THE MISSISSIPPI GULF COAST RESTORATION PLAN

A Path Toward Sustainable Ecosystem Restoration

2016 ADDENDUM

MISSISSIPPI DEPARTMENT of ENVIRONMENTAL QUALITY

NATIONAL FISH and WILDLIFE FOUNDATION

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INTRODUCTION

IN OCTOBER 2015, THE MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY (MDEQ) AND THE NATIONAL FISH AND WILDLIFE FOUNDATION (NFWF) RELEASED THE MISSISSIPPI GULF COAST RESTORATION PLAN, FUNDED THROUGH THE GULF ENVIRONMENTAL BENEFIT FUND (GEBF). THIS REPORT WAS VERSION 1 OF AN ITERATIVE PLANNING EFFORT THAT IS SCHEDULED TO EXTEND THROUGH 2017.

In order to improve restoration planning efforts and to continue to engage the public with restoration updates, MDEQ hosted a webinar in March 2016 to provide stakeholders an opportunity to learn more about the Mississippi Gulf Coast Restoration Plan (hereinafter referred to as the Plan). The webinar provided an overview of the Plan and explained how the Mississippi Comprehensive Ecosystem Restoration Tool (MCERT) and the Decision Support System (DSS) work synergistically to inform sustainable and successful restoration programs, projects, and outcomes.

In lieu of completely updating version 1 of the Plan, MDEQ has developed an Addendum to the 2015 release. There are several additions that will help refine the Plan and ensure that the state of Mississippi is as effective as possible in sustainable and successful restoration implementation. Additions within the addendum include:

Restoration Endpoints. Restoration endpoints for the restoration programs have been scientifically generated. These endpoints are restoration goals tied to specific resources: oysters, coastal marsh habitat, and the nearshore environment. The restoration endpoints provide background information about the resources and develop quantifiable strategies for restoring the Mississippi Gulf Coast.

Data Update. New data has been incorporated into MCERT. This section provides a summary of the types of data included between October 2015 and September 2016.

The Plan is a strategic outline for restoring the Gulf Coast environment. At its core, the Plan is a community driven, science-based plan that informs and provides feedback to prioritize restoration projects that are designed to be sustainable and successful in their implementation.

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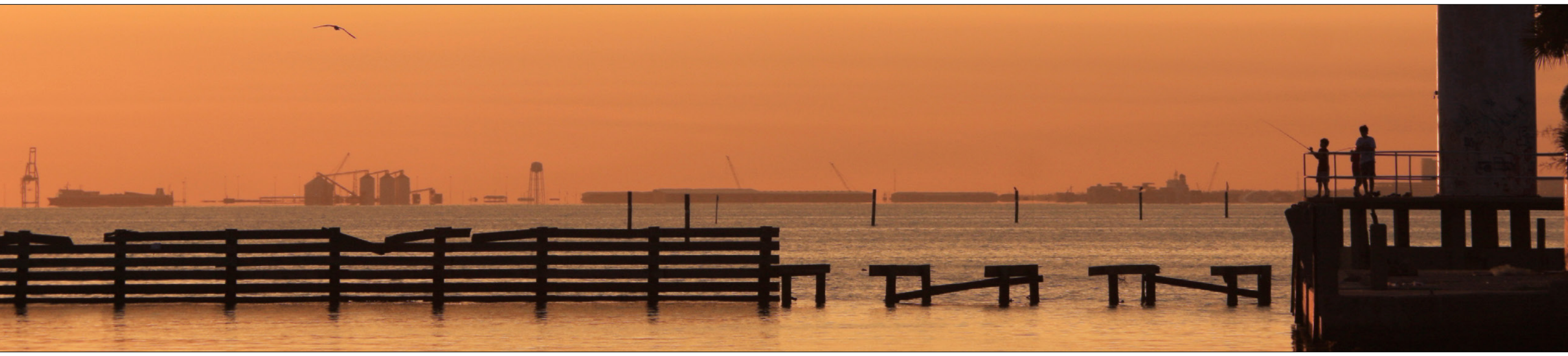
RESTORATION ENDPOINTS



THE MISSISSIPPI GULF COAST RESTORATION PLAN IS A COMMUNITY DRIVEN PRODUCT THAT IS BUILT ON A SCIENCE-BASED FOUNDATION.

Based on the Community Conversations, Resource Summits, and previous plan analysis, the following list outlines an overall restoration vision for Mississippi:

- Restore and enhance ecological function and connectivity of coastal and marine habitats.
- Restore and stabilize populations of ecologically and commercially/recreationally important coastal and marine species at sustainable levels.
- Restore and enhance the ecological and hydrological integrity of water resources, including water quality and quantity impairments of coastal bays and estuaries and coastal rivers and streams.

In order to ensure that the state of Mississippi is moving toward fulfilling these overarching restoration visions for the Mississippi Gulf Coast, MDEQ has placed markers, called "endpoints," on the horizon to outline the path for the vision outcomes, or endpoints. These endpoints were based on the following key factors:

- CREDIBILITY: An endpoint that is too high and therefore not achievable or an endpoint that is too low and thus easily surpassed has no value.
- SCIENCE-BASED: To ensure that endpoint targets were set appropriately, each endpoint was rigorously calculated using best available science.
- CLEARLY OUTLINED ASSUMPTIONS: These endpoints represent a target to aim for on the restoration horizon. However, each endpoint is simultaneously a moving target due to the inherent variability in the environment and restoration's subsequent impact on natural resources. Thus, clearly outlining all of the assumptions that were used to create the respective endpoints was imperative.
- HABITAT-BASED: When evaluating restoration benefits for specific resources, the approach that is often taken, and the one that the state of Mississippi is utilizing, is a habitat-specific restoration approach. By restoring habitats, multiple resources and ecosystem service benefits are enhanced.

Endpoints were chosen to be all-encompassing, to have connectivity to multiple resources and ecosystem service benefits, and to tie to the overall vision statements.

The restoration endpoints that were selected are:

- Oysters
- Nearshore Benthic Production
- Coastal Marsh Habitat
- Land Conservation and Restoration

All of the endpoints will rely heavily on MCERT and the DSS to understand specific restoration project delivery in the Mississippi coastal landscape.

RESTORATION ENDPOINT: OYSTERS

ECOLOGICAL JUSTIFICATION

Over the last century, oyster populations in the Mississippi Sound have been impacted by many factors. The seafood industry has been part of south Mississippi culture since the early 19th century. The Mississippi Historical Society reported that seafood factories processed two million pounds of oysters and 614,000 pounds of shrimp in Mississippi in 1890. By 1902, the canneries had an annual processing of 6 million pounds of oysters and 4 million pounds of shrimp, and Biloxi was referred to as the "Seafood Capital of the World" (Nuwer, 2006). In a review of historical abundance of oyster reefs compared to current abundance remaining, experts estimated that the Mississippi Sound has lost at least 90% of its oyster reefs (Beck et al., 2009). Oyster harvests have decreased from 400,000 sacks in 2004 to 26,000 sacks in 2015 (Governor's Oyster Council, 2015). Intensive fishing efforts, dredging, urban and industrial development, and altered hydrological regimes have all contributed to the decline in oyster harvests (Kirby, 2004; Demoran 1979; Beck et al., 2009). Historical descriptions of oyster reefs in the area include approximately 582 acres of oyster bottom in Biloxi Bay. By 1979, there were no oysters in that location (MDEQ, 2015; Moore, 1913; Demoran, 1979). Currently, only about 30 acres of oyster reefs exist in Biloxi Bay from restoration efforts by The Nature Conservancy in partnership with Mississippi Department of Marine Resources (MDMR) (MDEQ, 2015; La Peyre et al., 2014; Brumbaugh and Coen, 2009; Morhman, 2014). MDMR reports that the historical oyster reefs in Mississippi totaled 14,845 acres, and the Mississippi Marine Conservation Commission reported that there were 9,786 acres of oyster reef in Mississippi in 1966 (Christmas, 1973). Currently, there are approximately 7,400 acres of harvestable reefs in the western portion of the Mississippi Sound (MDEQ, 2015) (Figure 1). There have been numerous and extensive restoration efforts to reestablish and enhance oyster reefs in Mississippi prior to the *Deepwater Horizon* oil spill. Those restoration efforts have influenced the amount of shell bed that is available in the Mississippi Sound.

