AN ACCOUNTING AND SUMMARY OF OYSTER RESTORATION PROJECTS IN THE GULF OF MEXICO FUNDED BY DEEPWATER HORIZON OIL DISASTER FUNDS

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Oystermen deploy cultch in Apalachicola Bay, FL. Image courtesy Florida State University Coastal and Marine Lab

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EXECUTIVE SUMMARY

The practice of placing shell or cultch on oyster reefs to replace material lost to harvest and other natural processes is a traditional approach to oyster fishery management. Habitat restoration includes replenishment of lost material, reef construction, and installment of living shorelines for erosion protection. These efforts use a variety of materials and have been funded by a wide range of entities including non-profit organizations, local citizen groups, government funded programs and restoration grants. The outcomes of these projects are unclear as reports are not always readily available, and it is therefore challenging for practitioners to assess the most appropriate approach for their specific restoration goals and to take advantage of the lessons learned by others.

The Deepwater Horizon (DWH) explosion in 2010 was an ecological and economic disaster for the Gulf of Mexico, and subsequent lawsuits resulted in the largest environmental damage assessment in U.S. history ($20.8 billion). These funds have facilitated a significant number of research and restoration projects, including many that are focused on oysters. The Deepwater Horizon Project Tracker is a centralized repository for projects supported by the settlement funds. This system provides a unique opportunity to review the approach, objectives, and outcomes of multiple oyster restoration projects across the Gulf of Mexico. The overarching objective of this review is to create an inventory and synthesis of oyster restoration (and related) projects supported through the funding components of the DWH settlement. Projects included in the database encompassed those primarily related to oyster restoration such as cultch deployment on natural or artificial reefs, as well those in which oysters were a secondary focus, such as research, development of decision support tools, and tertiary projects that included oyster habitats as a beneficial byproduct of the primary objective. Key elements summarized in this report include the level of funding for oyster restoration activities, amount of oyster habitat created or restored, status of restored habitats, and level of monitoring during and after project completion. Anticipated users of this database include restoration practitioners, funding entities, and academic or non-profit institutions that are interested in restoration efforts and their outcomes. This inventory is intended to serve as a foundation from which to develop guidance for future restoration projects to maximize their effectiveness. Several of the funding sources are ongoing, so the database will become outdated over time. We hope this initial effort will create a foundation for additional updates and analysis as more oyster restoration work is conducted under these, and potentially other, funding initiatives.

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INTRODUCTION

Replacement of oyster habitat lost to harvesting and natural processes, such as shell erosion and dissolution (Pace et al. 2020), sedimentation, and storms, has been a common practice for many years. Habitat restoration includes replenishment of lost material, small- to large-scale reef restoration, and installment of living shorelines for erosion protection. These efforts use a variety of materials and have been organized and funded by a wide range of entities including non-profit organizations, local citizen groups, government funded programs, and large-scale restoration grants. The outcomes of these projects are unclear as information on their objectives, metrics of success, results of monitoring (if conducted), and reports are not always readily available. It is therefore challenging for practitioners to assess the most appropriate approach for their particular restoration goals and to take advantage of the lessons learned by other entities.

On April 20, 2010, the Deepwater Horizon (DWH) mobile drilling unit exploded and sank, resulting in the release of an estimated 3.19 million barrels of oil [1] into the northern Gulf of Mexico, although the estimated amount varies by source [2, 3]. This spill caused extensive ecological damage, killing or injuring marine birds and mammals, as well as turtles, fishes, and benthic fauna. The exact numbers are unknown, but the 2016 DWH Natural Resource Damage Assessment (NRDA) Trustees reported an estimated mortality of up to 84,500 seabirds and 7,600 adult and 160,000 juvenile sea turtles, and an increase (above average) in marine mammal deaths and strandings [1]. The Trustees also reported estimated losses of 4 billion to 8.3 billion oysters as well as significant economic impacts to fisheries and tourism [1]. A federal district judge approved $20.8 billion dollars in penalties to be paid by the owners and operators of the rig (British Petroleum, Anadarko, TransOcean, and Haliburton) under the Clean Water Act and the Oil Pollution Act. This was the largest environmental damage settlement in U.S. history [4]. This was not the only expense incurred by the responsible parties: In 2018, the costs of this incident had risen to $65 billion [5]. In 2012, the Obama Administration signed the RESTORE Act [6] into law, which allocated 80% of the Clean Water Act settlement funds to ecological and environmental restoration ($5.33 billion). This funding was intended for projects related to understanding the impacts of the spill on natural resources in the Gulf of Mexico, and mitigation and restoration of those impacts. The funding was allocated to various entities for administration and implementation of projects under their purview (Fig. 1). Each entity has a different mission; some are for ecosystem restoration, while others focus on research and increasing our understanding of the impacts of oil and associated materials.

The remaining 20% ($1.33 billion) of the funds were passed to the Oil Spill Liability Trust Fund (OSLTF) [7], which was created by Congress in 1986 to cover costs associated with oil-spill impacts. This funding supports federal, state, and Native American trustees to cover costs of oil cleanup, damage assessment, restoration, and research, and it pays damages to entities impacted by the spill. The DWH oil spill was an ecological and economic disaster, but the funds released have facilitated a number of ecological restoration and mitigation efforts under a structured and centralized system, with defined but varying reporting requirements. This structure facilitates tracking and assessment of ecosystem restoration efforts funded by the British Petroleum (BP) settlement, and provides a unique opportunity to review the approach, objectives, and outcomes of multiple oyster restoration projects across the Gulf of Mexico.

