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Distribution and direct impacts of marine debris on the Mississippi commercial shrimping

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Distribution and direct impacts of marine debris on the Mississippi commercial shrimping

industry

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Commercial shrimpers in the Mississippi Sound frequently encounter marine debris in their nets, which results in loss of time, loss of catch, and added repair costs. Yet, the spatial and temporal distribution of this marine debris and the economic impact faced by shrimpers in the Mississippi Sound is not well known. This study measured the quantity and economic impact of marine debris by surveying 20 commercial shrimpers. Participants logged marine debris encounters, fishing data, and damage to fishing gear during the July 2020 through December 2020 shrimping season. It was found that shrimpers encounter marine debris 19% of all tows, and the majority of all marine debris encountered by shrimpers (79%) was derelict crab traps. Additionally, 10% of all tows reported direct impacts.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Commercial shrimpers in the Mississippi Sound and neighboring waters frequently encounter marine debris, resulting in the loss of time and catch, and added repair costs. However, there is no formal reporting procedure in place for reporting these interactions and, thus, little data exists on the types, abundances, or economic impact of marine debris in the north-central Gulf of Mexico (ncGoM). Prior to this study, no information existed on the spatial and temporal distribution of marine debris that shrimpers encounter within the ncGoM and the subsequent economic impact on commercial shrimping. Collection and dissemination of this information will help improve understanding of the potential impacts of marine debris and optimize the implementation of preventive measures.

To characterize the quantity and impacts of marine debris, a sample of commercial shrimpers (20) were selected for a comprehensive data collection program. These participants were asked to maintain a logbook for every marine debris encounter over the shrimping season, July 2020 through December 2020. The logbook contained information on time spent fishing, types of marine debris encountered, and lost fishing time due to damaged gear. This information was used to address several objectives and associated hypotheses (listed below) related to the

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abundance, diversity, and distribution of marine debris encountered by shrimpers and its impact on the industry.

1.1   Research objectives and hypotheses:

1. Characterize the abundance and diversity of marine debris that shrimpers encounter including what is caught in their nets and floating near their vessels in the north-central Gulf of Mexico.

    o H_0: There will be no discernable trend in the composition of marine debris reported by shrimpers.

    o H_1: Because plastics are the most abundant type of marine debris, it is expected that plastics will be the most frequently encountered marine debris item reported by shrimpers.

2. Characterize the distribution of marine debris in the north-central Gulf of Mexico.

    o H_0: There will be no discernable spatial trend in distribution of marine debris reported by shrimpers within the Northern Gulf of Mexico.

    o H_1: There will be a higher concentration of marine debris encounters reported near the mainland.

3. Analyze the direct economic impact marine debris has on the Mississippi commercial shrimping industry.

    o H_0: Marine debris will have a negligible economic impact on the Mississippi commercial shrimping industry.

    o H_1: Marine debris will have a statistically significant economic impact on the Mississippi commercial shrimping industry.

CHAPTER II

THE DISTRIBUTION OF MARINE DEBRIS ENCOUNTERS BY MISSISSIPPI

COMMERCIAL SHRIMPERS

Commercial shrimpers frequently encounter marine debris in their nets. Prior to this study, no information existed on the spatial and temporal distribution of marine debris that shrimpers encounter. To characterize the quantity and spatial distribution of marine debris in the Mississippi Sound, twenty commercial shrimpers were selected for a comprehensive data collection program. Surveyed shrimpers encountered marine debris on 19% of tows, and results showed that derelict crab traps were an overwhelming issue for shrimpers, and the type of fishing gear used (skimmer vs. otter trawls) influenced the type of marine debris encountered.

2.1   Introduction and literature review

From single-use plastics to abandoned vessels, marine debris is an ever-increasing environmental and economic issue affecting aquatic and marine environments around the world (Beaumont 2019). The National Oceanic and Atmospheric Administration (NOAA) defines marine debris (MD) as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally, or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes (NOAA 2017). These materials end up in waterbodies through ocean-based sources, being dumped, swept, or blown off vessels and stationary platforms at sea, and land-based sources, being blown, swept, or washed out to sea (NOAA 2016).

The earliest evidence of MD was found during the 1960s; plastic fragments and pellets were found in marine environments and the stomachs of birds (Barnes 2009). However, there were few scientific investigations before 1980 on the topic. Mass production of plastic began in the 1950s, and due to its wide range of uses, it is estimated that 10 percent of all household waste is made up of plastic (Barnes 2009). Due to the rate of production and popularity, plastics make up 50 to 80 percent of MD found along beaches, floating on the ocean surface, and on the seafloor; of that, 46 percent of marine plastics float across the water's surface (Barnes 2009). The distribution of plastic MD is patchy for a variety of reasons, including local wind and current conditions, coastline geography and the varying points of entry into the system (Wessel et al. 2016).

The Mississippi Sound is an estuarine system that does not have distinct physical boundaries; however, it has been defined as "An arm of the sea forming a channel between a mainland and an island," and "A long, large, rather broad inlet of the ocean, generally extending parallel to the coast" (Gary et al. 1972). It is relatively shallow with an average depth of 9.9 feet

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with 3 channels that reach from the mainland to the Gulf of Mexico (Eleuterius 1976). There are several freshwater systems that drain into the Mississippi Sound from Louisiana to Alabama. The freshwater outflows and diurnal tides influence the currents that move between the mainland and the barrier islands (Eleuterius 1976; Figure 2.1).
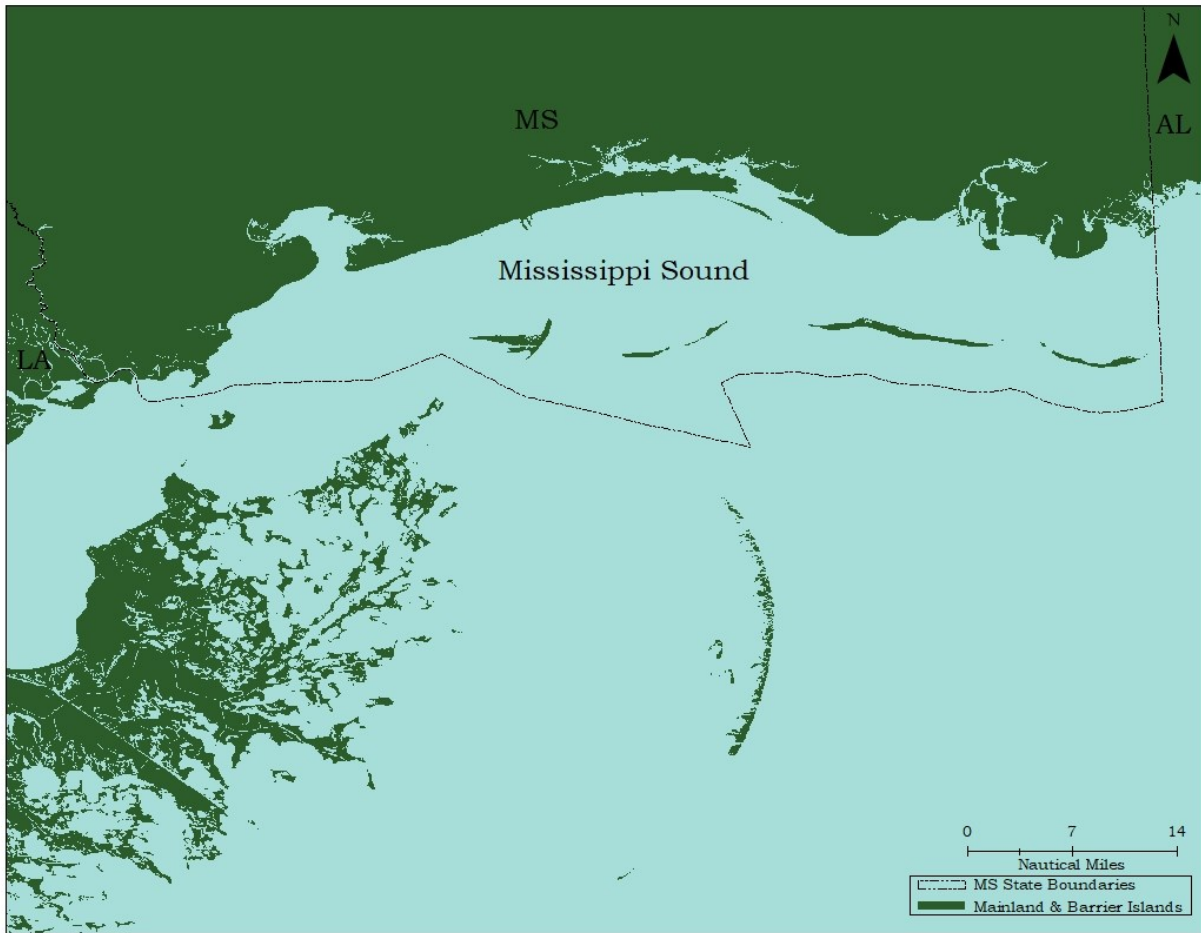
Figure 2.1   Map identifying study area.

Map identifying the Mississippi Sound and surrounding waters. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

Winds and currents throughout the Gulf of Mexico have a major influence on nearshore conditions. In the central Gulf of Mexico, winds typically blow in an offshore direction, while stronger winds in the western Gulf of Mexico typically blow in the onshore direction (Morey et al., 2005). These winds shift seasonally with southeasterly winds during the spring and summer months and north-north easterly winds during the autumn and winter months (Brown Jr. et al., 1976). While the Caribbean and Loop Currents travel clockwise from the Caribbean throughout the Gulf of Mexico (Ribic et al., 2011), shallow currents closer to the coastal shelf are influenced by river outflows, creating eddies that flow counterclockwise along the Gulf Coast, prevailing wind conditions, and wave refraction creating longshore currents (Bianchi et al., 1998;Morey et al., 2005). Research throughout the northern Gulf Coast region has shown greater accumulation rates of marine debris on the Texas coastline, the most westward coastline studied, compared to the coastlines in the eastern portion of the study areas (Wessel et at., 2019; Ribic et al., 2011). These findings suggest that in addition to higher populations along the Texas coast, the accumulation of floating marine debris is influenced strong onshore currents that carry floating marine debris from the east to the west, rather than the freshwater influxes throughout the region (Ribic et al., 2011; Wessel et al., 2019).

Much like floating MD is influenced by wind and water currents, the geographic distribution of benthic marine debris is influenced by hydrodynamics and bathymetry (Galgani et al., 2015). Depending on their size and flow rate, rivers can transport marine debris from upstream and empty into estuaries or even farther offshore while slower moving river systems and estuaries can easily accumulate marine debris (Galgani et al., 2015).

Compared to floating marine debris, marine debris that lies on the seafloor is less widely monitored (Galgani et al., 2015). A compilation of 26 studies between 1976 and 2007 worldwide

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compared a variety of methods used to quantify the amount of benthic marine debris (Spengler &
Costa 2008). This comparison of studies showed that the most common method used to quantify
benthic MD was using a bottom trawl net. Despite its popularity, there are disadvantages to this
method. Bottom trawl nets are limited to specific types of seafloor they can be used on,
underestimations can be made due to mesh size, and fibers from the net itself can skew results
(Spengler & Costa 2008; Galgani et al., 2015). As the topic of marine debris becomes more
popular, the number of studies on benthic MD are increasing. Many of these studies have
focused on derelict fishing gear due to its harmful effects on marine life and fisheries around the
world (Spengler & Costa 2008). Plastics have been found on the seafloor of every sea and ocean;
however, due to the few studies and lack of standardization of benthic MD, the total amount
worldwide is unknown (Spengler & Costa 2008; Galgani et al., 2015).