Oyster reefs provide many ecological benefits to a system. Oysters improve water quality and act as ecosystem engineers, creating conditions that are favorable for many other species to thrive in estuaries and bays (Beck et al., 2009). Oysters, and their associated habitat, arguably provide the most substantial ecosystem service delivery in estuarine systems, including the following:

1. Enhanced estuarine biodiversity as the only hard substratum for epi-biotic invertebrates (Gregalis et al., 2008);
2. Increased areal production of fish and invertebrates (Peterson et al., 2003); and
3. Improved water quality by removing suspended sediments, microalgae (Pomeroy et al., 2006; Kellogg et al., 2014) and stimulating denitrification (Newell et al., 2002).

In addition to being an ecological resource to the Gulf of Mexico, oyster reefs in the Mississippi Sound also have significant economic value. However, the decline in oyster abundance has impacted the oyster fishery economy in Mississippi. The commercial value of oysters in Mississippi has decreased from $6 million in 2000 to $1.5 million in 2013. This decline in oyster value is due to the decline in the oyster harvest, which have decreased from 3.5 million pounds in 2000 to 500,000 pounds in 2013 (Posadas, 2013).

Restoring and protecting the existing oyster reefs in the Mississippi Sound is critical to the ecological and economic sustainability of the region. Increasing the density and acreage of oysters will result in an increased number of sacks harvested from the area and will increase numerous estuarine ecosystem services. In turn, this restoration of ecosystem services has direct economuc benefits to the oyster fishery economy.

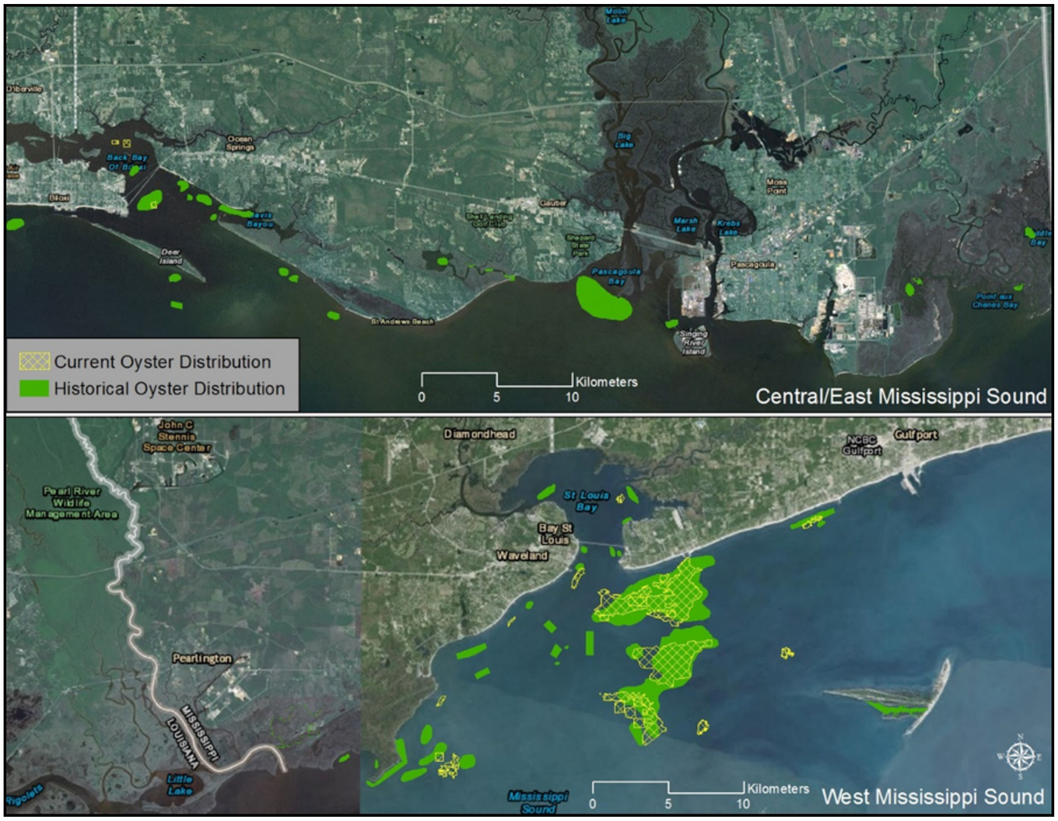


Figure 1. Current and historical distribution of subtidal oyster reefs in Mississippi.

CONSISTENCY WITH REGIONAL AND LOCAL RESTORATION IDEALS

Oyster restoration has been identified as a priority by multiple organizations. The Ocean Conservancy recommends the re-establishment and/or maintenance of existing oyster reefs and the expansion of publicly owned reefs (Ocean Conservancy, 2011). The Gulf Coast Ecosystem Restoration Task Force and Wildlife Mississippi recommended that oyster habitat be restored for ecosystem service purposes (GCERTF, 2012; Wildlife Mississippi, 2014). Mississippi Department of Wildlife, Fisheries, and Parks prioritized oyster reefs for habitat restoration and management in their Comprehensive Wildlife Conservation Strategy (MDWFP, 2005). The National Wildlife Federation proposed a project to construct up to 600 acres of sub-tidal oyster reef habitat in Saint Louis Bay and Biloxi Bay in the 2014 Restoring the Gulf of Mexico for People and Wildlife: Recommended Projects and Priorities Plan. The Nature Conservancy also proposed to restore up to 600 acres of sub-tidal oyster reef, which would be constructed using natural oyster shell or other natural materials (TNC, 2013).

Considerable oyster restoration efforts have already begun in Mississippi. An $11 million Oyster Cultch project was funded out of Natural Resource Damage Assessment (NRDA) Early Restoration. This project enhanced 1,430 acres of existing reef by placing cultch material in the Mississippi Sound. Additionally, in November 2015, NFWF awarded the state of Mississippi $11.8 million for oyster restoration and management, including water quality assessments and cultch deployment. This project began work in spring 2016. In addition to *Deepwater Horizon* oil spill funded restoration efforts, approximately $7 million was allocated to MDMR for oyster recovery due to the opening of the Bonnet Carré Spillway in May 2011. With these funds, MDMR has implemented the Long-Term Oyster Restoration and Resiliency Plan for oyster resource creation and management and will continue to support a variety of oyster fisheries restoration activities.

ENDPOINT GOAL

MDEQ's goal is to meet the Governor's Oyster Council Restoration and Resiliency objective to increase oyster reef productivity in the Mississippi Sound and produce one million sacks of oysters annually by 2025 (Governor's Oyster Council, 2015). Efforts to increase the productivity of the oyster reefs in the Mississippi Sound include improving water quantity and quality, enhancing public reefs, and promoting aquaculture (Governor's Oyster Council, 2015). In order to sustainably restore oysters and recognize the value of oysters and the ecosystem services they provide, a holistic ecosystem-based approach to restoration is needed. Specifically, in the Mississippi Sound, there are a number of foundational issues related to oyster sustainability that need to be addressed to ensure the end goal of sustainable production is achieved. These threats specifically are: 1) water resources – how quality and quantity interact with river inflows and Mississippi Sound dynamics; and 2) harvesting practices.