Oyster Restoration Funding Sources

National Fish and Wildlife Foundation Gulf Environmental Benefit Fund

In 2013, the National Fish and Wildlife Foundation (NFWF) received $2.544 billion from lawsuit plea agreements with BP and Transocean over the 2010 DWH oil spill [8]. The NFWF Gulf Environmental Benefit Fund (GEBF) monies are awarded to state and local organizations for projects that have immediate and long-term benefits for natural resources that were impacted by the oil spill.

National Fish and Wildlife Foundation Recovered Oil Fund for Wildlife

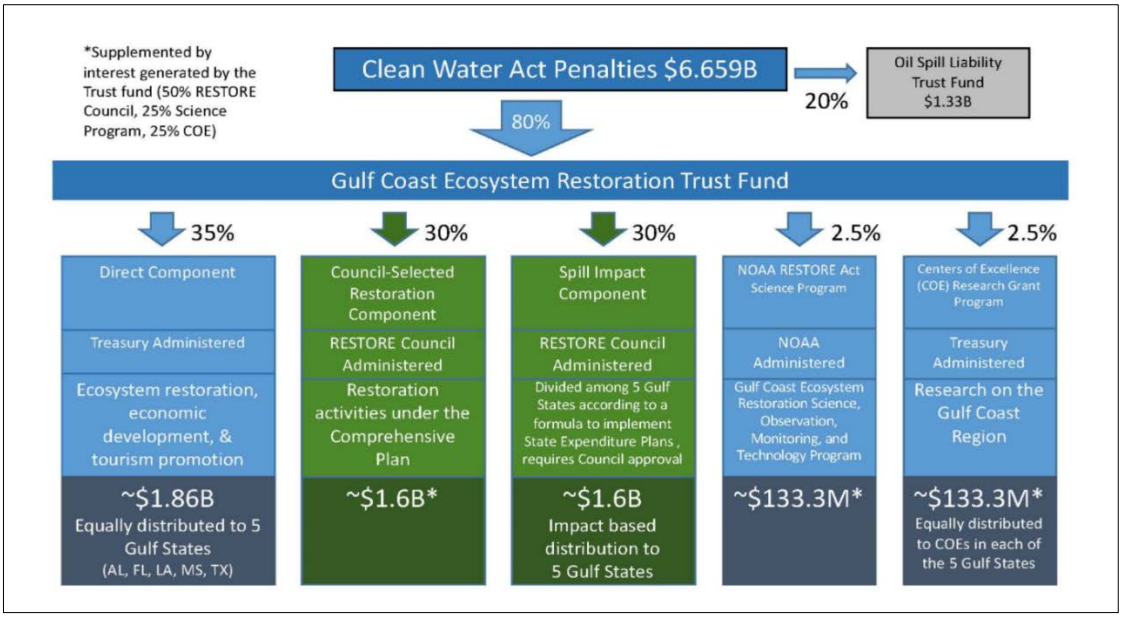
The NFWF Recovered Oil Fund for Wildlife (ROFW) program was launched in 2010 and has since terminated; it was supported by proceeds from the BP share of recovered oil from the DWH spill. The fund received at least $22 million from BP to support species most at risk from the oil spill, including turtles, oysters, shorebirds, waterfowl, and fishes. This money was distributed to ROFW partners in the five Gulf states [9].

The RESTORE Act

The Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast (RESTORE) Act of 2012 provided a mechanism for administration of penalties from the DWH oil spill. Under the RESTORE Act, 80% ($5.3 billion) of the DWH Clean Water Act penalties were allocated to the Gulf Coast Ecosystem Restoration Trust Fund and distributed to five funding “buckets” [10]. The program will run until the funds are depleted [11].

- Bucket 1: Direct Component – 35% (~$1.86 billion) administered by the Department of Treasury and split equally among the five Gulf of Mexico coastal states to fund ecological restoration, resource management, and economic development in impacted areas.
- Bucket 2: Council Selected Restoration Component – 30% (~$1.6 billion) allocated to the Gulf Coast Ecosystem Restoration Council to develop and implement the Council's Comprehensive Plan, which will guide the restoration activities undertaken with this funding bucket.
- Bucket 3: Spill Impact Component – 30% (~$1.6 billion) allocated among Gulf coast states in proportion to the impact of the spill, as stipulated in the RESTORE Act. These funds are for ecological and economic restoration and are disbursed according to State Expenditure Plans.
- Bucket 4: NOAA RESTORE Act Science Program – 2.5% (~$133 million) allocated to the National Oceanic and Atmospheric Administration (NOAA) to conduct research and monitoring to support long-term sustainability of the ecosystem, fish stocks, fish habitat, and the recreational, commercial, and charter fishing industries in the Gulf of Mexico.
- Bucket 5: Centers of Excellence Research Grant Program – 2.5% (~$133 million) split equally among the five Gulf coastal states for the establishment of Centers of Excellence (COE) in each state. These Centers will fund research being conducted in eligible disciplines within the Gulf Coast region through a competitive grant process.