Evidence shows that both floating and benthic MD directly impacts wildlife, habitats,
tourism, and the introduction of invasive species. Wildlife is prone to becoming entangled in or
ingesting MD, leading to injury, illness, suffocation, starvation, and even death (Eriksen et al.
2014). Marine debris that sits on the seafloor can also damage important ecosystems by scouring,
breaking, or smothering important habitats such as seagrasses and coral reefs (Sheavly &
Register 2007; Kühn et al., 2015). Environments with accumulations of benthic marine debris,
including plastics and abandoned fishing gear, have shown signs of both mechanical damages, or
the destruction of habitat, as well as impacts on the capacity of phototrophic and heterotrophic
nutrition (Kühn et al., 2015). Additionally, unsightly MD that floats along the ocean surface or
washes up on coastlines can cause a decrease in tourism, resulting in economic losses for those
popular destinations (Petrolia et al. 2019). Finally, as MD floats across oceans, it can carry alien

species to a new environment; these invasive species can have a devastating impact on fisheries and local ecosystems (Agamuthu et al. 2019).

A specific type of fishing that is particularly susceptible to marine debris impacts is trawl shrimping. The two primary types of trawls used in Mississippi are otter and skimmer trawls. Otter trawls are towed directly behind the boat while skimmer trawls are mounted on a frame and pushed along beside the boat. As shrimpers tow (otter) or push (skimmer) nets, marine debris can get caught in the net, which has the potential to cause substantial losses in catch and time dealing with marine debris as well as direct damage to vessels and fishing gear.

Derelict fishing gear (DFG) is a common type of MD; consisting of nets, lines, traps, and other recreational or commercial fishing equipment that has been lost, abandoned, or otherwise discarded (NOAA 2020). Studies in areas where the seafloor is littered with DFG have shown economic loss. A 4-year program in which DFG was removed, including over 31,000 crab traps, from Chesapeake Bay showed that lost blue crab pots are a significant source of MD (Bilkovic 2014). This program investigated the amount of bycatch associated with the DFG; almost 32,000 marine organisms were found in the DFG retrieved. Blue crabs experienced the highest mortality from lost pots with an estimated 900,000 animals killed each year, a potential annual economic loss to the fishery of $300,000 (Bilkovic 2014). In addition to DFG studies, research on the economic impact of marine debris has expanded in recent years (Bilkovic 2014; DelBene 2014; Beaumont 2019). However, one study published in 2019 suggested that it is not yet possible to accurately quantify the decline in annual ecosystem service delivery related to marine plastic based on available research (Beaumont 2019). Evidence does suggest, however, a substantial negative impact, a 1 to 5 percent reduction, on almost all ecosystems on a global scale (Beaumont 2019).

Despite the growing public awareness and knowledge of the negative effects of MD, it is a continuously growing issue. As the amount of MD escalates worldwide, fisheries show more apparent signs of distress. The industry regularly suffers from natural and anthropogenic disasters, and the effects of MD on the industry is currently unknown. To address gaps in research and provide aid to the struggling industry, I have designed a study that quantifies and removes the marine debris that these fishermen encounter.

2.1.2 Research objectives and hypotheses

1. Characterize the abundance and diversity of marine debris that shrimpers encounter including what is caught in their nets and floating near their vessels in the north-central Gulf of Mexico.
   - o H_0: There will be no discernable trend in the composition of marine debris reported by shrimpers.
   - o H_1: Because plastics are the most abundant type of marine debris, it is expected that plastics will be the most frequently encountered marine debris item reported by shrimpers.

2. Characterize the distribution of marine debris in the north-central Gulf of Mexico.
   - o H_0: There will be no discernable spatial trend in distribution of marine debris reported by shrimpers within the Northern Gulf of Mexico.
   - o H_1: There will be a higher concentration of marine debris encounters reported near the mainland.

2.2 Methods

2.2.1 Shrimper recruitment

Forty-four (44) shrimpers were surveyed in late 2018 to gather demographic, location, vessel and gear characteristics, fishing effort, and to gauge interest in participating in an incentivized data collection program. This survey was approved by the Institutional Review Board in 2019 (MSU IRB-18-533) and administered in both English and Vietnamese since those are the dominant languages used by MS shrimpers (Posadas 2021). The results of this survey are described in a recent study (Posadas et al., 2021), so this thesis is only considering how the shrimpers were selected for participation. From the participants that expressed interest in participating in an incentivized data collection study, we selected twenty (20) that represented a diverse and representative group of shrimpers. They were chosen based on the length of their boat, the type of fishing gear used (e.g., skimmer, otter trawl, and others), which coastal county their boat resides in, and fishing effort (i.e., the number of reported trips in 2018). The selected shrimpers were then trained on the data collection procedures in person and provided training materials in both English and Vietnamese. Shrimpers that successfully completed the data collection procedures for this study and the associated economic impact study (described in Chapter 2) were provided a stipend of $300 per month from July to September 2020 and $500 per month October to December 2020 (i.e., $2,400 per shrimper over the shrimping season).

2.2.2 Data Collection

To collect the data, shrimpers used logbooks where they were required to report data associated with every tow the completed over the 2020 shrimping season (e.g., July through December) throughout the MS Sound and surrounding waters (Figure 2.1). Data reported in each logbook entry contained information relevant to both this study and the Chapter 3 (economic

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impact) study. Specific fields from the logbook are listed below with an asterisk (*) indicating

fields from the logbook used for *Objectives 1 & 2* in Chapter 2 of the thesis.

- • *Specific times fishing nets were placed in the water and removed
- • *General location fished specified by gridded map (Figure 2.2)
- • *The types of marine debris encountered (e.g., plastic, fishing gear, metal, etc. – Table 2.1)
- • The amount of catch lost due to encountering marine debris (pounds)
- • The amount of fishing time lost due to encountering marine debris (minutes)
- • The damaged caused to fishing gear/vessel by marine debris (e.g., torn net, tangled motor, etc.)
- • The estimated cost of the damage that occurred ($)

Table 2.1   Types of marine debris encountered by shrimpers

Debris Code	Debris Type
0	Nothing
1	Derelict crab traps
2	Wooden materials
3	Other fishing gear (Nets, fishing poles, etc.)
4	Plastics (Styrofoam, bottles, plastic bags, food wrappers)
5	Tires
6	Rope
7	Clothing (Gloves, shoes)
8	Glass (Bottles)
9	Construction/Housing materials (Vinyl siding)
10	Others (General "trash" and unknown items)
11	Organic materials (Jelly fish, grass, logs, etc.)
12	Metal materials

Categorized types of marine debris documented by commercial shrimpers with corresponding codes used for data analyses. Organic materials were omitted from data analyses.
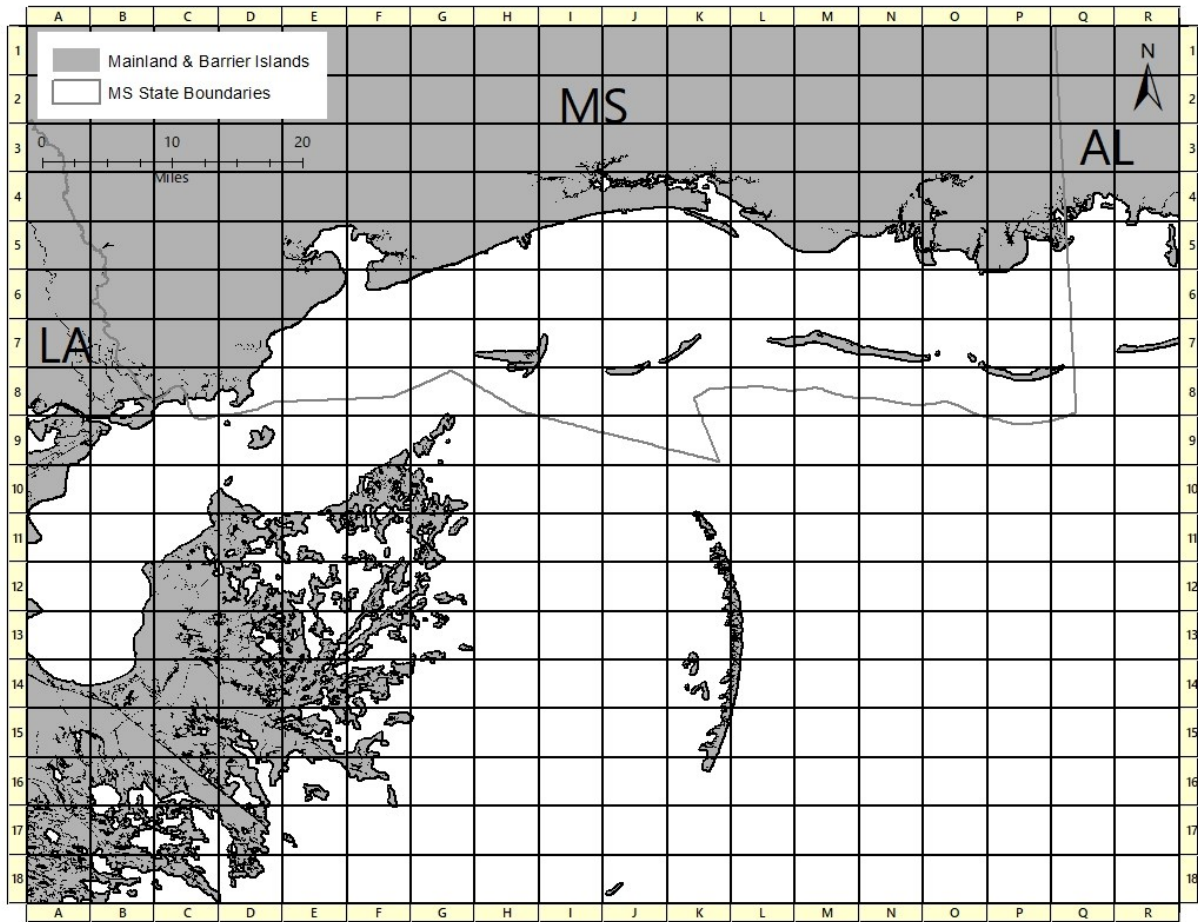
Figure 2.2   Grid map used by shrimpers

Shrimpers used the map to identify the general location in which they fished for each tow reported. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