The Governor's Oyster Council Restoration and Resiliency Final Report suggests that new management activities be implemented to manage Mississippi oyster harvests. Recommendations include:

1. Adopt management practices and metrics to assess the health of reefs and to determine harvest capacity by way of sacks not days;
2. Consider using the Shell Budget Model or other no-net change based models to establish quotas that leave sufficient biomass for sustaining or increasing fisheries the following year;
3. Improve enforcement of harvesting Best Management Practices (BMPs).

The Governor's Oyster Council also suggests that MDMR establish a shell recovery program and the implementation of a program that estimates the annual number of oysters available for harvest to ensure that harvesting is stopped before that threshold is reached (Governor's Oyster Council, 2015). MDEQ has formulated an endpoint range that takes into consideration the target and recommendations set forth by the Governor's Oyster Council.

FORMULATION OF THE ENDPOINT

In order to meet the Governor's Oyster Council goal of one million sacks harvested per year by 2025, sustainable management practices must be applied. The Haskin Shellfish Research Laboratory reports that fishing rates above 7% of stock abundance are unsustainable (HSRL, 2006; Powell and Klinck, 2007). Fishing rates above 7% remove more shell mass than can be replaced by natural processes. The HSRL also reports that oyster harvesting at any rate is not sustainable over the long term without shell replenishment. In order for Mississippi oyster reefs to continue to reproduce and provide the region with numerous ecosystem services, a strategic plan for the restoration/replenishment of shell mass or other cultch materials should be put in place (HSRL, 2006; Powell and Klinck, 2007). The Oyster Metrics Workgroup of the Sustainable Fisheries Goal Implementation Team of the Chesapeake Bay Program (2011) suggests that 30 – 100% areal coverage of the reef is a reasonable assumption and that the percent coverage is highly dependent on the type of restoration technique used. Oyster reefs are not typically uniformly covered in oysters, resulting in coverage variation and a patchy network of reefs distributed over an oyster area. Calculations from MDMR oyster sampling data indicates that over a six year period, there was an average of 74 oysters (shell size > 25 mm) per square meter across several subtidal reefs (Table 1) (MDMR, 2012).

Table 1. Mississippi Sound Oyster Density Sample Data (June 2006 - August 2012).

REEF SITE	PASS CHRISTIAN I	PASS CHRISTIAN II	PASS MARIANNE	ST. JOE	TELEGRAPH	LONG BEACH
Area (sq. m.)	40	20	20	20	20	4
Total	2,620	1,045	2,987	1,824	856	180
Density (m^2)	66	52	149	91	43	45
Average Mississippi Sound Density (m^2)	**74**					

Although one million sacks per year by 2025 is the ultimate endpoint, consideration of any proposed project must acknowledge that the harvest includes oysters coming off public and private leases. Restoration efforts, as described in this Addendum, will only focus on public leases. Based on historical oyster reef data, it is estimated that the public reefs in the Mississippi Sound will produce 70% of the one million sacks harvested per year. The formulation of this endpoint will result in an approximate number of restored acres needed to reach the public reef goal of 700,000 sacks harvested per year via a sustainably managed fishery. Equation 1 is used to determine the acreage needed to yield 700,000 sacks. This equation is based on the assumption that there are approximately 300 oysters per sack and approximately 74 oysters per square meter in Mississippi Sound reefs (Table 1) (MDMR, 2012). The equation depends on the rate of harvest and the assumed oyster coverage percentage.

EQUATION 1

MISSISSIPPI OYSTER ACREAGE FORMULA

$$\text{ACRES} = \left(\frac{S}{HR \bullet C}\right)\left(\frac{300}{74 \bullet 4{,}046.86}\right)$$

WHERE:

S - Number of Sacks
HR - Harvest Percentage Rate
C - Percent Cover
300 - Number of Oysters per Sack (approximate)
74 - Oyster Density in Mississippi Sound (Table 1)
4,046.86 - Number of Square Meters per Acre

Based on the current status of oyster populations in the Mississippi Sound, MDEQ calculated acreage endpoints using a conservative estimate of 30-70% coverage. Using Equation 1, acreage endpoints were calculated for a coverage range of 30-70% at a harvest rate of 10-20% (Table 2). It is important to note that studies show that a harvest rate of 10% or greater results in a distinct decrease in shell mass, which can lead to bed degradation and population decline (HSRL, 2006; Powell and Klinck, 2007). However, many of the restoration projects funded by NRDA and NFWF involve the deployment of cultch and shell resources, which, to some degree, counteract the removal of shell mass by fishing. The most conservative calculation suggests that approximately 23,000 acres of oyster reef are needed to produce 700,000 sacks, while a more aggressive harvest rate of 20% would require approximately 12,000 acres of oyster area to produce 700,000 sacks.

Table 2. Acreage endpoints based on coverage and harvest ranges.

ACRES			
	30% COVERAGE	50% COVERAGE	70% COVERAGE
HARVEST RATE 10%	23,375	14,025	10,018
HARVEST RATE 13%	17,981	10,788	7,706
HARVEST RATE 15 %	15,583	9,350	6,679
HARVEST RATE 20%	11,687	7,012	5,009

The Mississippi Sound has recently produced harvest yields equaling several hundred-thousand sacks of oysters. This level of production can be matched, increased, and sustained over the long-term with the inclusion of sustainable harvest methods and the addition of aquaculture techniques in the Mississippi Sound. MDMR has also proposed to place cultch material in approximately 23,930 acres of existing and historical oyster reefs. Phase I of MDMR's effort would occur from 2016-2018 and would enhance approximately 3,500 of the 23,930 acres proposed (USACE, 2015). This strategic plan for cultch deployment will ensure that the rate of harvest of shell material does not result in bed degradation and population decline.

In summation, the formulation of this endpoint assumed that all state resource agencies and NFWF agreed that the Governor's Oyster Council goal of harvesting one million sacks of oysters per year by 2025 was a reasonable and attainable goal. It was then assumed that 30% of the one million sack harvest would be produced by private leases, resulting in a final endpoint goal of 700,000 sacks harvested per year. In order to determine a sustainable harvest rate, the assumed average density of oysters in the Mississippi Sound was 74 oysters per square meter and the assumed number of oysters per sack was 300. A literature review led to the assumptions that an oyster area is usually 30-70% covered in harvestable oysters and that a sustainable fishing rate should be less than 10% unless there is significant cultch deployment to offset the removal of shell resource. Due to the cultch replenishment efforts by MDMR and the State of Mississippi, a 20% harvest rate was assumed during the formulation of this endpoint. In order to sustain the oyster fishery in the Mississippi Sound, the overall goal is to replenish the shell mass taken from the oyster reef with strategic cultch deployment restoration efforts.

ENDPOINT

An aggressive harvest rate (20%) at a conservative coverage rate (30%) would require 12,000 acres of oyster area to produce 700,000 sacks per year. Historical oyster data, coupled with oyster-resource focused restoration efforts, supports that the restoration endpoint is a realistic and attainable goal for the state of Mississippi.

RESTORATION ENDPOINT: COASTAL MARSH HABITAT

ECOLOGICAL JUSTIFICATION

Coastal marshes play a vital role in the ecological integrity of open shoreline habitats and, even more critically, are major components of ecosystem health within a broader landscape context of coastal ecosystems (USEPA, 2000). Between 1998 and 2004 wetland loss rates in the Gulf of Mexico were 25 times higher than anywhere in the U.S. (Stedman and Dahl, 2008). Specifically, within Mississippi, approximately 10,000 acres of coastal wetlands have been lost in the last 60 years (MDEQ, 2007). Coastal marshes are keystone habitats within the coastal environment as they provide the base for a host of ecosystem services and benefits such as:

- Serving as natural buffers to protect shorelines from eroding;
- Providing storm surge protection;
- Improving fisheries production;
- Enhancing water quality by trapping and holding sediment and creating biogeochemical conditions for nutrient assimilation and transformation;
- Providing faunal support;
- Sequestering carbon; and
- Providing habitat for a multitude of trophic levels within the ecosystem (Barbier et al., 2011; Mendelssohn et al., 2012).

