people who fish for the shrimp at this point. The other problems they face continue to appear more important to a majority of shrimp fishers in Louisiana. There are simply not enough grievances for them to mobilize around Gulf hypoxia at this point in time. The problem will likely need to get bigger and/or persist on the landscape longer to have a large enough impact on the brown shrimp fishery for shrimp fishers to take action. Unfortunately, the longer hypoxia is allowed to persist and grow in the area, the harder it will be to reverse.

The shrimp fisher and environmental activist/lawyer communities in Louisiana do currently exhibit some coalitions and trust that could be utilized in a joint effort to stem Gulf hypoxia. Furthermore, the reliance on Mother Nature by Cajun shrimp fishers could be used to facilitate common ground between the communities. Trust between the communities ebbs and flows and must be cultivated carefully in order to facilitate any litigation work between them. Leaders may be easier to find within the fishing community because they have already framed the problem—even though they have not necessarily embraced it. The fatigue and pessimism shrimp fishers expressed towards Gulf hypoxia in my research may be lessened by an influx of new ideas and energy that could stem from an emergence of coalition leaders from within the shrimp fishing community. Ultimately, activists and leaders will need to work on framing the problem with the brown shrimp fishery in mind if they are to make any political ground on stemming the nutrient pollution that makes its way into the Mississippi River Basin.

APPENDIX A

SEAMAP SAMPLING STATION BOTTOM DEPTHS, LATITUDES, AND LONGITUDES

Station ID	Bottom Depth (m)	Latitude (start)	Longitude (start)
1	7.3	29.716	-93.532
1	7.3	29.703	-93.603
2	16.5	29.201	-93.484
2	16.6	29.219	-93.546
3	20.1	29.007	-93.87
3	20.8	28.989	-93.566
4	25.6	28.731	-93.936
4	28.5	28.714	-93.525
5	36.8	28.573	-93.518
5	36.8	28.596	-93.449
6	42.4	28.501	-93.502
6	43	28.494	-93.446
7	18.8	29.051	-93.881
7	18.8	29.163	-93.405
8	13.9	29.505	-92.998
8	13.4	29.377	-93.294
9	104.2	28.018	-92.991
9	99.1	28.034	-93.144
10	45.7	28.498	-92.985
10	44.8	29.009	-93.012
11	14.6	29.442	-92.825
11	14.3	29.477	-92.932
12	25.2	29.003	-92.492
12	25.2	29.02	-92.717
13	24.7	29.015	-92.986
13	24.1	29.061	-92.697
14	49.4	28.498	-92.507
14	48.6	28.503	-92.6
15	91.4	28.097	-92.409
15	89.2	28.514	-92.492
16	29.3	28.732	-91.773
16	31.3	28.722	-91.852
17	20.1	29.102	-92.433
17	19.9	29.038	-92.197
18	9.1	29.108	-91.828
18	9.5	29.168	-92.166
19	101.1	28.071	-91.733
19	108.3	28.031	-92.069
20	21.9	28.64	-91.169
20	21.8	28.841	-91.652
21	11.7	28.997	-91.505

21	12.6	28.99	-91.572
22	11	28.998	-91.502
22	9.7	29.021	-91.655
23	36.6	28.514	-91.208
23	37.1	28.547	-91.398
24	5.5	28.973	-91.196
24	5.5	29.145	-91.376
25	31.1	28.593	-91.32
25	29.6	28.568	-91.184
26	12.8	28.887	-91.382
26	13	28.766	-91.033
27	7.3	29	-90.999
27	9.1	29	-91.001
28	27.4	28.546	-90.923
28	29.3	28.501	-91.001
29	32.9	28.502	-90.992
29	34.7	28.425	-90.981
30	11	28.855	-90.916
30	12.6	28.856	-90.86
31	31.1	28.492	-90.737
31	31.5	28.612	-90.72
32	29.3	28.528	-90.718
32	29.3	28.536	-90.661
33	36.6	28.471	-90.843
33	36.6	28.484	-90.632
34	34.7	28.499	-90.493
34	34.9	28.52	-90.558
35	9.1	28.999	-90.498
35	11	29	-90.499
36	16.5	28.899	-90.381
36	18.3	28.904	-90.367
37	23.8	29.001	-90
37	23.6	28.76	-90.33
38	23.8	29.072	-89.896
38	25.6	29.001	-89.999
39	20.1	29.033	-90.031
39	21.9	28.981	-90.083
40	91.8	28.673	-89.928
40	87.8	28.489	-90.003
41	27.4	29.073	-89.766
41	27.4	29.068	-89.69
42	7.3	29.224	-89.868
42	7.3	29.204	-89.598
43	23.8	29.098	-89.743
43	24.9	29.006	-89.591
44	14.6	28.998	-89.5
44	14.6	28.998	-89.498
45	89.6	28.254	-90.302
45	92.4	28.27	-90.219
46	32.9	28.717	-92.909
46	33.3	28.708	-92.903