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2.2.3   Analyses

While shrimpers reported location information within individual cells based on the grid map (Figure 2.2), these cells were grouped into 9 larger fishing areas for spatial analysis (Figure 2.3). While it was important to group the grid cells as evenly as possible, the fishing areas were grouped by distance from shore, and numbered northwest to southeast. An additional factor that was considered when creating the fishing zones was where the fishermen would logically fish during a single day of fishing. While area of the fishing area was considered and maintained by grouping 8 grid cells into each zone, the shape of each area differed from one another. The nearshore study areas (0 to 1.85 KM from shore) include areas 1, 2, 4, and 9 while the offshore study areas include 3, 5, 6, 7, and 8. Some surveys documented multiple areas from the grid map fished. For these, the most northwest quadrant was chosen to use for both spatial and economic impact analyses.
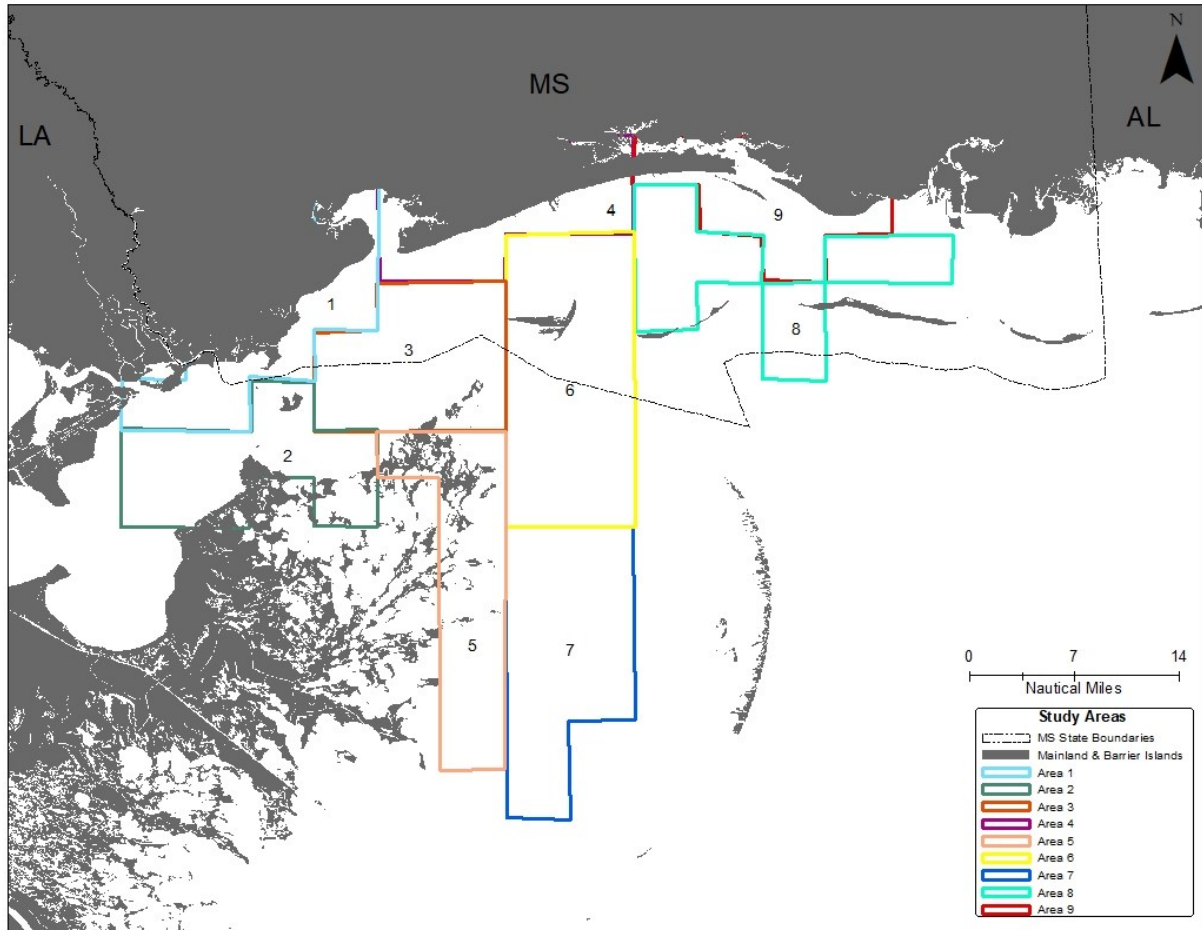
Figure 2.3   Study Areas created from the documented grid cells by shrimpers

Nine study areas created for data analysis. The different areas were created to find any north to south or east to west patterns. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

The Shapiro-Wilk normality test was used to assess the assumption of nonparametric data distribution (Yap & Sim 2011). To achieve *Objective 1*, the Kruskal- Wallis rank sum test (Smalheiser 2017) was used to determine the probability of encountering marine debris and trends in abundance and diversity of marine debris for each of these 9 study areas. Using the Euclidean Distance (882.89 meters), a nearest neighbor analysis (Aldstadt & Getis 2002) was used to evaluate the spatial distribution of MD (*Objective 2*) reported by shrimpers. The default

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search area was used to encompass all marine debris encounters without excluding those data points on the peripheral or over-extending the search area. Analyses with significant results were then applied to ArcGIS to create a series of choropleth maps showing the probability of MD encounters using base maps derived from ESRI.

2.3   Results

The participating fishermen submitted a total of 1,067 tow records. However, only 897 were used for data analysis; 117 were excluded because they were either submitted for dates outside of the range of the study, missing information, or not representative of a single tow (> 4 hours). Out of the 897 tows, 218 (24%) were reported as encountering MD; however, 50 (23%) of those encounters were attributed to organic materials, such as vegetation, which was not a focus of this study, and were excluded from the rest of the analyses.

Fishing effort was not uniform across the entire study area. 54% of all logbook records were submitted by fishermen whose boat resides in Jackson County, the land closest to Area 9, while only 4% of records were submitted by fishermen whose boat resides in Hancock County. Likewise, MD encounters varied by location (Kruskal-Wallis Rank Sum Test – $p = 0.010$) with the highest chance of MD encounters occurring in Area 8 (Figure 2.4). Dunn's post hoc tests indicated that the probability of encountering MD in Area 2 was very low; with Areas 2 and 6 ($p = 0.040$) and Areas 2 and 8 ($p = 0.030$) being significantly different from each other. Nearest neighbor tests showed that the observed clustered pattern in marine debris was not random ($p < 0.001$), which could indicate overarching anthropogenic and environmental drivers that influence these patterns.

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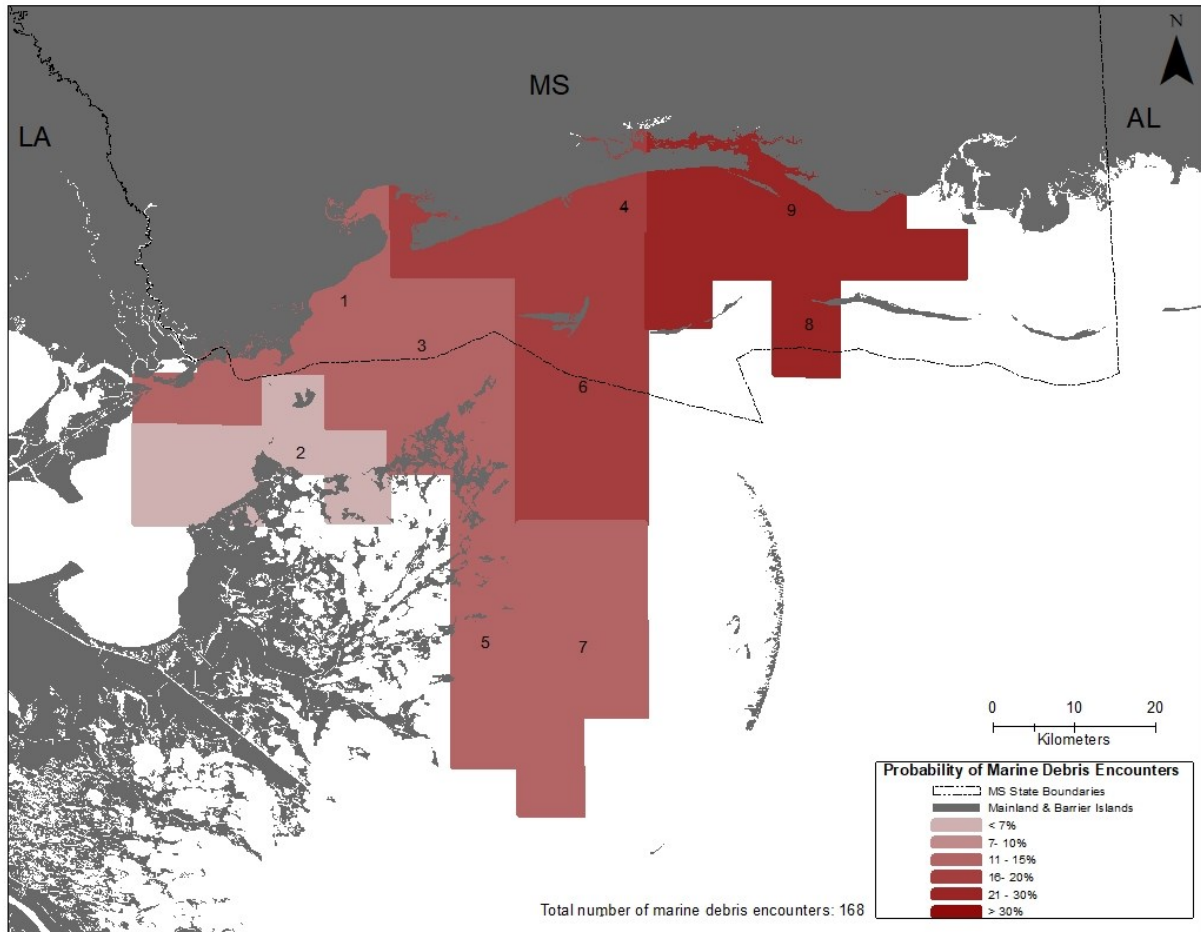
Figure 2.4   The probability of encountering marine debris reported by shrimpers

Shrimpers had the highest probability of encountering marine debris in Area 8 (28%; throughout Biloxi Bay and the mouth of the bay) followed by Area 9 (23%; offshore of the mouth of Biloxi Bay). Created from the results of the Kruskal-Wallis test (p = 0.010) when analyzing all 168 marine debris encounters. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

MD encounters also varied by month (Kruskal-Wallis Rank Sum Test – $p < 0.001$) with a higher percentage of encounters occurring in November (37%) and lowest occurring in September (12%) than other months (Table 2.2; Figure 2.5). Dunn's post hoc comparison showed that 3 comparisons were significant (e.g., July and September $p = 0.004$, August and November $p = 0.023$, and September and November $p < 0.001$; Figure 2.6).

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Table 2.2   Marine debris caught and the probability of occurrence

Types of Marine Debris Caught by Gear Type

	Otter Trawls	Probability of Occurrence	Skimmers	Probability of Occurrence
Derelict Crab Traps	46	10%	64	25%
Wooden Materials	1	0%	0	0%
Other Types of Fishing Gear	2	0%	5	2%
Plastics	2	0%	7	3%
Tires	1	0%	0	0%
Rope	0	0%	1	0%
Clothing	0	0%	2	1%
Glass	0	0%	1	0%
Construction/Housing Materials	4	1%	0	0%
Others/Unknown Materials	3	1%	3	1%
Metal Materials	0	0%	2	1%

Amount of each type of marine debris documented by shrimpers and the probability of encountering each type depending on the type of gear used.
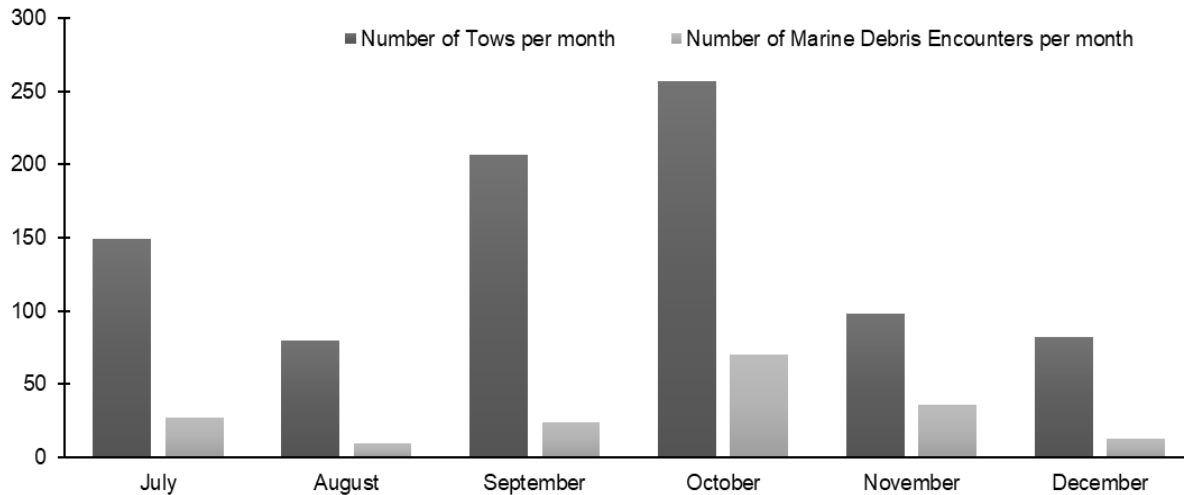
Figure 2.5   Tows vs. marine debris encounters each month

Comparison of total amount of tows and marine debris encounters each month. November had the highest probability of encountering marine debris (37%) while September had the lowest probability (12%).
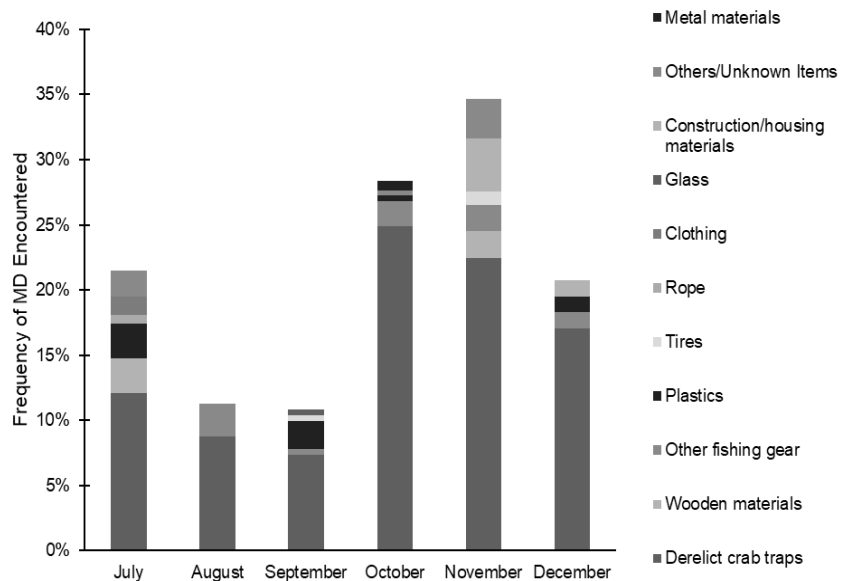
Figure 2.6   Frequency of marine debris encounters by type each month

Derelict crab traps were the most frequently encountered type of marine debris each month.