There are a significant number of drivers and stressors of coastal marsh loss, but discerning the differences between them can prove difficult. However, all the stressors and drivers result in marsh loss, and as such, two of the first specific actions to marsh restoration are to restore and protect existing marsh and re-create marsh previously lost. Restoring and replacing marsh are two critical first steps to ensure that a suite of ecosystem benefits is re-established and enhanced within coastal environments. By increasing the acreage of coastal marsh habitat to historical extents and protecting current coastal marsh habitat, Mississippi can maximize the ecosystem integrity of the coastal bays and bayous, as well as provide benefits to the broader Gulf ecosystem.

CONSISTENCY WITH REGIONAL AND LOCAL RESTORATION IDEALS

There have been several documents on coastal restoration strategies that highlight coastal marsh restoration as a priority investment for an ecologically and economically sustainable ecosystem. The Gulf Coast Ecosystem Restoration Task Force (GCERTF, 2011) identified "Restore and Conserve Near-Shore Habitats" as a main goal, with a focus on marshes. Similarly, USFWS Vision document (USFWS, 2013) highlighted restoring marsh within coastal bay and wetland systems by placing dredged sediment as a high priority conservation action. The Ocean Conservancy (OC, 2011) identified estuaries as a priority habitat to protect, with marsh identified as an extension component of that priority habitat in Mississippi. More Mississippi-centric strategies, such as the Mississippi Comprehensive Wildlife Conservation Strategy (Knight and Barber, 2005), highlighted estuarine marshes as the priority habitat within the marine and estuarine habitat for restoration and management. Furthermore, the National Audubon Society (NAS, 2012) highlighted the importance of using dredge sediments in Mississippi (specifically in Jackson County) for creating marsh and thus establishing bird nesting, roosting, and foraging areas.

Considerable marsh restoration and protection efforts have already begun in Mississippi. The Hancock County Marsh Living Shoreline, a NRDA Early Restoration Project, and is expected to create approximately 46 acres of marsh habitat, as well as six miles of breakwater that will prevent approximately 135 acres of marsh erosion over the life of the project (20 years). This project is located between Bayou Caddy and the mouth of the East Pearl River, within the 20,909 acre Hancock County Marsh Preserve (MDEQ, 2016). Additionally, under the Utilization of Dredge Material for Marsh Restoration Project, approximately 200 acres of sand beach and marsh habitat is being created at Round Island with approximately 2.5 million cubic yards of materials from the Port of Pascagoula. The project at Round Island is funded through the NFWF GEBF (MDEQ, 2016).

ENDPOINT GOAL

It is the goal of MDEQ to restore lost coastal marsh habitat equivalent to what has been lost over the past 60 years due to erosion, subsidence, and the *Deepwater Horizon* oil spill. Estuarine wetland loss can be offset through the conversion of adjacent uplands to marsh; however, development around tidal marsh areas is significant across the Mississippi coast with limited areas remaining available for unimpeded marsh migration. These areas will be targeted for acquisition to buffer habitats from development and/or to allow for marsh migration. Acquisition and management of these priority areas will demonstrate the importance of conserving coastal wetlands as a natural resource essential to the functioning of the entire estuarine ecosystem.

FORMULATION OF THE ENDPOINT

The coastal marsh restoration endpoint was formulated by comparing two different approaches of marsh loss and injury: 1) marsh injury from the *Deepwater Horizon* oil spill and 2) historic marsh loss over 60 years.

Deepwater Horizon Marsh Injury Analysis

This analysis modeled tidal inundation of Mississippi coastal marsh on dates where *Deepwater Horizon* oil was observed in adjacent waters from NOAA's Satellite and Information Service (NESDIS) satellite data products and Shoreline Cleanup and Assessment Technique (SCAT) surveys. The areal coverage oiling dataset was derived from the daily Synthetic Aperture Radar (SAR) Texture Classifying Neural Network Algorithm (TCNNA) re-analysis of the NESDIS polygons. The re-analysis was conducted by Florida State University, which created daily polygons of surface oiling from SAR data. The daily polygons were merged and dissolved in ArcGIS to create one footprint showing the total extent of surface oil from days that had satellite data within the observation period April 23, 2010, to August 11, 2010. Five Mississippi estuarine marsh complexes were examined in the analysis: Hancock County Marsh; Back Bay of Biloxi/Davis Bayou Marsh; Graveline Bayou Marsh; Pascagoula River Marsh; and Grand Bay Marsh.

After site selection was performed based on the oiling data, a standard workflow was created to apply to each marsh system:

1. Obtain elevation data.
2. Convert elevation data to appropriate vertical datum, if needed.
3. Obtain tidal gage data in appropriate datum on oiling days.
4. Map inundation model output.
5. Develop inundation area based on estuarine wetland layers.
6. Calculate acreage.

Once the water height was determined for an oiling day, the tidal height surface was applied to the elevation dataset in estuarine areas using map algebra. The resulting raster layer represents all surfaces that would be inundated at that specific tidal height. The data were then converted to polygon coverage and converged using a union and dissolve approach to obtain a single acreage value for the area (Table 3). The polygons were clipped based on 2010 National Wetland Inventory estuarine wetland layer to ensure all features represent coastal marsh habitat.

Table 3. Coastal marsh location and acres inundated on oiling days as estimated by the GIS model.

TIDAL INUNDATION ACREAGE - ESTUARINE WETLANDS MS			
MARSH SYSTEM	ACRES INUNDATED	OILING DATES	TIDE STATION
HANCOCK COUNTY MARSH	5,374.00	7/8/2010; 7/9/2010	BAY WAVELAND YACHT CLUB
BILOXI BAY/ DAVIS BAYOU	43.62	7/2/2010	PASCAGOULA NOAA LAB
BILOXI BAY/ DAVIS BAYOU	225.93	7/9/2010	PASCAGOULA NOAA LAB
GRAVELINE MARSH	0.97	7/2/2010	PASCAGOULA NOAA LAB
PASCAGOULA MARSH	342.79	7/2/2010	PASCAGOULA NOAA LAB
GRAND BAY MARSH	73.17	6/3/2010	PASCAGOULA DOCK E
GRAND BAY MARSH	208.87	6/26/2010	PASCAGOULA DOCK E
GRAND BAY MARSH	11.53	7/1/2010	PASCAGOULA DOCK E
GRAND BAY MARSH	3.70	7/2/2010	PASCAGOULA DOCK E
TOTAL	6,284.58	6 DAYS	

Historic Coastal Marsh Loss

In the Mississippi Coastal Streams watershed, low intensity development has been the largest factor for wetland loss (NOAA C-CAP Landcover Atlas, https://coast.noaa.gov/ccapatlas/). Forty percent of this loss is caused by urban sprawl in the coastal zone, spreading from population centers such as Gulfport and Biloxi and along highway corridors, and projections indicate continued population increase (NOAA, 2013). These densely populated areas will likely have a heightened rate of human impact. Additionally, 30% of this coastal wetland loss is attributed to conversion of estuarine wetlands to open water in the Hancock County Marsh complex and the Grand Bay Estuary. This conversion was primarily caused by shoreline erosion from natural processes including wind-driven wave action (MDMR, 1999). The final 30% can be attributed to anthropogenic factors intensifying shoreline erosion. For example, channel dredging starves adjacent marshes of sediment inputs, recreational and commercial boating increases turbidity and shoreline erosion, and shoreline hardening interrupts natural migration of marsh into upland areas as sea-level rises and shorelines retreat. Thus, approximately 6,000 acres of marsh have been lost due to environmental factors of erosion, subsidence, and sea-level rise. Shoreline erosion in Mississippi's salt marsh systems is extensive, with losses in some areas, such as Grand Bay, recorded at more than 24 feet/year and upwards of 7 acres/year of marsh loss solely caused by erosion (Schmid, 2000). This rate of loss continues today and will be intensified by predicted increases in sea-level rise (USGCRP, 2009).