Figure 1. Summary of funding allocated to the five components the Gulf Coast Ecosystem Restoration Trust Fund. Image: www.restorethegulf.gov/history/about-restore-act



Natural Resource Damage Assessment

The Natural Resource Damage Assessment (NRDA) is the legal process that authorizes Trustees from certain federal agencies (NOAA, Department of the Interior, Environmental Protection Agency, Department of Agriculture), states, and Native American tribes to evaluate impacts to natural resources by oil spills, hazardous substance releases, and grounding incidents in national marine sanctuaries [12]. After the DWH oil spill, the DWH-NRDA Trustee Council [13] was formed to assess the effects of the spill and manage BP settlement funds (up to $8.8 billion) for natural resource restoration. The Trustee Council and State Trustee Implementation Groups (TIGs) identify specific restoration projects for each affected Gulf state. Some of this funding was allocated to Early Restoration Phases (ERP) I-V prior to the finalized settlement to allow priority restoration activities to begin quickly [14]. The remainder were post-settlement phase funds.

Gulf of Mexico Research Initiative

In May 2010, BP committed up to $500 million over 10 years (2010-2020) to fund the Gulf of Mexico Research Initiative (GoMRI), which is an independent research program (GoMRI) to study the impact of the oil, dispersed oil, and dispersant on the ecosystems of the Gulf of Mexico to improve understanding of the dynamics of oil spills, their environmental impacts, and the public health implications [15]. Program objectives also included advancing technologies for oil and gas detection, characterization, and remediation to improve oil spill mitigation. The funds that were distributed using peer-reviewed evaluations were used strictly for research activities such as sampling, modeling, and studies, and research was published in scientific journals without requirement for BP approval. The GoMRI program initially awarded one-year blocks of funding of $10 million to each state to collect baseline data [15]. The subsequent six funding cycles were awarded under a series of requests for proposals (RFPs) to consortia (RFP-I and IV), individual scientists (RFP-II and V), bridge grants (RFP-III), and research grants (RFP-VI) [16].

National Academies of Sciences, Engineering, and Medicine Gulf Research Program

After the DWH oil spill, the National Academies of Sciences, Engineering, and Medicine (NASEM) formed the Gulf Research Program (GRP) [17], which received $500 million in settlement payments. The program is comprised of three broad categories of activities: research and development, education and training, and environmental monitoring. The overarching objective of this funding is to use

science and public health information to better anticipate, mitigate, and recover from future spills.

Additional Funding

In addition to the primary funding, several of the projects in this study received additional funding from a number of different sources, including non-profits organizations and state and local governments. These were often used to expand the spatial extent of the project restoration activities or to expand monitoring of restored areas. Additional funding streams are sometimes mentioned in the project summaries and reports but are not included in the DWH funding totals.

OBJECTIVES

The overarching objective of this review is to create an inventory and synthesis of oyster restoration (and related) projects supported through the significant funding components of the DWH settlement (Fig. 1 and others described above). These funding sources provide ready access to metadata and project products through the Deepwater Horizon Project Tracker website (listed at the end of this document, together with other relevant websites). Projects included in the review were: 1) those primarily related to direct oyster restoration efforts such as living shorelines, shell planting and recycling, and natural or artificial reef restoration; 2) projects in which oyster restoration was a secondary focus, such as research and development of decision support tools; and 3) marginal or tertiary projects that included oyster habitats as a beneficial byproduct of the primary objective.

Key elements summarized in the report include the level of funding for oyster restoration activities, the amount of oyster habitat created or restored, the status of restored habitats, and the level of monitoring during and after project completion. Anticipated users of this database include restoration practitioners, funding entities, and academic or non-profit institutions that are interested in restoration efforts and their outcomes. This inventory is intended to serve as a foundation from which to develop best practices or guidance for future restoration projects to maximize their effectiveness.

METHODS

Project Information Sources

The Deepwater Horizon Project Tracker (dwhprojecttracker.org) is a centralized directory of projects that were funded from the DWH oil spill settlements. Since this web portal contains a comprehensive

inventory of projects awarded under the DWH settlement and associated funds, it was the initial source of information for this report and database. However, this database does not capture every DWH related project; new or recently awarded projects may be missing and some funding streams that originated from the oil spill are not included. For example, Florida sued BP independently from the federal settlements and received $2 billion in damages. Grants awarded from these funds are not recorded in the Deepwater Horizon Project Tracker Database. Project information can be accessed through an ArcGIS map tool or a list option that can be searched by project name, state, funding program, or project category (environmental, science, human and social, recreational, other). Each project is listed by the DWH project number; the project links contain basic metadata such as funding level, funding source, a brief project description, and contact information for project leads. The website does not house project deliverables (e.g., reports, maps, publications) but contains links to project websites hosted by other institutions and funding programs, such as those listed below, where additional project documentation can be found.

The NFWF hosts a website database specifically for projects funded by the NFWF-GEBF (www.nfwf.org/gulf-environmental-benefit-fund/projects). Project information can be accessed through the ArcGIS map viewer that shows locations of each project, with embedded information on project metadata and links to additional information and project summaries. Progress reports and final reports are not available through the NFWF website and have to be requested directly from the project leads, if not already in the public domain through another mechanism (e.g., peer-reviewed publications). The NFWF-ROFW website (https://www.nfwf.org/restoration-gulf-coast-recovered-oil-fund-wildlife) has very little project information; however, basic metadata for projects funded under this program can be found in the DWH project tracker.