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Overall, shrimpers reported encountering MD on 19% of tows. The dominant type of debris reported by shrimpers was derelict crab traps (79% of tows with MD encounters) followed by other types of fishing gear (5%), single use plastics (5%), and unknown trash items (4%) (Figure 2.7). Generally, the assemblage of MD encountered was similar in each area (Kruskal- Wallis Rank Sum Test – p = 0.430) but varied by month (Kruskal-Wallis Rank Sum Test – p = 0.007). However, that monthly result was driven by the difference in MD assemblage between October and November (Dunn's post hoc test- p = 0.019) with all other monthly pairwise comparison showing no statistical difference (p > 0.050).
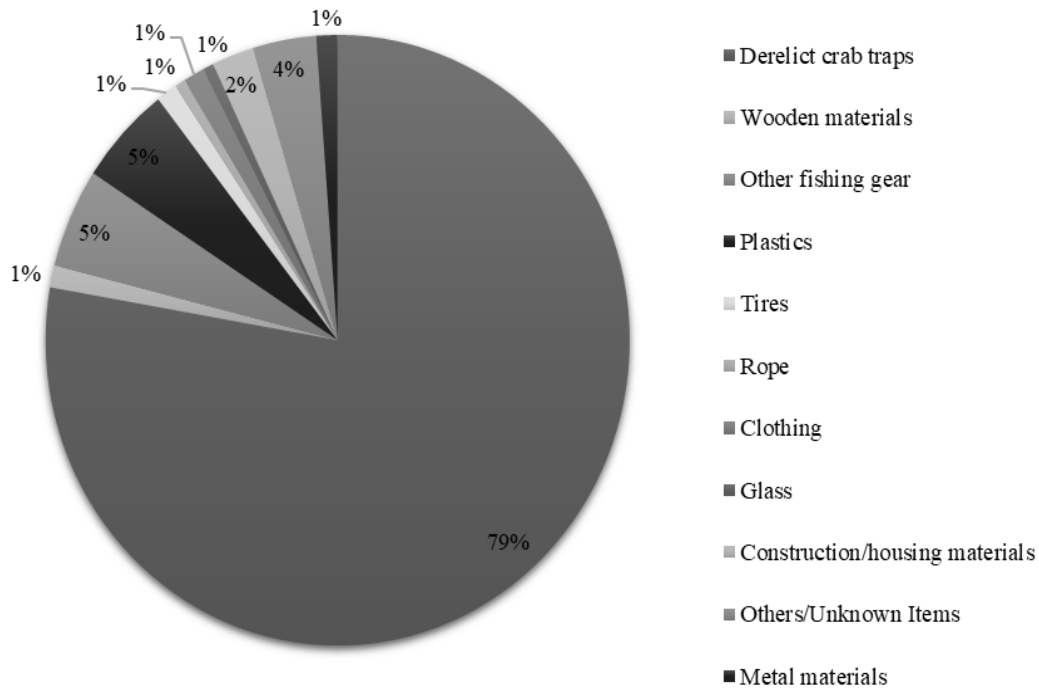
Figure 2.7   The abundance and diversity of marine debris reported by shrimpers

The diversity of all 168 reports of marine debris. Derelict crab traps made up the majority of all reports (79%).

The pattern of MD occurrences was heavily influenced by type of fishing gear (Kruskal-Wallis Rank Sum Test – p = 0.002). The two distinct gear types used were skimmer (29% of all reported tows) and otter (52% of all reported tows). The remaining 19% of tow reported using either both types of gear or other, unidentified gear. The difference in likelihood of MD encounters between these two gear types was significant with over 31% of Skimmer and only 13% of Otter tows reporting encountering MD (Kruskal-Wallis Rank Sum Test – $p < 0.001$). The probability of MD encounters between the two gear types also had a spatial variation (Kruskal Wallis Rank Sum Test- p-value = 0.0002; Figure 2.8 and Figure 2.9). The use of skimmers resulted in more MD encounters in Area 8 while the use of otter trawls resulted in more MD encounters inshore and mostly in Area 4. Additionally, the types of debris caught by these two gear types were different (Kruskal Wallis Rank Sum Test – $p < 0.001$; Table 2.2). Skimmers caught both more and a wider variety of MD than otter trawls.
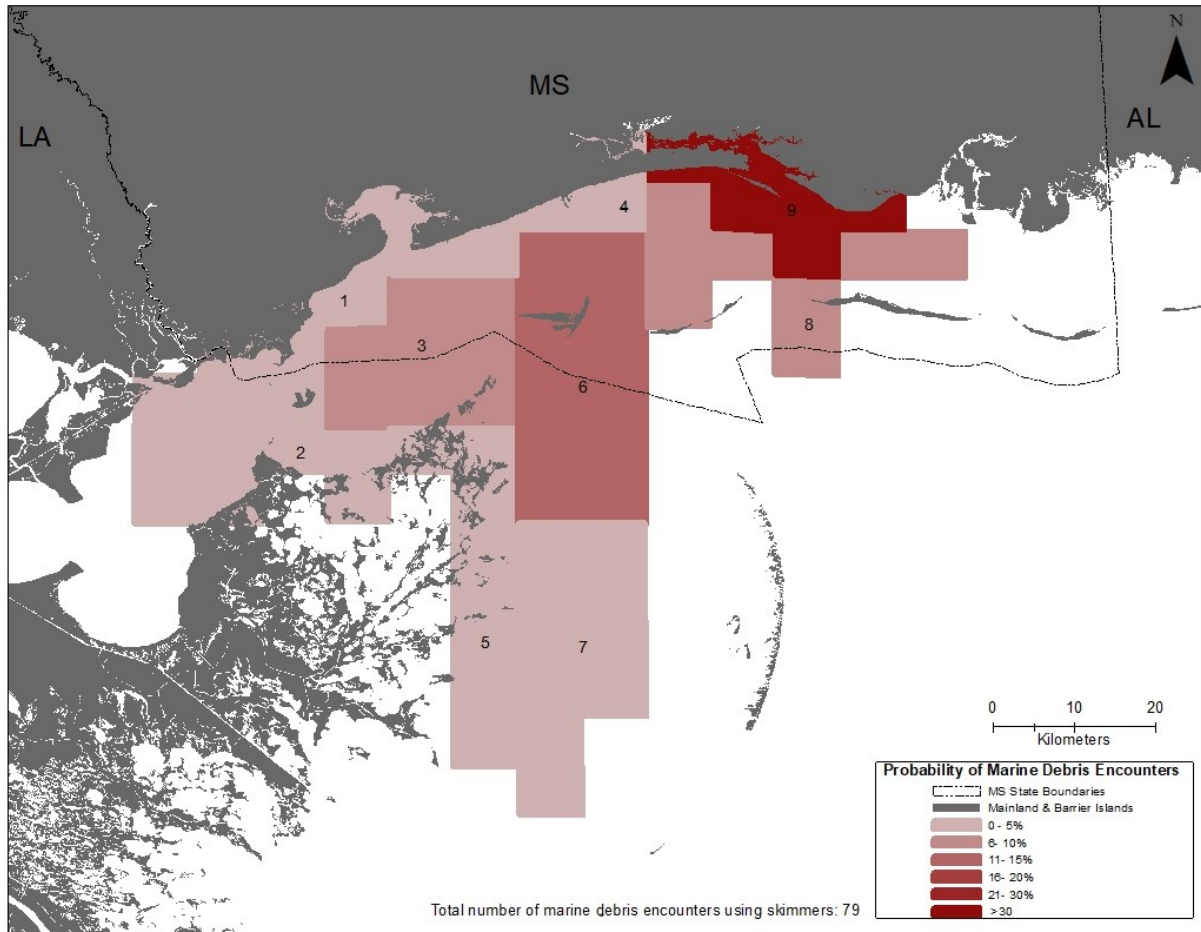
Figure 2.8   Map of spatial probability of encountering marine debris using a skimmer

There was a total of 79 marine debris reports using a skimmer. Study Area 8 (throughout Biloxi *Bay and the mouth of the bay) had the highest chance of encountering marine debris (70%). Created from the results of the Kruskal-Wallis test (p < 0.001) when analyzing all tows that reported using a skimmer. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community*

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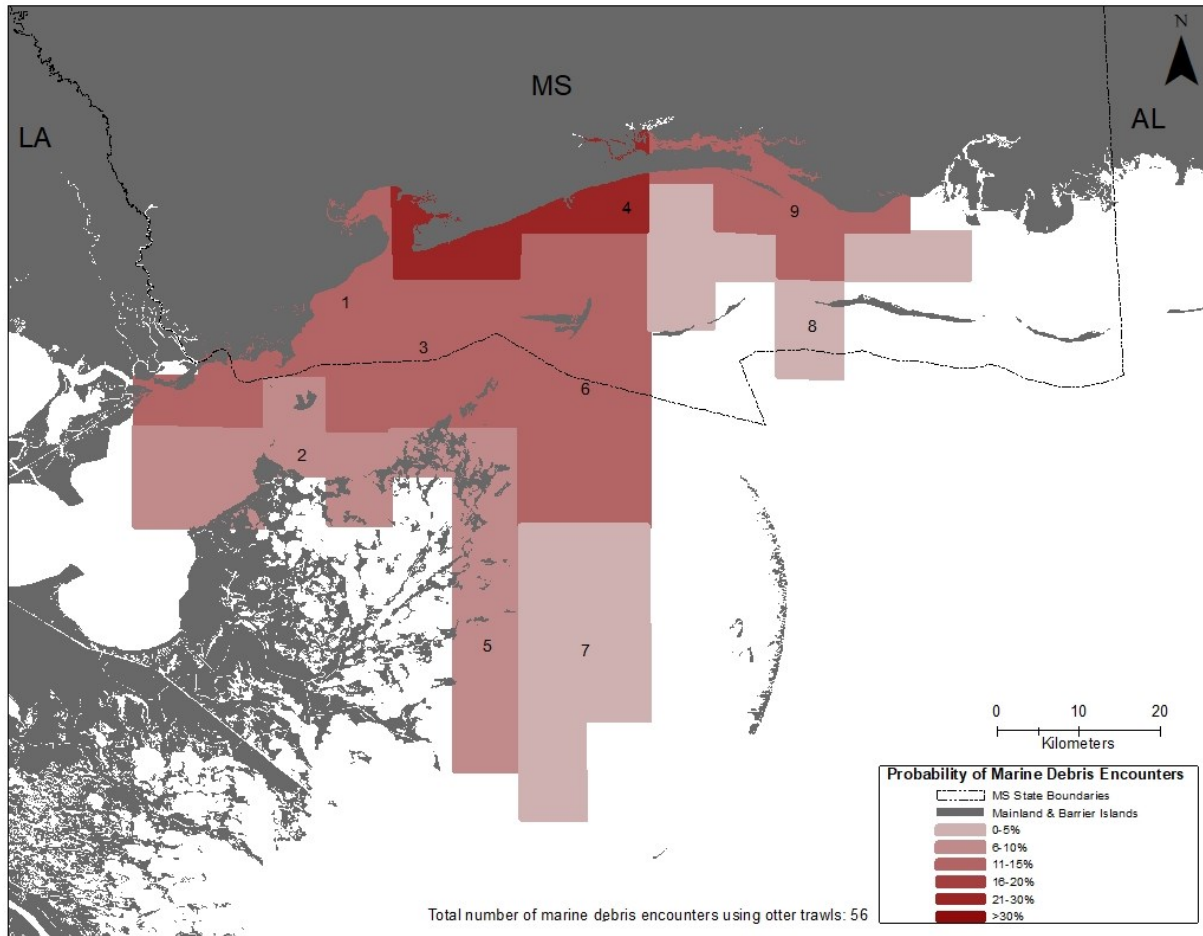
Figure 2.9   Map of spatial probability of encountering marine debris using an otter trawl