Influence of Sea-Level Rise

Modeling habitat responses to sea-level rise can strengthen the understanding of the mechanisms that control the behavior of ecosystems within the physical landscape, identify hotspots of wetland loss, facilitate the assessment of wetland vulnerability, and form a basis from which effective plans can be developed to manage wetland changes on limited resources (McFadden et al., 2007). Rising sea level may result in tidal marsh submergence and habitat migration as salt marshes transgress landward and replace tidal freshwater habitats and brackish marshes (Smith 2013; Craft et al., 2009; Donnelly and Bertness, 2001). Estuarine areas such as the Pascagoula River Marsh system are predicted to facilitate a northward migration of tidal emergent marsh (Wu et al., 2015) and are well suited to accommodate the process due to a minimal number of physical barriers and the presence of seamless eco-tonal transition areas. Although MDEQ recognizes sea-level rise as an influence on restoration actions over time, the amount of marsh acres that could be impacted and increases in transitional landcover types (e.g. upland to marsh transitions) were not included in this endpoint analysis due to a lack of supportive data. The Gulf-wide Sea Level Affecting Marshes Model (SLAMM) data were analyzed for inclusion into the endpoint calculations, but large amounts of habitat misclassifications were found that render the data unusable for substantive restoration planning. However, upland transition areas are crucial as a marsh loss mitigation strategy, as numerous studies predict significant habitat transitions of coastal wetland types as a result of rising sea levels and high salinity regimes moving inland (Shirley and Battaglia, 2006; Craft et al., 2009; Doyle et al., 2010; Feagin et al., 2010; Tate and Battaglia, 2013; Wu et al., 2015).

ENDPOINT

Approximately 60,000 acres of coastal marsh currently exist in coastal Mississippi with variations in tidal exposure, salinity, and species composition (Figure 2). However, only an estimated 31,000 of those acres are under protection of some degree, primarily through the MDMR's Coastal Preserve Program. The goal of MDEQ is to restore and protect an additional **6,285 acres** of marsh in coastal Mississippi (Table 4). This number equals the number of acres injured by the *Deepwater Horizon* oil spill as shown in Table 3, which is almost the equivalent of the 6,000 acres lost over 60 years, and represents a 20.27% increase in current restored and protected marsh habitat in Mississippi. Efforts to mitigate this loss include the creation of marsh though the utilization of beneficial use sediments; marsh protection and conservation techniques including living shorelines; and acquisition and protection of upland habitats adjacent to coastal marsh habitats that can serve as habitat transition corridors with the threat of sea-level rise.

Table 4. Restored/conserved acres and percent increase in marsh habitat relative to current distribution and currently protected marsh habitat.

PROTECTED ACREAGE (ACRES)	RESTORATION ENDPOINT (ACRES)	INCREASE IN COASTAL MARSH (%)
31,000	10,000	32.25%
31,000	6,285*	20.27%
31,000	5,000	16.12%
31,000	2,500	8.06%
31,000	1,000	3.22%
31,000	0	0.00%

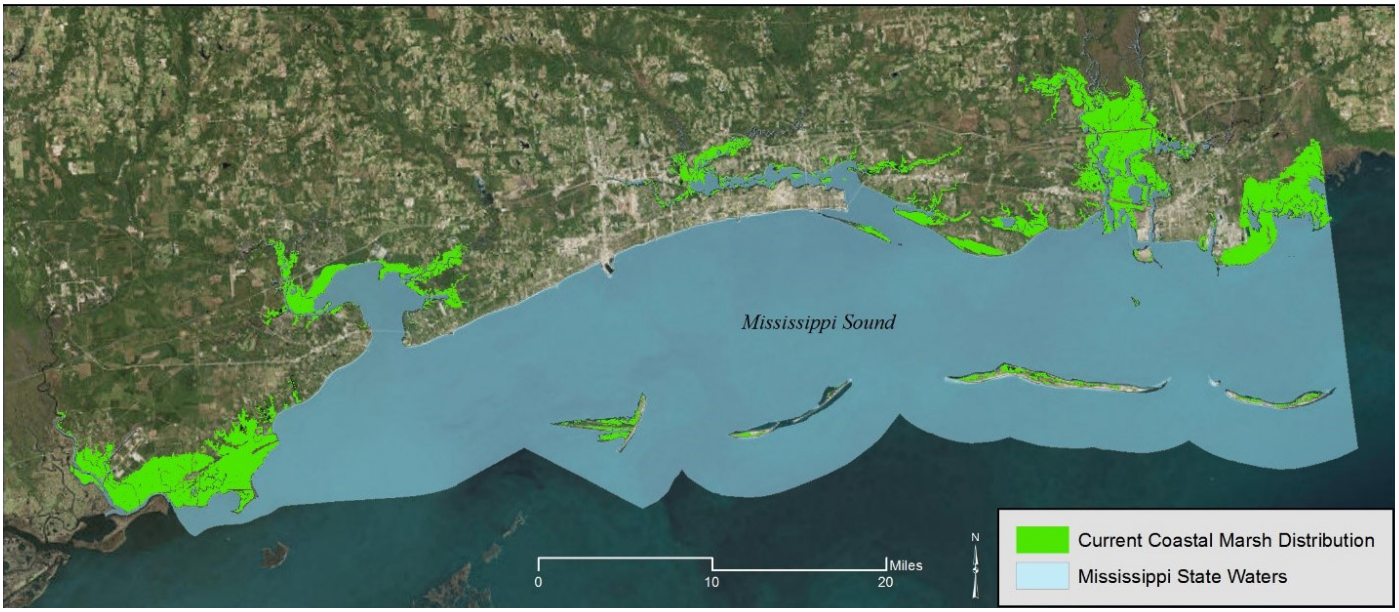


Figure 2. Current marsh distribution in coastal Mississippi.

RESTORATION ENDPOINT: NEARSHORE BENTHIC PRODUCTION

ECOLOGICAL JUSTIFICATION

Soft sediment habitats make up a majority of the Mississippi Sound benthos (~ 427,379 acres) and suffered considerable losses to secondary productivity from the *Deepwater Horizon* oil spill. Nearshore soft sediment communities in the Gulf are largely composed of macroinvertebrate groups such as mollusks, sponges, polychaetes, echinoderms, and crustaceans. These benthic communities perform critical ecological functions in the nearshore food web and contribute substantially to benthic biomass. Taxa include many filter-feeding species, which remove and digest phytoplankton and particulate organic matter and deposit processed materials to the substrate (Felder and Camp, 2009). Several groups (e.g., shrimp and crabs) are also commercially important to the Mississippi Gulf Coast seafood industry. In order to recoup losses from soft bottom habitat injury, restoration techniques that use hard bottom to increase productivity are often used. Hard habitats are defined as all substrate, other than soft sediments, that allow organisms to attach. Hard substrate habitats (including artificial reefs and natural reef or rock substrates) provide essential fish habitat in state managed waters and habitat for multiple benthic organisms and fish, increasing biodiversity in estuaries. Typically, benthic faunal biomass is higher on hard habitats than on mudflats (Castel et al., 1989; Hosack et al., 2006). Generally, studies have found relatively higher densities, biomass, and species richness with hard habitats compared to unstructured habitats (Coen et al., 2007; Peterson, 2003). Peterson et al. (2008) observed secondary production of oyster reefs that was 21 times higher than seagrasses, and 22 times higher than sub-tidal mudflats in North Carolina. Additionally, based on AQUATOX 3.1 Nearshore Marine Environment model estimates from the State of Mississippi *Deepwater Horizon* injury assessment, hard bottom is found to be about five times more productive than soft bottom habitats (Blancher et al., 2015). AQUATOX is a model that explores ecosystem level effects from multiple stressors over time including food web and ecotoxicological effects, fate and bioaccumulation of organics, and nutrient and eutrophication effects (EPA, 2016).