The main website for the RESTORE Act has information about the program with links to the different funding buckets (https://www.restorethegulf.gov/history/about-restore-act) and information on the projects funded under each bucket. These include the Centers of Excellence established by the states to administer Bucket 5 research funding.

Projects funded under the NRDA settlements are described on NOAA's Gulf Spill Restoration website (https://www.habitat.noaa.gov/storymap/dwh/index.html). Projects can be searched by state, region, or the open ocean, and each project webpage contains information on the project status, metadata, funding, activities, monitoring, and associated reports.

The GoMRI website has a page dedicated to projects funded under the different funding cycles

(https://research.gulfresearchinitiative.org/research-awards/). Within each link is a list of grants and their associated metadata and products, including any publications.

The NASEM-GRP website (https://www.nationalacademies.org/gulf/gulf-research-program) has general information about the program but does not have readily available information on the projects supported with these funds. Project details can be obtained through the DWH project tracker.

The Mississippi Department of Environmental Quality (MDEQ) created a comprehensive ArcGIS-based story map (http://www.msrestoreteam.com/ProjectStoryMap/) that displays the state's restoration projects on an interactive map with an information tile for each project that includes metadata and links to reports. Projects can be searched by individual funding source or by all sources combined.

While the websites are very useful, some are better than others on providing project outcomes and reports. Where information was unavailable online, individual project leads were contacted for specific information or requests.

Database Structure

The restoration database accompanying this report is housed in an excel spreadsheet with two worksheets. The first is named project information and contains 29 columns, broken into the broad categories of metadata, funding, description, and links to project information. Reports, publications, or other products are also provided, if available. Data is either numerical (which can be manipulated mathematically), categorical (which can be sorted to facilitate interpretation), or text. The overall structure of the database is shown in Table 1.

Table 1. Database structure showing column letter and title, broad category, and type of data.

Column	Column Title	Category	Data Type
A	Database Number	Metadata	Numerical
B	Project Name	Metadata	Text
C	State	Metadata	Categorical
D	Region	Metadata	Categorical
E	County	Metadata	Categorical
F	Lead Agency/Organization	Metadata	Categorical
G	Project Lead/Contact	Metadata	Text
H	Contact Email	Metadata	Text
I	Contact Phone Number	Metadata	Numerical
J	Award Year	Funding	Numerical

K	Award End Year	Funding	Numerical
L	Project Status	Funding	Categorical
M	Funding Source	Funding	Categorical
N	Funding Received	Funding	Numerical
O	Additional Funding	Funding	Numerical
P	Focus on Oysters	Project Description	Categorical
Q	Project Type	Project Description	Categorical + Text
R	Project Activity	Project Description	Text
S	Project Description	Project Description	Text
T	Project Objectives	Project Description	Text
U	Project Footprint	Project Description	Categorical + Text
V	Outcomes/Products	Project Description	Text
W	Activities Conducted	Project Description	Text
X	Monitoring Status	Project Description	Categorical
Y	Level of Monitoring	Project Description	Categorical
Z	Deepwater Horizon Project	Project Description	Text
AA	Links to Project Documents	Project Description	Text
AB	Reports and Publications	Project Description	Text
AC	Comments	Project Description	Text

Each column in the database can be filtered to display a subsample of the data, so users can select their choice of categories to display (e.g., by state, project type, funding agency). Numerical data can be manipulated to provide summaries of interest, such as the amount of funding allocated to oyster restoration in a particular state or by a certain agency. The second worksheet (column definitions) shows the column letter, title, and a definition or explanation of the contents of the information in the respective column on the main worksheet. These definitions are shown in Table 2. All projects in the database were assigned a category for "focus on oysters" and "project type" based on the criteria in the category descriptions (Table 2). These criteria were developed after reviewing the objectives and activities of the projects, and the categories allow similar projects to be easily sorted for analysis. Some projects encompassed more than one project type component; for example, habitat enhancement and aquaculture (production of spat on shell). In these cases, all elements are listed under the project type, which results in more overall project types than the total number of projects.

Table 2. Definitions of categories in the restoration database.

Column	Column Title	Definition
A	Database Number	Project number used for this database reference
B	Project Name	Official project name
C	State	State(s) where project work is focused
D	Region	Region of U.S. where project work is focused
E	County	County/counties where project work is focused
F	Lead Agency/Organization	Listed organization responsible for project administration
G	Project Lead/ Contact	Listed primary contact/project lead, responsible for ensuring timely completion of deliverables
H	Contact Email	Listed email of primary contact/project lead
I	Contact Phone Number	Listed phone number for primary contact/project lead
J	Award Date	Date when funding was received
K	End Date	Completion date or anticipated end date of project
L	Project Status	Awarded: Project proposal has been approved and selected by the funding group Active: Project is currently underway Completed: Project goals have been completed, may include monitoring after completion date
M	Funding Source	DWH settlement entity that awarded funding
N	Funding Received	Total amount of funding received from DWH funding entity (red text is information from project leads and is different from the project summaries)
O	Additional Funding	Additional external funding or leveraged funds
P	Focus on Oysters	Primary: Oysters are the primary targeted species for project objectives Secondary: Oysters are included in the project objectives but either share importance with other species or project is not directly involved with oyster restoration efforts Tertiary: Project is tangentially related to oyster restoration but lists oysters as a species that will benefit from the project