There was a total of 56 marine debris reports using an otter trawl. Study Area 4 (inshore Harrison County) had the highest chance of encountering marine debris (21%). Created from the results of the Kruskal-Wallis test (p < 0.001) when analyzing all tows that reported using an otter trawl. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

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2.4   Discussion

This study is the first to our knowledge to quantify the distribution and types of MD encountered by commercial shrimpers. These shrimpers reported that 19% of all tows encountered MD, and 79% of these encounters were with derelict crab traps. MD encounters also varied by location with the highest chance of MD encounters occurring in Area 8. Study Areas 8 and 9 are located just south of Jackson County, whose shrimpers had the highest participation rates. Additionally, crabbing is also an important industry for the MS Gulf Coast, and there are no regulations for where crabbers can drop traps. As of 2018, there were 129 registered crabbers in MS. The highest percentage of the registered crabbers was in Jackson County; with 47 registered crabbers, the county made up 36% of all crabbers in MS. Therefore, the higher number of crabbers in this area could explain a higher probability for shrimpers to encounter MD in the waters offshore of Jackson County.

While July through September is generally the peak of the shrimping season (Posadas 2021), the logbook submissions did not peak until October. The onset of "shelter in place" orders due to the COVID-19 pandemic stalled fishing efforts and logbook participation at the beginning of the season which started June 2020. A general increase in fishing efforts and additional participating fishermen lead to a peak of logbook submissions in October. Following the "shelter in place" orders, fishermen dealt with an incredibly busy hurricane season with 3 major storms making landfall along the Gulf Coast (NOAA 2020; Moore 2020). Hurricane Sally made landfall near Gulf Shores, Alabama in mid-September 2020, and both Hurricane Delta and Zeta made landfall during the month of October in Louisiana and Mississippi (NOAA 2020). These hurricanes brought storm surges, winds, and rain that may have moved and/or created MD throughout the study areas. Additionally, the higher tides allowed for shrimpers to fish in areas

that were previously too shallow to reach. Peaks in MD occurrences during the month of October suggest that these areas fished were likely littered with MD that accumulated over long periods of time.

There was little diversity in the type of MD that was encountered throughout the entire study area and a clustered pattern was observed. Crab traps made up 79% of the MD reported by shrimpers. Crabbers use metal traps that are and sit on the seafloor possibly with a buoy attached to mark their location. To increase productivity, crabbers typically drop their traps close proximity to each other (Arthur et al. 2020); resulting in the clustered pattern observed with the nearest neighbor analysis. These traps are not extremely mobile except for being dragged by a boat's propellors or strong storm surges affecting the currents and dragging them across the seafloor (Guillory 2001). Once crab traps are abandoned or lost at sea, they are considered MD (Arthur et al. 2020). Other types of debris encountered included tires, housing or construction materials, single use plastics, fishing gear, clothing, and rubber material.

Due to the type of gear used for shrimping, shrimpers encounter benthic MD, which sits on the seafloor, more often than encountering floating MD (Spengler & Costa 2008). The two most common types of trawls used in Mississippi are otter and skimmer trawls. Otter trawls are towed directly behind the boat and must be taken completely out of the water when MD is caught (Coale et al. 1994). Skimmers are mounted on a frame and pushed along either side of the boat, fishing the entire water column. Individually, the skimmer nets are about half the width of the otter trawls; however, because two skimmer nets are used at the same time, the two types of gear cover about the same area while fishing (Coale et al. 1994). The difference in likelihood of marine debris encounters between these two gear types was significant with over 31% of skimmer and only 13% of otter trawl tows reporting encountering marine debris. Although the

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most frequently fished area reported for both types of gear was Area 9, the probability of marine debris encounters between the two gear types also had a spatial variation. The use of skimmers resulted in more MD encounters in Area 8 while the use of otter trawls resulted in more MD encounters inshore and mostly in Area 4. A possible explanation for these differences is, skimmers fish the entire water column while otter trawls only fish along the seafloor. Additionally, the longshore current that runs from east to west (Ribic et al. 2011) paired hurricane winds and affected water currents may have pushed MD from Jackson County or near the mouth of Biloxi Bay westward into the neighboring study areas. Coale's (1994) study comparing rates of bycatch between the two types of gear, showed that skimmers were unable to fish in waters with greater depths than 3.7 meters. The more frequent and wider variety of MD encounters with skimmers may be a result of these nets being susceptible to both benthic and floating debris.

Despite the high percentage of derelict crab traps reported, the findings in this study may underestimate the amount of benthic MD that littered the floor of the MS Sound. In January 2019, the EPA's Gulf of Mexico Program funded a 2-year collaborative effort from the Mississippi State University Extension Service, Mississippi-Alabama Sea Grant, Mississippi Commercial Fisheries United, and the NOAA Marine Debris Program to create a year-round derelict crab trap removal and research program in Mississippi Sound. Nearly 2,300 traps were removed from the waters between 2019 and 2020 (Sartain et al. 2021). While most commercial shrimpers fish throughout the Mississippi Sound and its neighboring waters, it can be speculated that many of the records submitted to the study are from the fishermen's final tow as they are on their way in from a day or night of fishing, resulting in an uneven distribution of fishing efforts throughout the study areas. Study Area 9 also contains a high traffic area for both recreational

and commercial boats from neighboring harbors in both Harrison and Jackson County, skewing the results further.

This research has been the first to quantify the impacts of MD on the commercial shrimping industry. However, Arthur et al. (2020) analyzed the benefits of a derelict crab trap cleanup along the Gulf Coast. This study concluded the removal of these traps would be beneficial for both the blue crab and finfish fisheries with additional benefits for the economy, marine mammals and sea turtles, and boating traffic (Arthur et al. 2020). The higher number of MD occurrences per tow documented in October and November suggest that distribution and patterns of encountering MD could have been heavily influenced by hurricanes in the Gulf of Mexico during the study period. Additionally, the type of gear used influenced the type of debris that was caught. To alleviate and prevent these MD encounters, shrimpers may want to consider the type of gear that they choose, and benthic MD focused cleanups should be done before the start of both the hurricane and shrimping seasons each year. Marine debris is frequently encountered commercial shrimpers and has been reported to cause economic impacts (discussed in Chapter 3).

CHAPTER III

THE DIRECT ECONOMIC IMPACTS OF MARINE DEBRIS ON THE MISSISSIPPI

COMMERCIAL SHRIMPING INDUSTRY

Commercial shrimpers frequently encounter marine debris in their nets, resulting in the loss of time and catch, and added repair costs. Prior to this study, no information existed on the spatial and temporal distribution of marine debris that shrimpers encounter and the subsequent economic impact on commercial shrimping. To characterize the quantity and impacts of marine debris, twenty commercial shrimpers were selected for a comprehensive data collection program within the Mississippi Sound, USA. Results showed that derelict crab traps were an overwhelming issue for shrimpers, and the type of fishing gear used (skimmer vs. otter trawls) influenced both the type of marine debris encountered and the subsequent economic impacts. Surveyed shrimpers encountered marine debris on 19% of tows and lost an average of 18.21 minutes, 7.88 kg of catch and $6.37 (USD) costs in gear damage per tow with encounters, resulting in loss of $7,702 (USD) per year per shrimper.

3.1 Introduction and Literature review

Marine debris and its impacts can be found on virtually any ocean, seafloor, and beach worldwide. Estimates show that nearly 2 billion tons of waste is produced each year, most of which is made of plastic and other hard, durable materials (Kaza et al. 2018). The majority of all MD consists of plastics whose production began in the 1950s. The production of plastic has been increasing since its creation, and as world populations and cities grow, plastic production will likely continue to increase (Serra-Gonçalves et al. 2019). In addition to the production of plastics and other types of solid wastes, it is anticipated that solid waste emissions will increase to 2.6 billion tonnes of carbon dioxide equivalent by 2050 (Kaza et al. 2018). As these greenhouse gas emissions increase, the effects of anthropogenic climate change will also increase. As global temperatures rise, low pressure storms are predicted to increase in both frequency and intensity (Mora et al. 2019). With both the production of plastics and the frequency of hurricanes set to increase, the generation of MD will likely increase as well. The 2020 hurricane season showed signs of these effects, and as MD increases, the frequency in which shrimpers and other fishermen are affected will increase.

Once known as "the seafood capital of the world," the Mississippi Gulf Coast developed and flourished with the seafood industry (Boudreaux 2011). Although it continues to have a significant role in the state's economy, there has been a significant decrease in the role that it has played in recent decades.

The Mississippi seafood industry contributes a total output of goods and services, jobs provided in harvesting processing, wholesaling, fish markets, and restaurants. In 2015, the entire seafood industry contributed a total of $465.4 million to the state economy (Posadas 2018). Mississippi's commercial shrimp industry contributed a total of $215.4 million to the state

www.manaraa.com

economy in 2015, created 4,276 jobs, and generated total personal income of $88.5 million (Posadas 2018).

The seafood industry is sensitive to natural and anthropogenic stressors that often occur simultaneously and have forced the industry to continuously struggle (Rozier 2021). In general, commercial fisheries are seeing a shift in demographics. There is an aging population of fishermen while younger generations are seeking alternative careers (Gulf States Marine Fisheries Commission 2012). In 2020, over 45% of commercial fishermen along the Gulf States were 55 or above while those younger than 35 only made-up less than 15% (Posadas 2021). This significant loss of the younger generation to other career fields has led to a "greying of the fleet" among fishermen who increasingly depend on migrant workers (Gulf States Marine Fisheries Commission 2012).

In addition to the aging population, fishermen must constantly adapt to the changes in the environment that occur both naturally and anthropogenically. Freshwater from the Mississippi River pours into the Mississippi Sound each time the Bonnet Carré Spillway is opened in Louisiana. This results in reduced salinity, stunting the growth of important fisheries such as oysters and shrimp. The effects of opening the Bonnet Carré Spillway were seen in 2011, and in 2019 when the spillway was opened twice. Impacts of the spillway will also be seen in companies involved in the processing, wholesaling, and retailing of these products for years to come (Carskadon 2019).

Still recovering from the 2019 openings of the Bonnet Carré Spillway, the Covid-19 pandemic has brought another threat to the state of Mississippi's commercial fisheries. With "shelter in place" orders, many processors and dealers are concerned that they will not be able to

reopen, and fishermen are concerned about having the finances available to them to continue fishing (Lallo 2020).