APPENDIX B

DATES OF SEAMAP SAMPLING STATIONS

Station	Date
1	7/3/00
1	7/5/02
2	7/1/02
2	7/10/00
3	7/1/02
3	7/9/00
4	7/1/02
4	7/8/00
5	7/1/02
5	7/9/00
6	7/1/02
6	7/9/00
7	7/1/02
7	7/9/00
8	7/4/02
8	7/10/00
9	7/6/02
9	7/13/00
10	7/5/02
10	7/12/00
11	7/4/02
11	7/11/00
12	7/5/02
12	7/11/00
13	7/5/02
13	7/12/00
14	7/7/02
14	7/13/00
15	7/7/02
15	7/14/00
16	7/8/02
16	7/15/00
17	7/8/02
17	7/11/00
18	7/8/02
18	7/16/00
19	7/16/02
19	7/15/00
20	7/18/00
20	7/9/02
21	7/9/02
21	7/16/00
22	7/17/00
22	7/9/02
23	7/16/02
23	7/16/00

24	7/2/00
24	7/4/02
25	7/18/00
25	7/16/02
26	7/15/02
26	7/16/00
27	7/17/00
27	7/9/02
28	7/10/02
28	7/17/00
29	7/10/02
29	7/17/00
30	7/15/02
30	7/17/00
31	7/18/00
31	7/14/02
32	7/10/02
32	7/17/00
33	7/14/02
33	7/17/00
34	7/18/00
34	7/14/02
35	7/17/00
35	7/9/02
36	7/19/00
36	7/11/02
37	7/19/00
37	7/14/02
38	7/11/02
38	7/18/00
39	7/11/02
39	7/18/00
40	7/13/02
40	7/19/00
41	7/19/00
41	7/12/02
42	7/3/02
42	7/20/00
43	7/19/00
43	7/12/02
44	7/19/00
44	7/12/02
45	7/13/02
45	7/19/00
46	7/5/02
46	7/12/00

APPENDIX C

SHRIMP FISHER INTERVIEW SCRIPT

1. How long have you been a fisherman?
   a. Do you fish for other things besides the brown shrimp?
   b. What percentage of your time, over a whole year, is devoted to catching brown shrimp?
   c. When you're shrimp fishing, do you go out for days at a time, sleep on your boat?

2. Have you heard about the dead zone out on the shelf?
   a. What have you heard about the dead zone out on the shelf?
   b. Have you seen it yourself?
   c. Is the dead zone in the same area as where you find the brown shrimp?
   d. Does its size change, and does where it's at change?

3. Does the dead zone worry you?
   a. Do you think the dead zone is affecting the brown shrimp?
   b. In a good way or a bad way?
   c. Do you think the dead zone is a threat to your livelihood?
   d. Are other shrimp fishers talking about the dead zone, worried?

4. Have you changed how you fish for shrimp (brown or other) because of the dead zone?
   a. Have you ever fished in a different area than you wanted to because of the dead zone?
   b. Can you explain how this happened; walk me through it?
   c. Has it ever made you fish for something else than brown shrimp?
   d. Has it ever made you just not go out?
   e. Have you considered doing other kinds of work because of the dead zone?

5. Have you heard why the dead zone happens?
   a. Do you know how the dead zone happens?
   b. Have you heard scientists talk about it?
   c. Who's responsible for the dead zone?
   d. Do you remember a time when it wasn't around?

6. Have you heard of any measures people are taking to try to weaken the dead zone?
   a. Do people talk about fixing the dead zone?
   b. What kind of people talk about this?
   c. Do you have any common interests with these people?
   d. Do you think it can be done?

e. If it doesn't get fixed, do you think it might get worse?

7. Do you think environmental lawyers can help fix the dead zone?
   a. What do you think about environmental lawyers?
   b. Do they ever do anything you think is useful?

APPENDIX D

ENVIRONMENTAL LAWYER AND ACTIVIST INTERVIEW SCRIPT

1. Involvement with the dead zone]
   a. What is your involvement with the dead zone in the Gulf? What kind of work do you do?
   b. What ways are you and/or your organization working on reversing the dead zone?
   c. How long have you been working on the issue?
   d. Can you give me an example of some of this work, walk me through it?
   e. Have you ever worked on a problem similar to this, maybe somewhere else?
   f. Are other environmental organizations in the area working on this topic?