Column	Column Title	Definition
Q	Project Type	Planning: Planning phases for larger projects or the selections of future projects Habitat enhancement: Oyster reef restoration, usually through placement of cultch Habitat creation: Creation of new habitat for oyster restoration or related objective Research: Research focused on oysters, oyster habitats, or oyster communities Decision support: Development of tools or reports to be used in future restoration planning Aquaculture: Direct use of aquaculture (e.g., spat on shell or seed) for oyster restoration Outreach: Promote public awareness of science, science education Shell recycling: Collection and curing of oyster shells for restoration purposes
R	Project Activity	Short description of activities proposed, conducted, or completed by the project
S	Project Description	Description of project objectives, activities, outcomes, and location
T	Project Objectives	Short description of project objectives
U	Project Footprint	Spatial extent: Small <0.5 km2 (<124 acres), Medium 0.5-5 km2 (124-1236 acres), Large > 5 km2 (>1236 acres) Linear extent: Small <1000m (<3281 ft), Medium 1000-10,000m (3,281-32,808 ft), Large > 10,000m (>32,808 ft) Undefined: The project information does not stipulate area or linear extent
V	Outcomes/Products	Expected outcomes, products, or deliverables of the project
W	Activities Conducted	Activities completed or underway as of December 31, 2020
X	Monitoring Status	Status of monitoring efforts that are integral to the project deliverables
Y	Level of Monitoring	Monitoring frequency and metrics measured by category
Z	DWH Project Tracker Link	Link to project in the Deepwater Horizon Project Tracker website
AA	Links to Project Documents	Links to project-specific website and/or other documents
BB	Comments	Any additional information not captured by the other categories
CC	Reports and Publications	Documents produced by the project in addition to those available through website links

RESULTS

Overview of Projects in the Restoration Database

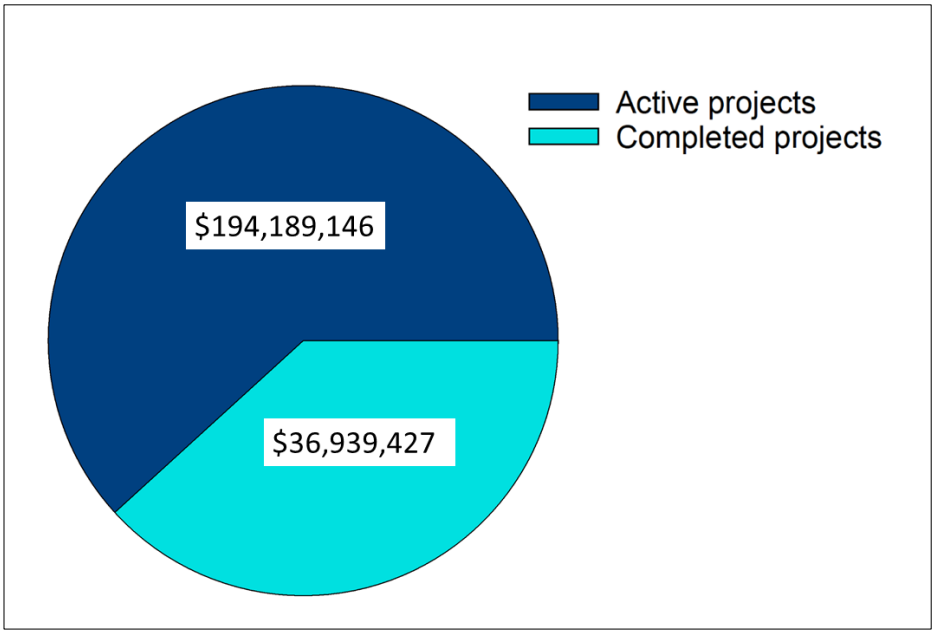
The restoration database contains information on 68 oyster-related projects across the five Gulf states, which were supported by DWH settlement funding ($231,128,573). These projects were funded by different entities, with varying investment in oyster restoration and related efforts (Table 3). The disbursement of the DWH funds is ongoing, so additional oyster-related projects will be supported through these funds in the coming years. The GoMRI (2010-2020) and NFWF-ROFW are closed, but the remaining funding entities are ongoing and will remain open until funds are spent. This report only includes projects that were listed in the Deepwater Horizon Project Tracker as of December 31, 2020.

Table 3. Allocation of funds to each of the entities described below for oyster restoration and related projects, and the number of projects supported by each funding source. Note the total number of projects does not include the "additional funding" row as this was supplemental funding for existing projects.

Funding source	Amount allocated	No. projects funded
NFWF-GEBF	$118,912,118	24
RESTORE Act total	$ 40,395,665	20
Bucket 1	$9,146,801	4
Bucket 2	$8,131,774	3
Bucket 3	$16,109,722	4
Bucket 4	$4,507,368	5
Bucket 5	$2,500,000	4
NRDA	$ 68,917,682	16
NFWF-ROFW	$1,858,920	4
GoMRI	$574,814	3
NASEM-GRP	$469,374	1
Additional funding	$70,962,146	12
Total	$231,128,573	68

Of the 68 total projects, 26 have been completed, 39 are currently active, one has been awarded but the work has not yet started (project #68), and one has been approved (project #28) but funding has not yet been received (Fig. 2). For the calculations in this report, the awarded and approved projects are included in the active category.

Figure 2. Number of oyster projects and funding amounts for active and completed projects.