CONSISTENCY WITH REGIONAL AND LOCAL RESTORATION IDEALS

Although secondary benthic productivity is not specifically identified in regional and local conservation and restoration plans and visions, oyster restoration and the associated multiple ecosystem benefits, including enhancements to benthic communities, have been identified as a priority by multiple organizations and can be used as a proxy to prioritize uplift of estuarine secondary benthic productivity. Oysters are a component of benthic productivity that includes all other attached organisms that live within and on benthic substrates. The Ocean Conservancy (Ocean Conservancy, 2011) recommends the re-establishment and/or maintenance of existing oyster reefs and the expansion of publicly owned reefs. The Gulf Coast Ecosystem Restoration Task Force (GCERTF, 2012) and Wildlife Mississippi (Wildlife Mississippi, 2014) recommends that oyster habitat be restored for ecosystem service purposes. Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP, 2005) prioritizes oyster reefs for habitat restoration and management in their Comprehensive Wildlife Conservation Strategy. The National Wildlife Federation proposed a project to construct up to 600 acres of sub-tidal oyster reef habitat in Saint Louis Bay and Biloxi Bay in the 2014 Restoring the Gulf of Mexico for People and Wildlife: Recommended Projects and Priorities Plan. The Nature Conservancy also proposed to restore up to 600 acres of sub-tidal oyster reef, which would be constructed using natural oyster shell or other natural materials (TNC, 2013).

Considerable reef restoration efforts have already begun in Mississippi. An $11 million Oyster Cultch project was funded out of NRDA Early Restoration, in which 1,430 acres of existing reef were enhanced by placing cultch material in the Mississippi Sound; however, these reefs are utilized for commercial harvest. Additionally, the NRDA Early Restoration Artificial Reef Enhancement project added over 100 acres of material to existing reefs to add vertical relief (4-6 inches) and enhance benthic productivity (Figure 3). Numerous other reef restoration efforts in the estuarine environment have been completed over the past 10 years by TNC and the National Oceanic and Atmospheric Administration (Figure 3) with the purpose of creating reef habitat.

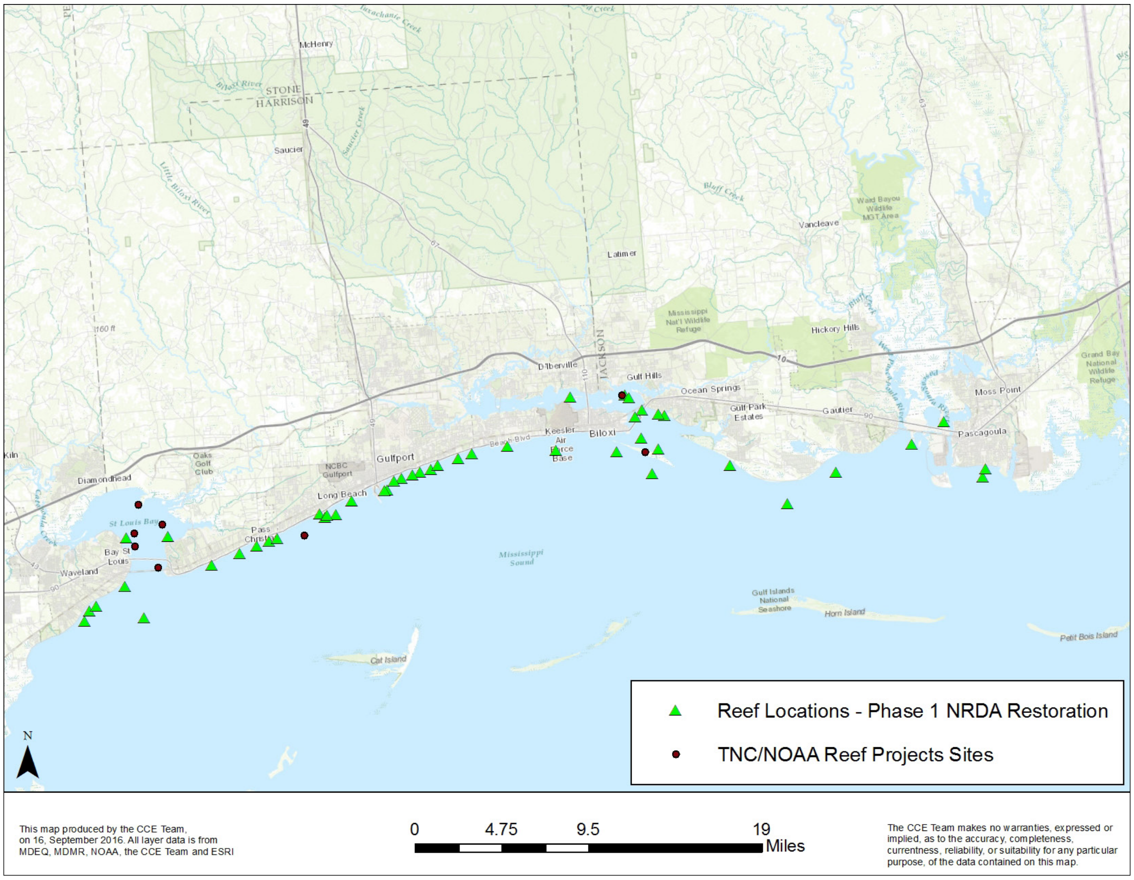


Figure 3. MDMR artificial reefs NRDA Phase I restoration locations; TNC and NOAA reef location map.

ENDPOINT GOAL

It is the goal of MDEQ to restore lost secondary benthic productivity (that includes oysters) that occurred as a result of the *Deepwater Horizon* oil spill. The strict definition of secondary productivity is the rate of production of consumers (heterotrophs) in an ecosystem (Edmondson & Winberg, 1971). For purposes of nearshore reef restoration, secondary productivity is more narrowly defined as production of herbivores and detritivores (the P2 production level in Odum and Smalley, 1959) and in particular, the net production of mobile and sessile invertebrate fauna associated with hard bottom substrates in the estuarine environment. Oyster production is a portion of secondary benthic production and is included in the endpoint. Gains in secondary benthic productivity will be accomplished through hard bottom restoration using low-profile artificial reefs and cultch material as well as living shoreline structures, where appropriate, in the nearshore environment. Low-profile reefs can be defined as man-made hard bottom structures constructed in nearshore areas by the placement of shell or other materials (e.g. limestone, crushed concrete) on soft substrate to an average height of 4 inches above the soft substrate (typically no more than 6 inches) (Gregalis, 2009) upon which the production of sessile and mobile invertebrate fauna will be enhanced.

FORMULATION OF THE ENDPOINT

Secondary Productivity Losses

The loss of secondary productivity was extracted from the AQUATOX 3.1 NME model application (Clough et al., 2015) that was developed and utilized by the State of Mississippi for injury assessment after the *Deepwater Horizon* oil spill. AQUATOX calibrates a food chain based injury which accounts not only for toxic effects from direct oil exposure but the additional injuries and lost productivity due to food chain effects and trophic cascading (Clough et al., 2015). This includes resources such as plankton, nekton, reef, and seagrass. Model output covers a wide selection of physiological and ecological endpoints including: daily growth rates, net primary and secondary productivity, and dynamic trophic-level calculations for every biotic group modeled in four primary habitats selected by the state of Mississippi. The four primary habitats are: intertidal marsh edge habitats (with and without Submerged Aquatic Vegetation (SAV)); intertidal beach habitats (with and without SAV), sub-tidal oyster reef habitats, and sub-tidal soft bottom benthic habitats. The results of the calibrated model are presented in the comprehensive technical report on the AQUATOX 3.1 NME effort for Mississippi (Clough, et al., 2015). Using this methodology, Mississippi accounted for the direct toxicity to organisms, their loss of growth, and additional food chain effects due to energetic losses through the various trophic levels. There are a number of assumptions associated with this injury number. The assumptions on AQUATOX include:

- The initial injury assessment is based on secondary productivity of oysters and all other sessile/mobile fauna.
- Assessment is based on modelled predictions and not observed data.
- Assumed oyster productivity based on Peterson et al. (2008) at Cedar Point, Alabama and AQUATOX background productivity estimates (Clough, 2015).
    - (600g)(m^{-2})(yr^{-1}) - AFDW (Ash Free Dry Weight) Productivity

For the purposes of this restoration endpoint, only secondary productivity injury is included which, as estimated from the AQUATOX model, equals approximately **12,191,207 kg** of lost productivity.