2. Perceptions of the problem
   a. What different kinds of people does this problem affect an intimate way?
   b. What kind of people are interested in this problem, who do you hear talking about it and engaging with the issue?
   c. Can you give me an example of how the dead zone is affecting _____?
   d. What about shrimp fishers, the ones who fish on the shelf?
   e. Do you think the local shrimp fishers are affect negatively by the dead zone?

3. Causes of the problem
   a. What do you think is the biggest factor contributing to the dead zone?
   b. Has this changed over time, or has ____ always been the biggest problem?
   c. Is there self-reflection here, do you think the biggest contributors to the problem know what they're doing?

4. Reversing the problem
   a. Is this process reversible?
   b. What would it take to reverse it?
   c. What do you think is the biggest challenge to reversing the dead zone?

5. Challenges to above
   a. Is there a way to litigate this problem?
   b. Has anyone tried litigation over nonpoint source pollution?
   c. Are there novel ways you might consider (re-word)?

6. PTD possibilities (Lawyers only)
   a. Are you familiar with the Public Trust Doctrine?
   b. Do you know of anyone who thinks using the PTD could provide a foothold into the nonpoint source pollution problem?
   c. Do you think the PTD could be used if it was shown that some resource users, say fishers, were being impacted by the dead zone?

d. If so, how? And what are the biggest challenges with that approach?
e. How strong is the Public Trust Doctrine in Louisiana?
f. Does the Public Trust Doctrine in Louisiana provide support for marine resource users?
g. Would the PTD need to be used/strong in all of the upstream states, where the problem is generated, or only here in LA? Or would it take a federal PTD?

APPENDIX E

LOUISIANA FISHER SURVEY

1. How many years have you been fishing as a primary activity?
   _____________ years

2. What animals do you fish for regularly?
   [Brown shrimp] [White shrimp] [Other shrimp] [Crab] [Oyster]
   [Fish:_______________] [Other:_______________]

3. How much time do you spend fishing each year? (Indicate the number of months you spend fishing on a regular basis; regular basis being a full work-week)
   [0-1 months] [1-4 months] [5-8 months] [9-12 months]

4. Where do you regularly fish?
   [Inshore (state waters only)] [Offshore] [Both]

5. What are the biggest threats to your fishing livelihood? (Rank the threats in order of severity by placing a number next to the problem, with 1 meaning biggest threat)
   ___ Diesel Prices
   ___ Freshwater Diversions/Coastal Master Plan
   ___ Gulf Dead Zone
   ___ Hurricanes
   ___ Imports
   ___ Oil Spills
   ___ TEDs (turtle excluder devices)
   ___ Wetland Loss
   ___ Other:______________
   ___ Other:______________

6. Have you heard of the dead zone in the Gulf?
   Yes / No / Not Sure

7. How did you first hear about the dead zone?
   [News source] [Friend or relative] [Other fisher(s)] [Fishing association]
   [Other: ________________]

8. Do you know why the dead zone forms every year?
   Yes / No / Not sure

9. Have you ever seen the dead zone yourself?
   Yes / No / Not sure

10. If you answered yes to #9, how many times have you seen it?
    [1-3] [4-7] [8-12] [12-20] [more than 20]

11. Have you ever fished near the dead zone?
    Yes / No / Not sure

12. Has the dead zone ever forced you to fish in an area different from where you planned to fish?
    Yes / No / Not sure

13. Has the dead zone impacted your fishing in any way?
    Yes / No / Not sure

14. If you answered yes to #13, please explain how the dead zone has impacted your fishing.

15. What do you think will be happening with the dead zone in 10 years?

16. Please provide any additional comments you think might be useful.

APPENDIX F

PAIRWISE DIFFERENCE TABLE

Sampling Station	Shrimp Count: Low Hypoxia Year (2000)	Shrimp Count: High Hypoxia Year (2002)	Difference
1	147	0	147
2	4	6	-2
3	1	1	0
4	0	21	-21
5	3	45	-42
6	0	102	-102
7	4	14	-10
8	0	0	0
9	0	25	-25
10	0	0	0
11	154	3	151
12	0	59	-59
13	0	95	-95
14	0	11	-11
15	5	0	5
16	22	2	20
17	0	0	0
18	5	10	-5
19	15	9	6
20	23	8	15
21	0	1	-1
22	0	22	-22
23	12	198	-186
24	127	0	127
25	19	82	-63
26	3	0	3
27	0	3	-3
28	52	16	36
29	0	1	-1
30	39	0	39
31	5	0	5
32	23	13	10
33	7	12	-5
34	0	10	-10
35	0	10	-10
36	26	48	-22
37	0	147	-147
38	0	10	-10

39	0	0	0
40	0	2	-2
41	0	0	0
42	411	0	411
43	0	4	-4
44	0	4	-4
45	8	15	-7
46	0	8	-8

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