The majority of projects in the database are still active, and more could be added to this list as additional projects are supported with the remaining settlement funds. Completed projects (65% funded within five years of the DWH spill) were predominantly research/planning/decision support (77%) versus habitat enhancement or creation (31%). Most of the active projects (81%) were awarded more than five years post-spill, and these were dominated (71%) by projects with direct restoration goals such as habitat enhancement and creation, development of juvenile oysters for seeding reefs, and shell recycling for restoration efforts (Fig. 3).

As the restoration emphasis shifted over time, so did the funding allocations (Fig. 4). The early awards were focused on understanding oil spill impacts, direct restoration of damaged habitats and wildlife, and planning for future efforts.

Figure 3. Distribution of project types (by percent of all projects) within the completed and active project categories. Note: More than one category can occur within a single project.

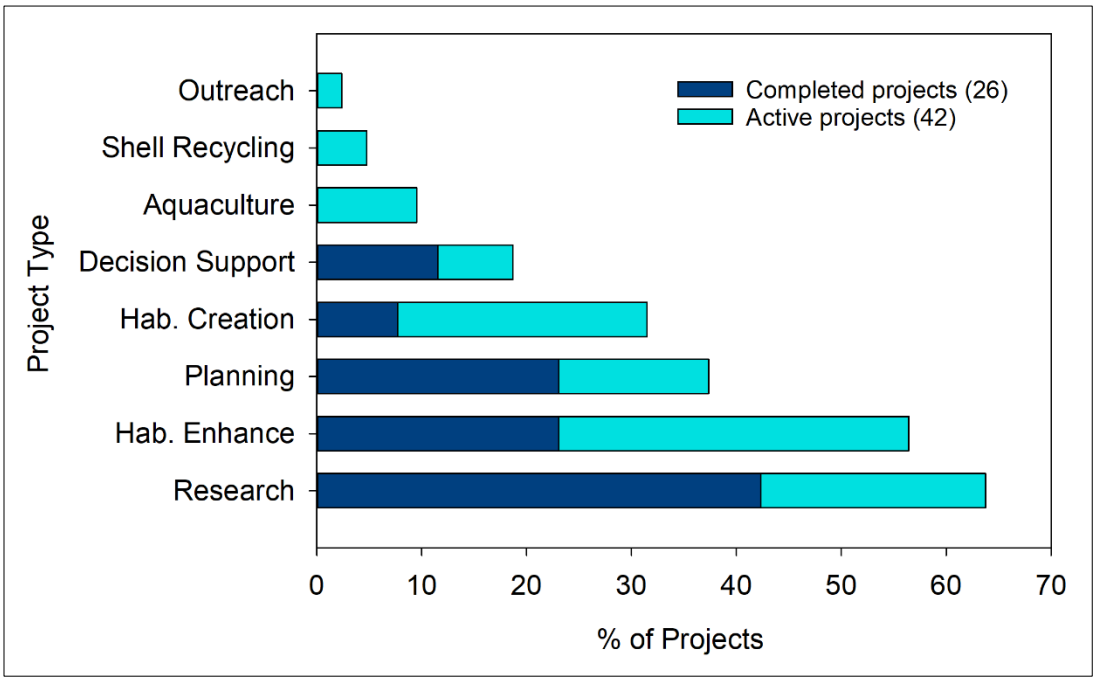
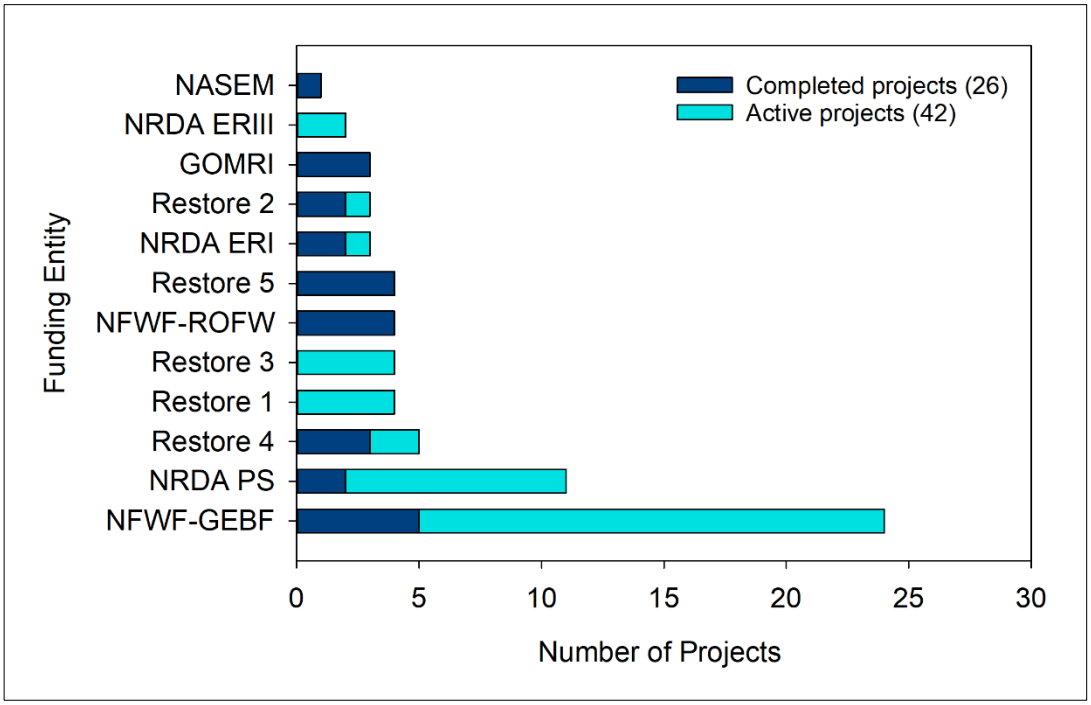


Figure 4. Distribution of completed and active projects by funding entity, indicating a shift from early post-spill to later post-spill funding sources.