Additionally, hurricanes and other tropical weather events are common throughout the Gulf of Mexico. These tropical weather events are known to significantly hinder the capacity of fisheries throughout the area. For example, Hurricane Katrina in 2005, resulted in damages to the Mississippi's processing plants and seafood dealers costing $101 million, and 87 percent of commercial vessels were damaged, resulting in $35 million (US Department of Commerce 2007; Posadas 2008). Marine-based supplies such as fuel and ice became hard to obtain, and most of the marinas were damaged. The damage resulted in labor shortages, and commercial landing revenue for 2005 resulted in a 79 percent decline from the previous year (US Department of Commerce 2007). Just five years after Hurricane Katrina, the Deepwater Horizon oil rig exploded 42 miles off the coast of Louisiana (The Ocean Team Portal), resulting in significant mortality within many ecological and commercial species while also closing most fisheries (Buck 2005). The 2020 hurricane season was record breaking with 30 named storms and 12 making landfall throughout the continental United States, 3 major storms made landfall along the Gulf Coast (NOAA 2020; Moore 2020). After months of fishermen taking precautions throughout the busy hurricane season, Hurricane Zeta hit the Gulf Coast during a highly productive time during the shrimping season. In an interview following the landfall of Hurricane Zeta on October 28, 2020, Ryan Bradley, director of Mississippi Commercial Fisheries United, stated that the seafood industry and infrastructure sustained damaged that would take months to recover (Moore 2020).

The seafood industry faces another threat as the magnitude of marine debris increases worldwide. The National Oceanic and Atmospheric Administration (NOAA) defines marine

debris (MD) as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally, or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes (NOAA 2017). These materials end up in waterbodies through ocean-based sources, being dumped, swept, or blown off vessels and stationary platforms at sea, and land-based sources, being blown, swept, or washed out to sea (NOAA 2016). The earliest evidence of MD was found during the 1960s; plastic fragments and pellets were found in marine environments and the stomachs of birds (Barnes 2009). Due to the rate of production and popularity, plastics make up 50 to 80 percent of MD found along beaches, floating on the ocean surface, and on the seafloor; of that, 46 percent of marine plastics float across the water's surface (Barnes 2009).

Derelict fishing gear (DFG) is common type of MD; consisting of nets, lines, traps, and other recreational or commercial fishing equipment that has been lost, abandoned, or otherwise discarded (NOAA 2020). Studies in areas where the seafloor is littered with DFG have shown economic loss (Bilkovic 2014). In addition to DFG studies, research on the economic impact of marine debris has expanded in recent years (Bilkovic 2014; DelBene 2014; Beaumont 2019). Posadas et al. (2021) surveyed 44 commercial shrimpers on the Mississippi Gulf Coast for perceptions on the frequencies and impacts in which MD occurred in 2018. The results of this study concluded that shrimpers frequently encounter MD, mostly DFG, and it has significant impacts on their operations, indicating that MD has a large impact on the industry (Posadas et al. 2021). While fisheries are a source of the DFG, they are often subject to the economic impacts of MD (Newman et al., 2015). Commercial fisheries suffer from both the direct and indirect impacts of MD. Direct impacts include the extra costs of repair damages, loss of catch and earnings due to loss of productive fishing time. Indirect impacts include loss of earnings due to

the impacts on fish stocks and loss of value of fishery resources (Newman et al., 2015). Despite the growing popularity, studying the economic impacts of MD is difficult because of the wide range of economic, social, and environmental impacts that must be considered in these studies (Newman et al., 2015). However, evidence suggests a substantial negative impact, a 1 to 5 percent reduction in marine ecosystem services (Beaumont 2019).

The majority of studies on MD target coastlines and floating MD; additionally, there is no standardization for the few studies that have targeted the seafloor, making the amount of MD across the seafloor is unknown (Spengler & Costa 2008; Galgani et al., 2015). The most accepted technique of studying benthic marine debris is using bottom trawl nets (Galgani et al., 2015). These nets are like the nets used by commercial shrimpers and drag across the seafloor, picking up whatever is caught.

While researchers hope to collect MD in their nets, it is a nuisance for shrimpers. Catching just one derelict crab trap, or other potentially damaging marine debris, in a shrimp net is an ordeal for shrimp vessels and fishermen (Guillory et al. 2001). Derelict traps can get caught in shrimping gear, resulting in torn nets, reduced catch, and less time spent shrimping. Nets may even have to be replaced completely while at sea, meaning shrimpers must maintain multiple sets of nets (Guillory et al. 2001). Despite the continuous issues derelict crab traps cause, they are often left in the water, creating a continuous, destructive loop.

As the amount of MD increases around the world, its impacts are becoming increasingly apparent. The economic state of the Gulf Coast is heavily dependent on the health of fisheries in the Gulf of Mexico. This fragile ecosystem and economy have suffered tremendously in recent decades from natural and anthropogenic disasters. Studying the effects of marine debris on the commercial shrimping industry is important to prevent the collapse of this important fishery.

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3.1.1   Research objective and hypothesis

1. Analyze the direct economic impact marine debris has on the Mississippi commercial
shrimping industry.

- o H_0: Marine debris will have a negligible economic impact on the Mississippi
  commercial shrimping industry.
- o H_1: Marine debris will have a statistically significant economic impact on the
  Mississippi commercial shrimping industry.

3.2   Methods

3.2.1   Shrimper recruitment and data collection

The data collected from the logbooks of the 20 participating shrimpers described in Chapter
2 was also used to evaluate the direct economic impacts of MD on the commercial shrimping
industry. Specific fields from the logbook are listed below with an asterisk (*) indicating fields
from the logbook used for this portion of the thesis.

- *Specific times fishing nets were placed in the water and removed
- *General location fished specified by gridded map (0)
- *The types of marine debris encountered (e.g., plastic, fishing gear, metal, etc. –
- Table 3.1)
- *The amount of catch lost due to encountering marine debris (pounds)
- *The amount of fishing time lost due to encountering marine debris (minutes)
- *The damaged caused to fishing gear/vessel by marine debris (e.g., torn net, tangled
  motor, etc.)
- *The estimated cost of the damage that occurred ($)

Additionally, the locations described in Chapter 2 (Figure 3.1) were also used to analyze

the impacts of MD.

Table 3.1   Types of marine debris encountered by shrimpers

Debris Code	Debris Type
0	Nothing
1	Derelict crab traps
2	Wooden materials
3	Other fishing gear
4	Plastics
5	Tires
6	Rope
7	Clothing
8	Glass
9	Construction/housing materials
10	Others/Unknown Items
11	Organic materials (Jelly, grass, logs, etc)
12	Metal materials

Categorized types of marine debris documented by commercial shrimpers with corresponding codes used for data analyses. Organic materials (11) were omitted from data analyses.
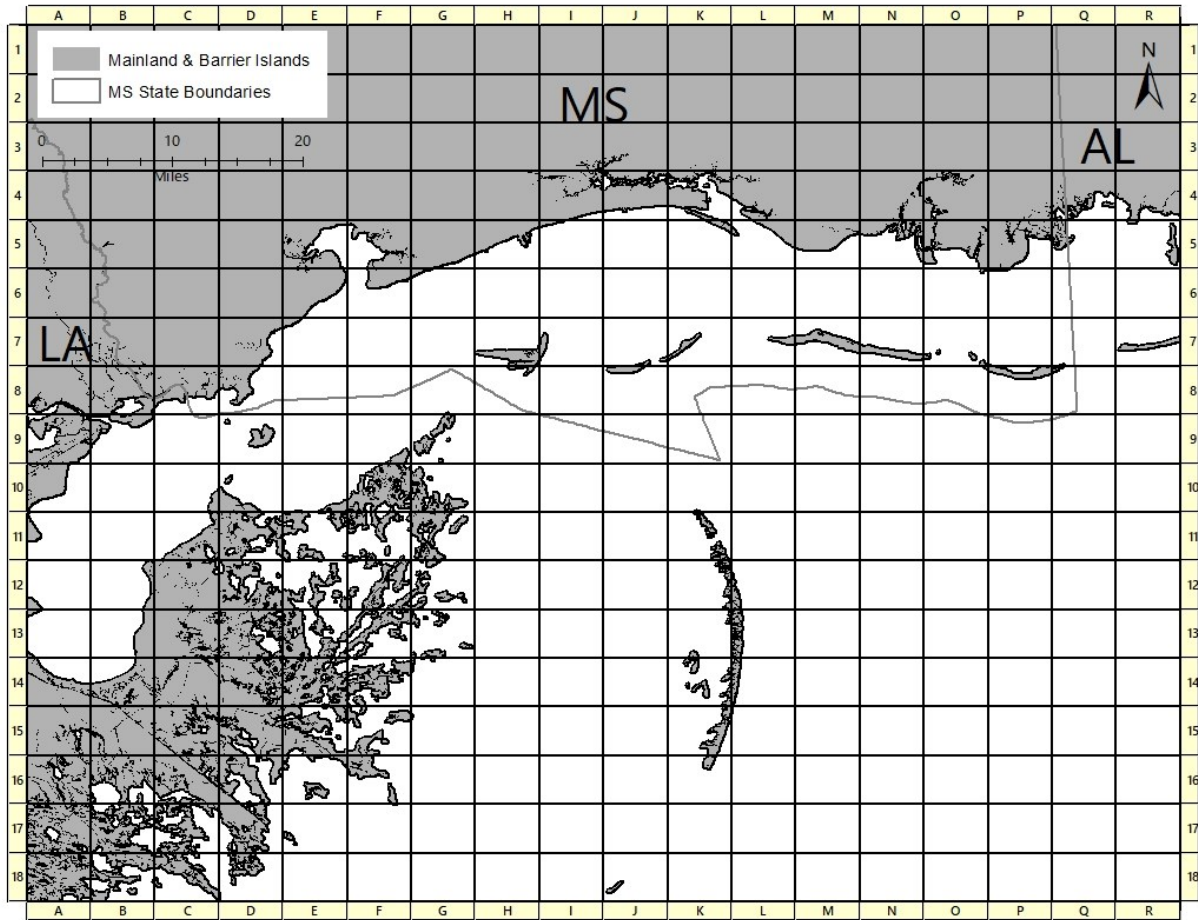
Figure 3.1   Grid map used by shrimpers

Shrimpers used the map to identify the general location in which they fished for each tow reported. Base map sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

3.2.2   Analyses

To assess the direct economic impact of MD on the commercial shrimping industry (*Objective 1*), Catch lost, Lost time, and Damage cost from MD reported by the shrimpers was converted to total sales in dollars ($USD in 2020) lost. Estimating total sales lost was done by combining sales lost directly due to marine debris per tow and sales lost due to fishing time lost during marine debris encounters. Sales lost directly due to marine debris per tow was calculated

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by multiplying 2020 pounds lost per tow from the logbooks by the 2019 average dockside price, $4.53 ($/kg, 2020 NOAA Fisheries; EPA 2021).

The logbooks kept by shrimpers during the 2020 season did not account for how many pounds of shrimp were caught per tow; because of this, data from 2019 was used in the formula for sales lost due to fishing time lost due to marine debris encounters. Sales lost due to fishing time lost during marine debris encounters was calculated by multiplying 2020 fishing time lost per tow from the logbooks by the 2019 average catch per minute, 0.364 kg ($\pm$ 0.395), and the 2019 average dockside price per kilogram ($4.53, 2021 NOAA Fisheries; EPA 2021).

Due to lack of normality, non-parametric tests were used (e.g., Kruskal-Wallis and Dunn's post hoc test) were used to assess the impacts of MD (*Objective 1*). To assess the effect of fishing location (n=9) and month (n=6) on the response variables of pounds lost, time lost, damage costs, and cumulative direct economic impact, multiple Kruskal- Wallis Rank Sum tests were conducted following the procedures of Queen et al. (2002). Each Kruskal- Wallis test assessed the effect of fishing location and month on an individual response variable (i.e., pounds lost, time lost, and damage costs) across all the records (with and without MD occurrences) and separately for records with MD encounters (i.e., 2 separate ANOVAs for each response variable). If location was significant, but month and the interaction between location and month were not, dates were pooled for Dunn's post hoc comparisons among locations. If a significant interaction between location and month occurred, or location and month were both significant, but the interaction was not, post hoc comparisons were done on each date separately.