Restoration to Recover Lost Secondary Productivity

The amount of restoration required to meet the endpoint was calculated by equating the estimated loss of services resulting from the injury with a predicted gain in services resulting from restoration in acres. In this way, the calculation is used to scale the amount of restoration required to offset the injury. The focus of this injury or loss assessment is kilograms of productivity, and as such, restoration comes in the form of kilograms of secondary productivity per year. Using information about the productivity of hard bottom structures derived from the literature and MDMR (e.g., density, biomass, production, etc.), "lost productivity years" due to the *Deepwater Horizon* oil spill can be estimated. On the restoration side, projects designed to create habitat appropriate for the enhancement of secondary productivity can be examined and scaled to the size of the project such that it meets the amount lost from the injury (Table 5).

From the table, the respective secondary productivity production levels have been calculated for a 10 year growth cycle for the life of a hypothetical hard substrate surface area with an annual growth rate of 33% until maturity after 3 years using a calculation (Equation 2) that scales the number of acres placed in restoration to the secondary productivity biomass derived:

EQUATION 2

$$RI = \sum^{t=10} \left[\left(600g \bullet m^{-2} \bullet yr^{-1} \right) \bullet M_t \bullet A \right]$$

WHERE:

RI - Recovered Injury in kg of Secondary Productivity
M_t - Maturity Rate (at time t) of the reef
t - indexes time in years
A - Area (acres)

To ensure the derived benefits exceed the calculated secondary productivity numbers, approximately 725 acres of hard substrate will need to be restored and/or created. There are several assumptions built into the analysis:

- Reefs will reach full maturity after 3 years of existence: Average between structural maturity of sessile invertebrates (Coen, 2000) and attainment of natural densities of mobile crustaceans and fish after reef restoration (Peterson, 2003).
- Reefs have a defined 10 year project lifespan. Reefs will maintain a high level of productivity over a ten year project period, but are subjected to degradation over time from a multitude of factors including the uncertainty regarding the effects of storms, water quality, diseases, and degradation of reef materials (Peterson, 2003).

Table 5. Secondary productivity gain by acerage with hard bottom restoration in the Mississippi Sound.

YEAR	MATURITY (YEAR END)	SECONDARY PRODUCTIVITY FOR PROJECTS (WITH OYSTERS)			
	%	KG 100 ACRES	KG 200 ACRES	KG 500 ACRES	KG 725 ACRES
2017	0%	0	0	0	0
2018	33%	80,400	160,000	400,000	580,000
2019	67%	160,800	320,000	800,000	1,160,000
2020	100%	241,200	480,000	1,200,000	1,740,000
2021	100%	241,200	480,000	1,200,000	1,740,000
2022	100%	241,200	480,000	1,200,000	1,740,000
2023	100%	241,200	480,000	1,200,000	1,740,000
2024	80%	192,960	384,000	960,000	1,392,000
2025	60%	144,720	288,000	720,000	1,044,000
2026	40%	96,960	192,960	482,400	699,480
2027	25%	60,992	121,378	303,444	439,994
	TOTAL	1,701,632	3,386,338	8,465,844	12,275,474

ENDPOINT

Gains in secondary productivity to exceed the endpoint of 12,191,207 kg will be accomplished through the restoration and/or creation of approximately **725 acres** of hard bottom habitat in the nearshore environment. Nearshore environment is defined as Mississippi state waters that are considered non-harvestable for oysters, as well as not directly managed as an oyster resource (i.e., artificial reefs).

RESTORATION ENDPOINT: LAND CONSERVATION AND RESTORATION

ECOLOGICAL JUSTIFICATION

In general, land acquisition projects are being considered across coastal Mississippi utilizing different funding sources (i.e. NRDA and RESTORE). In each case, MCERT will be used to make science-based decisions on the best parcel location for the specific criteria of those programs. Through coordination of land conservation funding opportunities, Mississippi has the capability to focus on strategic connectivity of lands that will allow for better management of coastal lands, provide migration corridors for priority species, and increase core areas of natural ecological functioning and integrity across the Mississippi coastal landscape.

Although the land conservation and restoration endpoint is currently in progress, and is targeted to be released in the 2017 Mississippi Gulf Coast Restoration Plan, the prioritization scheme for the generation of the endpoint has been created. The success of any acquisition project hinges on willing sellers and the successful transfer of property into state management. Therefore, the prioritization scheme includes giving priority to, but is not limited to, the following factors: interested and willing sellers, properties that would fill gaps in large areas of state or other conservation land, areas adjacent to proposed restoration, large parcels, parcels connecting fragmented conservation areas to enhance management continuity, etc.

03

DATA UPDATE

DATA UPDATE

IN THIS ADDENDUM, DATASETS HAVE BEEN INCORPORATED INTO THE MCERT FRAMEWORK TO IMPROVE OUTPUTS AND BUILD DATA LAYERS IN THE MARINE ENVIRONMENT WHERE INFORMATION IS SPARSE.

This effort includes seasonal dolphin density data for the Mississippi Sound, beach closure data, oyster reef restoration data, and updated shipping density information. Additional data will be added in 2017 including benthic habitat data from the NFWF GEBF Oyster Restoration project, updated landcover data, and a land conservation and restoration prioritization scheme.

MARINE MODEL UPDATE

Updates to the marine model include the addition of data types as well as changes to the methodology to create the environmental resource, stressor, and restoration effort index datasets.

The methodology is described as follows: In order to assess the influence of a particular environmental resource or impact/stressor on a particular marine planning unit, the first step is computing a raw value to represent the degree or extent of local presence of that factor. Multiple approaches were necessary corresponding to the various data types in which input data were available. For point data, the number of points falling within the unit is determined, while for line or polygon data, the relevant figure was the total linear mileage or area intersecting the unit, respectively. If the input was represented by a range of values rather than simple presence/absence, its mean value was determined within each unit. Raster data represented a special case which necessitated determining the mean value of all raster cells within the unit. Finally, the influence of terrestrial inputs (e.g., impervious surfaces) on the adjacent marine environment is determined by applying a 1-km buffer to input data and assigning values to those units that intersected the buffer.

Once the raw values were determined for each input within each unit, normalizing the data was necessary to constrain each factor to the same scale. This normalization was done by using the linear scaling transform equation, which transformed values for each input to a scale of 0 (minimum value found for all units within the study area) to 1 (maximum value found for all units within the study area). With all input values now on an equivalent 0-1 scale, a weight multiplier was applied to each input. Weights are assigned to each dataset based on the professional judgment of the restoration planners and partners and are chosen to reflect not only each input's relative importance or impact but also the reliability and completeness of the data.

The next step is to sum all normalized and weighted environmental resource input values for each planning unit to determine that unit's total Environmental Resource (ER) score. The same is done with impact/stressor input values to determine the unit's total Impact/Stressor Rating (ISR) score. The Jenks Natural Breaks methodology is then applied to these total scores in order to divide all units into three Environmental Resource zones and three Impact/Stressor zones. A fourth zone was established to identify those areas where data is insufficient to make informed decisions on restoration. These areas require a cautionary approach and identify information gaps and research needs. The Restoration Effort Index (REI) is then calculated by adding the ER and ISR matrices together (see Chapter 3 of The Mississippi Gulf Coast Restoration Plan) (Figure 4).