Some funding entities focus on a specific type of project or objective (e.g., GoMRI and RESTORE Act Bucket 5 only fund research), whereas others have a broader scope (e.g., NFWF-GEBF and NRDA post-settlement funds). Table 4 shows the proportion of each project type within the suite of projects in the database, broken down by funding entity. Several of the awards have more than one project type, so the sum of the percentages may be greater than 100. For example, habitat enhancement may be an element of 50% of the projects under a particular funding entity, and research may be an element of 75% of the projects, so 25% have both.

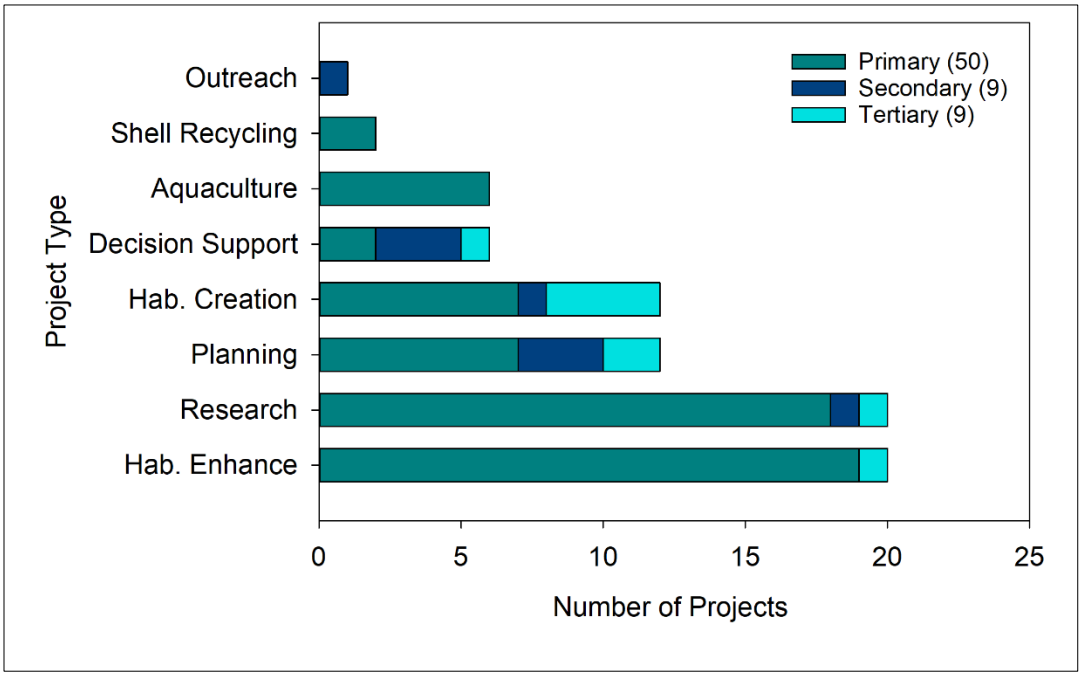
Oysters were the primary focus of 50 of the projects, secondary focus of nine, and tertiary focus of another nine (Fig. 5). Within the primary focus category, most were either habitat enhancement (19), research (18), or habitat creation (7). Secondary focus projects included planning (3), decision support (3), habitat creation (1), research (1), and outreach (1). Those projects with a tertiary focus on oysters included habitat creation (4), planning (2), habitat enhancement (1), decision support (1), and research (1). Habitat creation in the secondary and tertiary categories was for construction of living shorelines/breakwaters that could support oyster populations, but their primary purpose was shoreline erosion prevention.

Table 4. Percentage of projects that incorporate different project types, broken down by funding entity. Table abbreviations: **Pl** – Planning; **HE** – Habitat Enhancement; **HC** – Habitat Creation; **Res** – Research; **DS** – Decision Support; **Aq** – Aquaculture; **SR** – Shell Recycling; **Ou** – Outreach. Note: projects may contain more than one project type and blank cells represent zero projects in that category. Blue cells indicate the largest percentage of project types for a given funding entity.