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3.3   Results

Of the 897 tows analyzed, shrimpers reported a direct economic impact of MD (i.e., lost fishing time, lost catch, and/or gear damage) for 10% of them. Of the quantified direct economic impacts of MD, lost fishing time and catch were more impactful than gear damage (Figure 3.2 & Figure 3.3; Table 3.2). Fishermen reported 56% and 54% of all MD occurrences resulted in lost time and catch, respectively, whereas gear damage was only reported in about 7%. Overall, shrimpers reported losing between 0 and 240 min, 0 and 68 kg of shrimp catch, and $0 and $200 in gear damage per tow due to MD (Table 3.2).

Table 3.2   Impacts marine debris had on shrimpers per tow

Impacts of Marine Debris at each Percentile

		25%	50%	75%	Mean
Kg Lost	All Tows	0.00	0.00	0.00	2.01
	MD Encounters	0.00	4.54	13.04	7.88
Fishing Time Lost (minutes)	All Tows	0.00	0.00	0.00	4.61
	MD Encounters	0.00	5.00	30.00	18.21
Damage Costs ($)	All Tows	$-	$ -	$ -	$ 1.30
	MD Encounters	$-	$ -	$ -	$ 6.37
Total Sales Lost	All Tows	$-	$ -	$ -	$16.66
	MD Encounters	$-	$29.79	$110.96	$65.63

The impact marine debris had on shrimpers per tow including kilograms lost, fishing time lost, total sales lost, and damage costs.
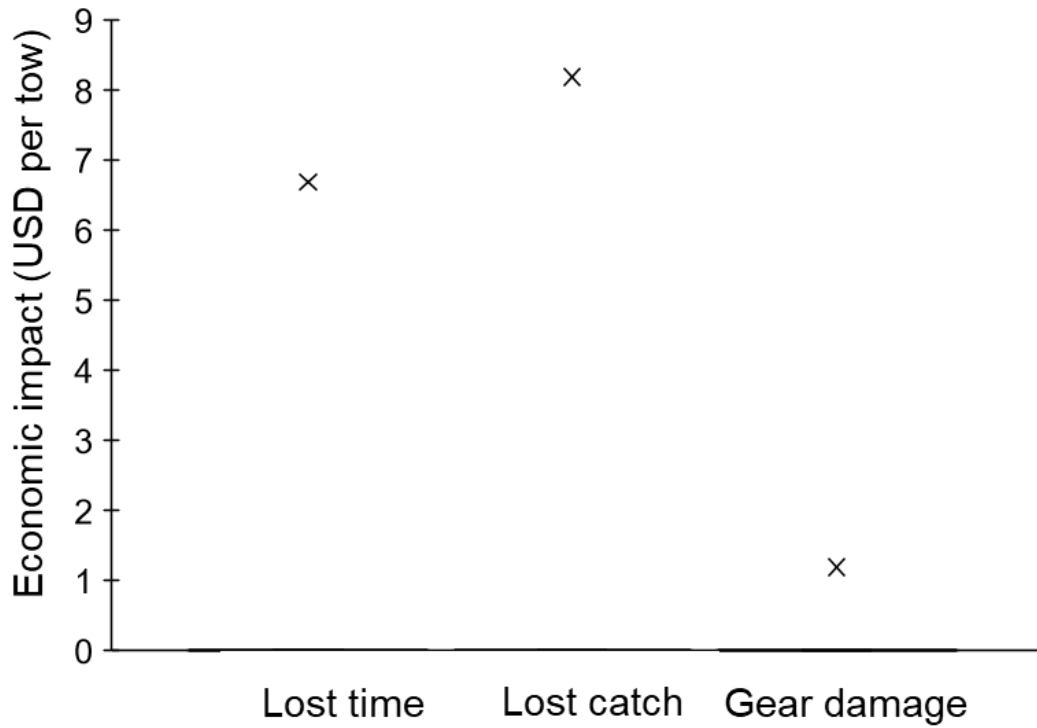
Figure 3.2   Comparison of the observed impacts when analyzing all reported tows

10% of all tows reported impacts. There was an average loss of 4.61 minutes, 2 kilograms, and shrimpers spent an average of $1.30 in damage per tow when analyzing all tows.
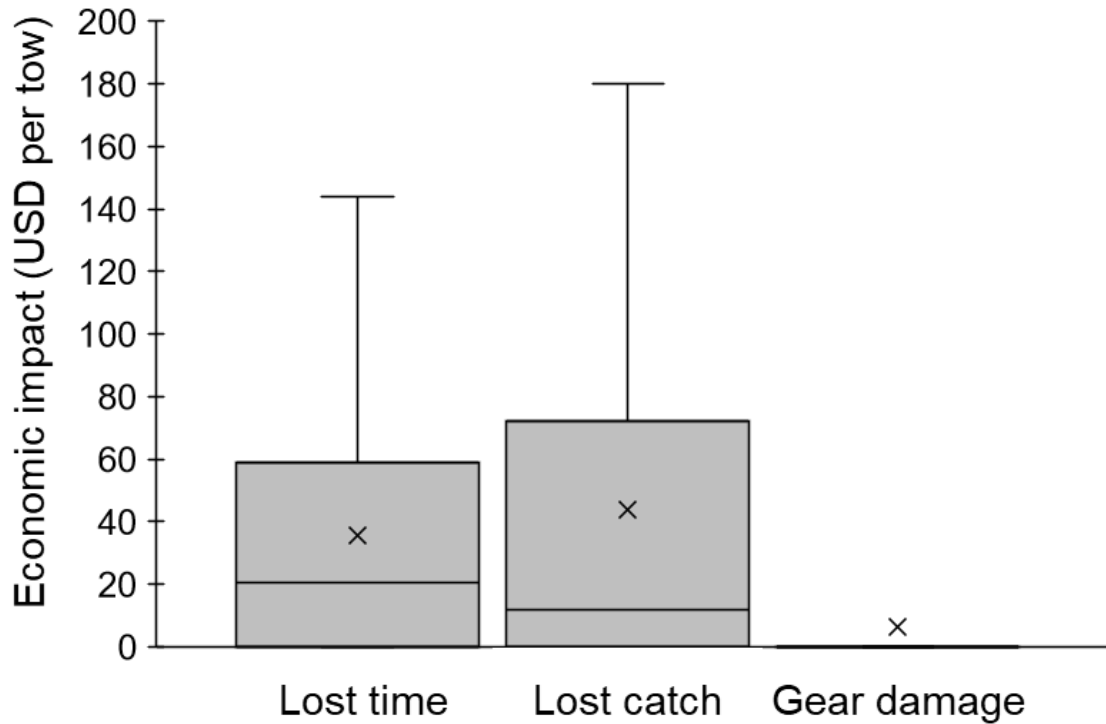
Figure 3.3   Comparison of the observed impacts when analyzing only marine debris encounters

There was an average loss of 18.21 minutes, 7.88 kilograms, and shrimpers spent an average of $6.37 in damage per tow when only analyzing the marine debris encounters.

The length of tows of each gear type was not affected by MD occurrence (Figure 3.4;

Kruskal- Wallis Rank Sum Test – p = 0.221). However, the impact of MD on lost fishing time

(Kruskal-Wallis Rank Sum Test – p < 0.001) and lost catch (Kruskal-Wallis Rank Sum Test – p

< 0.001) was heavily influenced by gear type used (Figure 3.5). Because damage costs did not

occur frequently, it did not show an influence of gear type (Kruskal- Wallis Rank Sum Test – p =

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0.466).
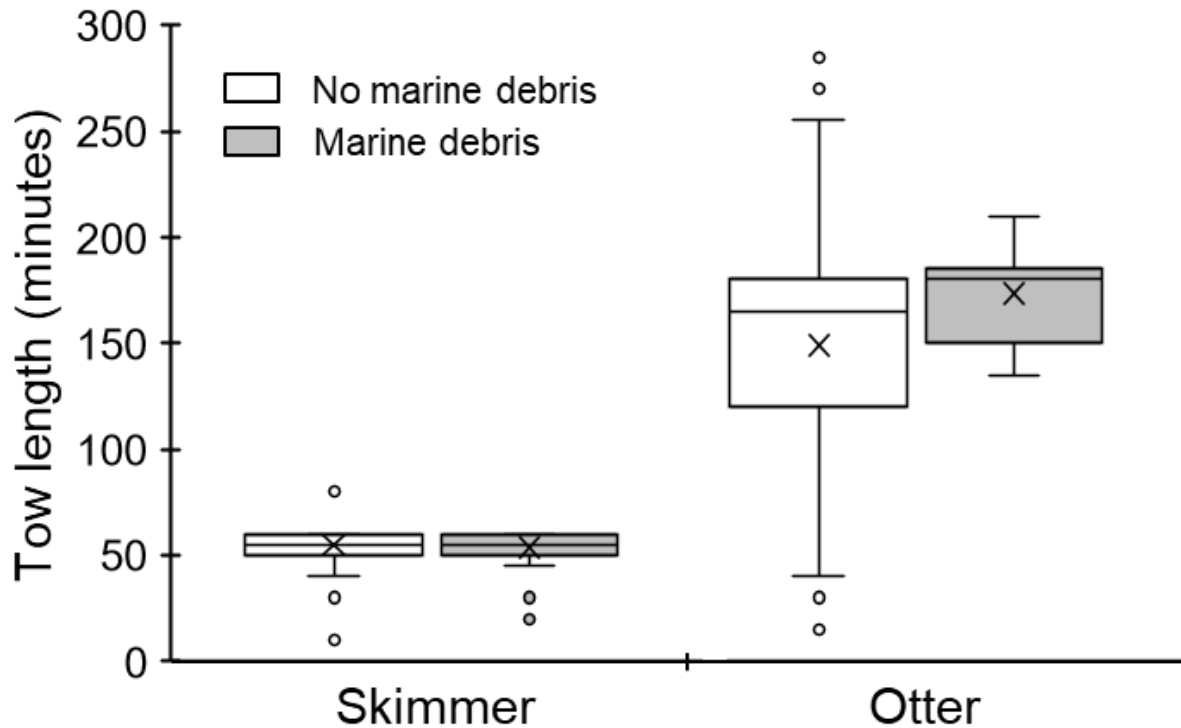
Figure 3.4   Comparison of the length of tows for each gear type with and without marine debris encounters

Encountering marine debris did not influence the length of tows; however, skimmers had much shorter tows than otter trawls.