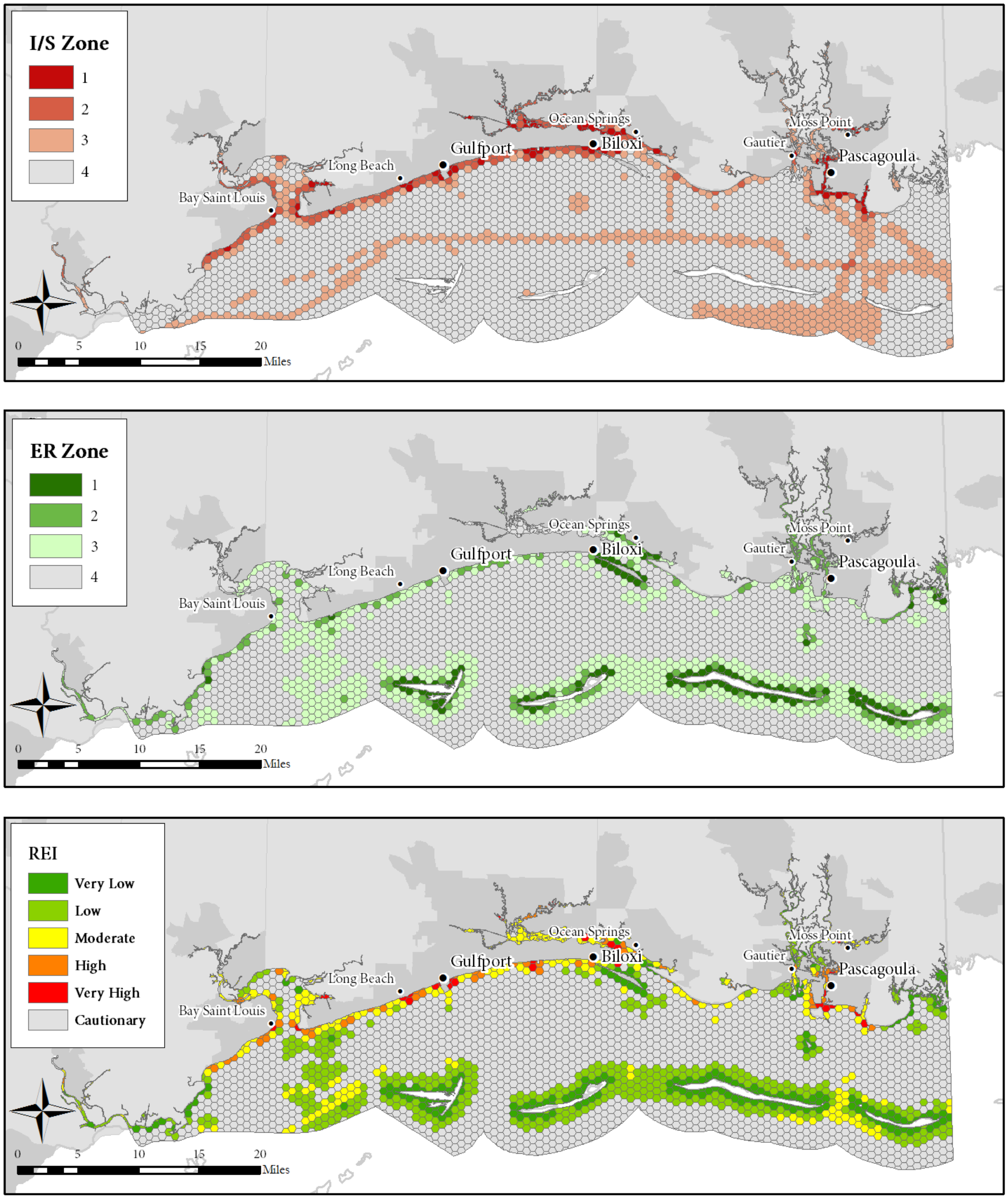
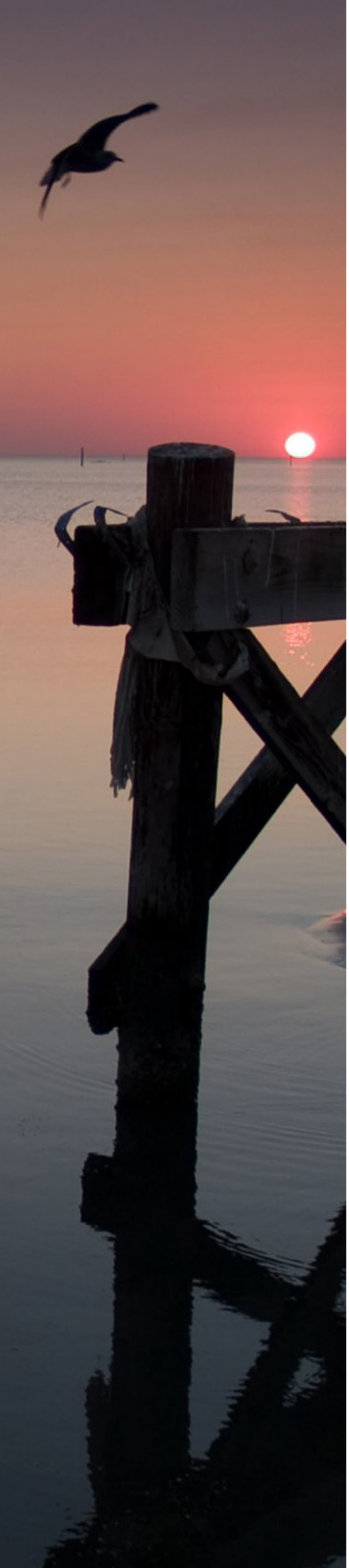


Figure 4. Updated ISR, ER, and REI based on the 2016 data update.

04

CONCLUSION



THE PURPOSES OF THIS ADDENDUM ARE TO EXPAND ON THE OVERALL STRATEGY FOR RESTORATION IN COASTAL MISSISSIPPI THROUGH THE CREATION OF SCIENTIFICALLY-BASED RESTORATION ENDPOINTS FOR PRIORITY HABITATS AND RESOURCES, TO PROVIDE DATA AND MODEL UPDATES TO CONTINUALLY IMPROVE MCERT AND DECISION MAKING, AND TO INCORPORATE PUBLIC QUESTIONS AND COMMENTS THAT ULTIMATELY DRIVE RESTORATION PRIORITIES FOR THE STATE OF MISSISSIPPI.

MCERT will continue to be refined with data inputs, particularly as restoration related project data become available from funded efforts (e.g., acres restored, habitats mapped). These updates may include data (i.e., inputs, model refinements), restoration outcomes (i.e., project-specific monitoring, comparing observed results with model outputs), and environmental dynamics (i.e., landcover change, occurrence of natural disasters, etc.).

MDEQ will continue to seek opportunities through which funding streams can be integrated, leveraged, and coordinated to continue to enhance and maximize the ecological benefits of restoration projects. MCERT and the DSS will continue to be used to help understand prioritization of restoration projects and to ensure those projects that are implemented will be successful and sustainable in their implementation. To help with understanding where Mississippi restoration is headed, endpoints for oysters, coastal marsh habitat, nearshore benthic production, and land conservation and restoration are being charted. These restoration endpoints were created as a guide to restoration implementation. As more is learned about the resources and more scientific understanding of the impact of certain restoration actions on these habitats and resources is gained, these restoration endpoints will be adapted to reduce uncertainty in derivation and to help define the restoration horizon, all in an effort to Make Mississippi Whole.

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