Overall, there were 79 and 56 MD encountering tows reported for skimmer and otter trawls respectively. While skimmer trawls were over 2 times more likely to encounter MD than otter trawls (31% vs. 13% encounter rate per tow), otter trawls accounted for most impactful MD encounters. Of those MD encounters with skimmers, only 19% reported lost catch and 24% reported lost fishing time due to MD. Conversely, over 88% and 86% of otter tows with MD encounters reported lost catch and fishing time respectively. Mean catch lost when MD was encountered was nearly 15x greater for otter trawls with MD encounters (14.23 kg per tow) than

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skimmer trawls (1.61 kg per tow; Figure 3.5). Time lost showed a nearly identical pattern with

reported means of nearly 28 min and 8 min per tow dealing with MD for otter and skimmer
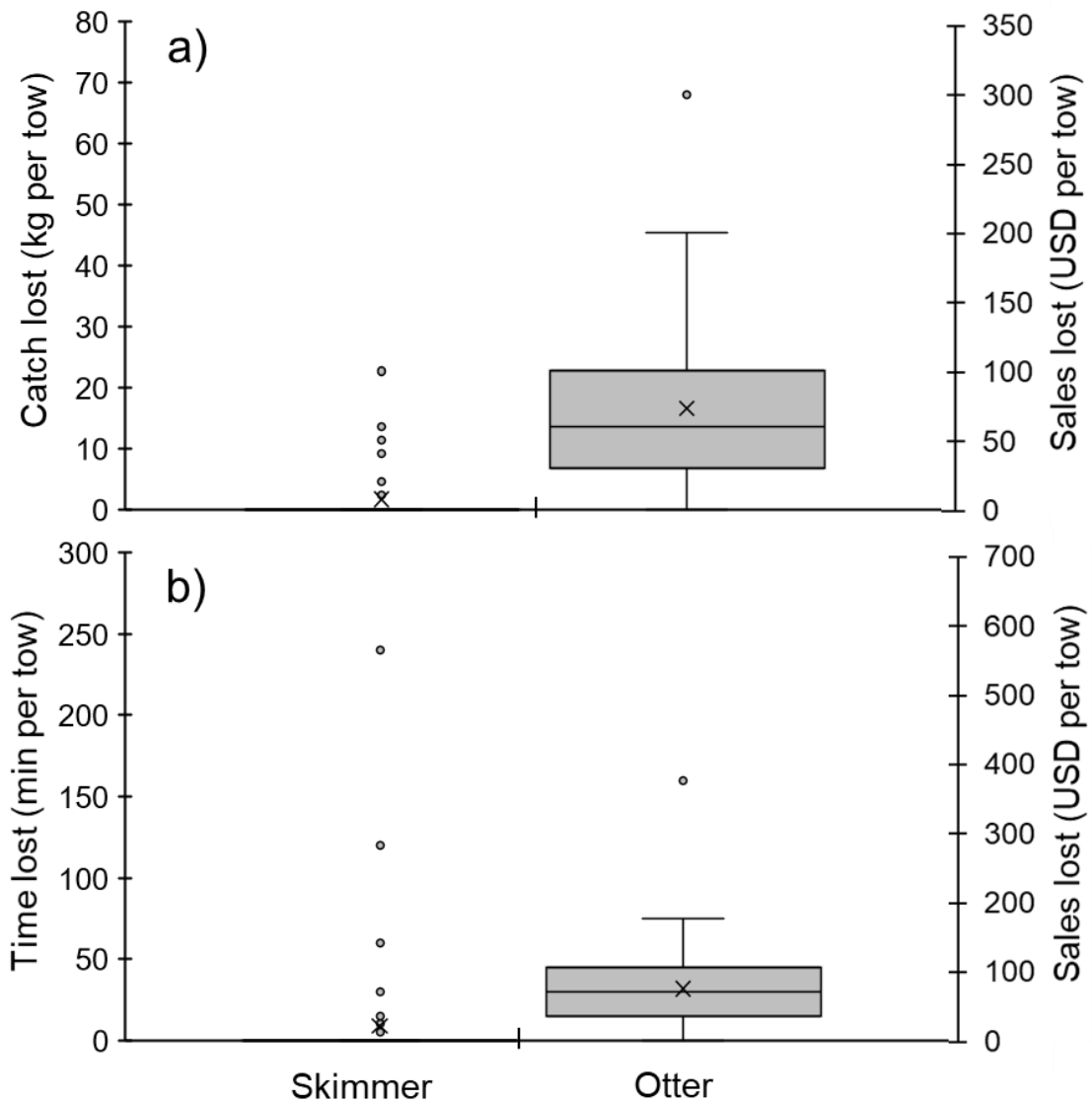
trawls respectively (Figure 3.5).

Figure 3.5   Comparison of impacts caused by marine debris for both gear types

Shrimpers using otter trawls were much more likely to suffer from the observed impacts than those using skimmers.

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When analyzing all tows (i.e., with and without marine debris encounters), shrimpers lost an average of 4.61 (± 15.33) minutes removing and disposing of MD and lost an average of 2 (± 6.42) kg of shrimp per tow. These losses lead to an average of $16.66 (± 51.21) lost in direct sales per tow. The cost of damage is considered a labor income loss, and while not as frequent, an average of $1.30 (± $14.35) per tow was lost due to damage to fishing nets due to encounters with MD. These differences in rates of impacts of each gear type should be considered as MD increases. If the rate of MD encounters increases to every tow, shrimpers are at risk of losing an average of 18.21 (± 29.13) minutes and 7.88 (± 11.3) kg per tow, increasing the average direct sales lost per tow to $65.63 (± $91.50). The rate of MD causing damage to the fishing nets could result in an average of $6.37 (± $31.76) per tow due to repair costs.

3.4 Discussion

This is the first quantitative study of the impacts on MD on the commercial shrimping industry. Posadas et al. (2021) analyzed the results from the preliminary survey used to select fishermen for this study. Many of the fishermen who participated in the 2018 survey participated in the data collection program for this study. This survey assessed the perceived frequency and impacts caused by MD in 2018. Ninety-eight percent (98%) of shrimpers reported that they encountered MD during their fishing trips with 85% encountering it frequently, and the majority of shrimpers indicated reduced catch (80%), lost fishing time (82%), and/or vessel repairs (75%) due to MD (Posadas et al. 2021). While similar, the perceptions of impacts from this survey do differ in some respects from the results of this quantitative study.

Shrimpers who participated in the qualitative surveyreported the crab traps and other abandoned fishing gear were the most common and most destructive types of MD encountered

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(Posadas et al. 2021), which agreed with the results of this study. Logbook results showed that derelict crab traps accounted for 79% of MD encounters followed by other types of derelict fishing gear (DFG) in the Mississippi Sound and north-central Gulf of Mexico. Additionally, and like studies in other areas (Bilkovic 2014), crab traps and DFG were responsible for the majority of impactful MD encounters.

Like the results of this study, Posadas et al. (2021) indicated that MD has higher impacts on reduced fishing time and catch than gear damage. This study indicated that 56% and 54% of MD encounters reported suggested lost time and catch whereas only 7% of MD encounters reported direct gear damage. However, the impact of MD on lost fishing time and lost catch was heavily influenced by gear type used. The two most common types of trawls used in Mississippi are otter and skimmer trawls. Otter trawls are towed directly behind the boat and must be taken completely out of the water when MD is caught (Coale et al. 1994). Skimmers are mounted on a frame and pushed along either side of the boat, fishing the entire water column. Individually, the skimmer nets are about half the width of the otter trawls; however, because two skimmer nets are used at the same time, the two types of gear cover about the same area while fishing (Coale et al. 1994). It is possible that because the skimmers fish the entire water column, they are more susceptible to catching both benthic and floating MD while otter trawls are dragged along the seafloor, so they only encounter benthic MD less frequently. Benthic MD mostly consists of DFG, including crab traps, which our results show is the likely cause of most impactful marine debris encounters for shrimpers. There was an average loss of 2 (± 6.42) kg of catch, 4.61 (±15.33) minutes, and $1.30 (± $14.35) costs in gear damage per tow; these collectively corresponded to about $16.63 (± $51.21) per tow in direct losses per tow.

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Overall, shrimpers submitted an average of 7 tows per day, so these losses would equate to $116.41 per day. These shrimpers reported fishing an average of 11 days per month (Posadas et al., 2021) during shrimping season, so these MD impacts could be extrapolated to total $7,683.06 (2020 $USD) each 6-month shrimping period. The MD recorded in the data collection is likely an underestimation of the MD in the Mississippi Sound. EPA's Gulf of Mexico Program funded a 2-year collaborative cleanup effort specifically incentivizing commercial shrimpers to remove derelict crab traps from the seafloor. Nearly 2,300 traps were removed from the waters between 2019 and 2020 (Sartain et al. 2021), so much of the MD that would have impacted fishing efforts has already been removed. However, as MD inevitably increases in the future and assuming shrimpers encounter marine debris on every tow, shrimpers are at risk of losing $30,321.06 over a season.

The expenses caused by MD could become critical for an industry that is already subjected to a variety of stressors such as an aging work force and increasing frequencies of natural and anthropogenic disasters. As development and litter increase worldwide, the MD crisis is expected to escalate as well (Kaza et al. 2018). For shrimpers, damaging encounters with MD will likely escalate as well. Along with potentially increasing sales lost from lost fishing time and catch and costs of damage caused by MD, shrimpers must also balance rising costs of marine diesel (Seba 2019) and the falling prices of both dockside and wholesale prices for shrimp (Posadas 2020). The Gulf States have provided over 86% of commercially caught wild shrimp for the nation (Posadas 2020); the impacts of MD paired with natural and anthropogenic disasters, rising fuel costs, and falling prices of wild shrimp could be crippling for the industry.

In addition to DFG studies, research on the economic impact of MD has expanded in recent years (Bilkovic 2014; Beaumont 2019; Posadas et al. 2021). Arthur et al. (2020) analyzed

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the benefits of a derelict trap cleanup throughout the Gulf States and found that it would be beneficial for both the economy, multiple fisheries and recreational boaters, and other aquatic wildlife A 4-year program in which DFG was removed, including over 31,000 crab traps, from Chesapeake Bay showed that lost blue crab pots are a significant source of MD (Bilkovic 2014). This data collection program began after about 2,300 derelict traps were already removed from the studied fishing areas. Additional impacts of marine debris such as bycatch caused by DFG, microplastics affecting the development of fisheries, and loss of habitat caused by MD were not considered in this study (Arthur et al. 2020; Erikson et al. 2014). The direct impacts observed in this study could be considered underestimates of both the amount of MD and the impacts that it has on the commercial shrimping industry. Despite expanding efforts to quantify the economic impacts of MD, a 2019 study suggested that it is not yet possible to accurately quantify the decline in annual ecosystem service delivery related to marine plastic based on available research (Beaumont 2019). Evidence does suggest, however, a substantial negative impact, a 1 to 5 percent reduction, on almost all ecosystems on a global scale (Beaumont 2019).

CHAPTER IV

CONCLUSION

Marine debris is an increasing issue worldwide. As the amount of marine debris

increases, it will continue to impact natural environments as well as industries and economies

that depend them. In Mississippi, commercial shrimpers frequently encounter marine debris,

resulting in the loss of time and catch, and added repair costs. Prior to this study, there was no

information on the spatial and temporal distribution of marine debris that shrimpers encounter

and the subsequent economic impacts on the industry.

Twenty (20) commercial shrimpers were selected based on a preliminary survey taken in

late 2019. This survey was used to gather demographic, location, vessel and gear characteristics,

fishing effort, and to gauge interest in participating in an incentivized data collection program.

These fishermen maintained a logbook for every marine debris encounter over the shrimping

season, July 2020 through December 2020; the logbook contained information on time spent

fishing, types of marine debris encountered, and lost fishing time due to damaged gear.

897 logbooks were included in the analysis to find the distribution and abundance of

marine debris in the north-central Gulf of Mexico and its direct economic impacts. 19% of all

tows reported encounters with marine debris and 10% of all tows reported time lost, catch lost,

and/or gear damage. The majority of the marine debris documented was derelict crab traps

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(79%), and most of the documented marine debris was found in the eastern portion of the study areas which is also where the most fishing effort was logged. When looking at total fishing efforts, shrimpers lost an average of 4.61 minutes removing and disposing of MD and lost an average of 2 kg of shrimp per tow. These loses lead to an average of \$16.67 lost in direct sales per tow.

The pattern of encountering marine debris was heavily influenced in the type of gear used. Shrimpers using skimmers, the nets that hang from either side of the boat, encounters marine debris more often than those who used otter trawls which are pulled underwater, behind the boat; however, when those fishing with otter trawls did encounter marine debris, it resulted in more impacts. Both gear types fish along the sea floor, but skimmers also fish throughout the entire water column unlike otter trawls. While both primarily catch benthic marine debris, the differences in area can account for the differences in types of debris caught and the impacts they cause. Additionally, when marine debris is encountered, the otter trawl must be taken completely out of the water unlike the skimmer where the marine debris can be targeted and easily removed without removing the net from the water. The difference in handling the gear may be the reason that the otter trawls were more prone to lost time and catch.

Studies have found that derelict fishing gear focused cleanups are beneficial for several reasons. Despite this being the first study to estimate the direct impacts of marine debris on the commercial shrimping industry, the economic impact of marine debris is an expanding area of research. As marine debris increases worldwide, many coastal communities will be impacted; however, cleanup efforts such as the one described in this study will also increase in efforts to minimize the crisis.

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