	Project Type							
Funding Entity	**Pl**	**HE**	**HC**	**Res**	**DS**	**Aq**	**SR**	**Ou**
GoMRI				100				
NASEM-GRP				100				
NFWF-GEBF	25	33	33	17	4			
NFWF-ROFW		25	50	25	25			
NRDA-ERI		100				33		
NRDA-ERIII		100						
NRDA-PS	36	18	18	27		18		
RESTORE Bucket 1				25		50	25	25
RESTORE Bucket 2	67	33		33				

RESTORE Bucket 3		75		25		25	25	
RESTORE Bucket 4				20	80			
RESTORE Bucket 5				100				

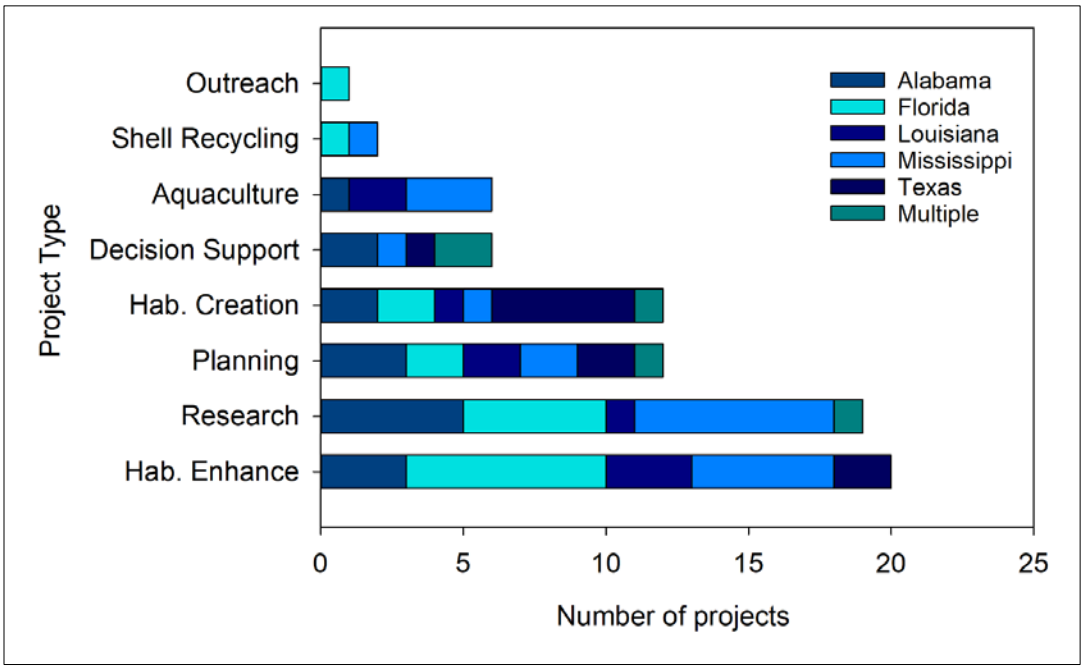
Figure 5. Distribution of oyster focus within each category. Projects were divided into three categories by the level of focus on oysters. Primary focus included habitat enhancement or creation, secondary focus included oyster research or management, and tertiary focus included living shorelines or other projects where oysters were a beneficial byproduct of the primary goal.



Geographical Distribution of Funding

Mississippi had the largest number of projects awarded (17) totaling over $61 million, followed by Florida (14) for almost $63 million, Alabama (14) for more than $42 million, Texas (10) for $17.5 million, and Louisiana (8) for more than $45 million, with five additional projects for just over $2 million that covered multiple states. The number of projects and associated funding by state are shown in Fig. 6, and a more comprehensive description of state-specific projects is provided below, with a focus on projects that created or enhanced habitat. Projects involving more than one state are listed as multiple and appear after Texas.

Figure 6. Distribution of projects and funding across the Gulf of Mexico states.



Alabama

Of the 14 oyster-related projects (restoration database projects #1-14) awarded to Alabama, eight had oysters as a primary focus. These included project type categories of research (4); habitat enhancement (3), which usually involves cultch placement; habitat creation (1), such as oyster habitat or living shoreline construction; aquaculture (1); and restoration planning (1). Two of these projects (#6, 8) were a combination of research and habitat enhancement or creation. These eight projects received a total of $11,818,886 in funding.

The six remaining projects were secondarily focused on oysters and involved planning (2), decision support (2), research (1), and habitat creation (1). These projects received $30,306,924, more than half of which ($16,578,000) was awarded to the Lightning Point Restoration Phase II (project #4) for the creation of breakwaters primarily to protect and enhance marshes, with a secondary benefit of providing potential oyster habitat.

Most of the projects are currently active (10), with anticipated end dates ranging from 2022 to 2025 or have an unknown end date (#2, 13). Of the four projects (#1, 5, 6, 8) that primarily focused on oyster habitat enhancement and creation, one (#1) has been completed (2020). This Restoration and Enhancement of Oyster Reefs in Alabama project (NFWF-GEBF funded)

deployed 46,256 m^3 (60,501 yd^3) of limestone and shell on 3.21 km^2 (794 acres) of public oyster reefs in Mobile Bay and Mississippi Sound; 0.79 km^2 (194 acres) more than the original target. The reefs were also supplemented with spat-on-shell (57,555,000) and seed (41,069,890) for a cost of $3,716,355. The project final report (attached to restoration database, obtained from project lead) documented methods, data, and lessons learned from the project. Reef monitoring will continue under the Alabama Department of Conservation and Natural Resources (ADCNR) oyster monitoring program. The remaining three active projects were funded by the BP settlement funds that went to the NRDA program; one is focused on oyster gardening (#8) for transplantation on existing reefs and the other two (#5, 6) have a combined cultch footprint of 2.53 km^2 (625 acres) for a cost of $3,719,747 and include objectives such as spat/seed placement and monitoring.

Florida

Of the 14 oyster-related projects (#15-28) funded in the state of Florida, 12 were primarily focused on oysters. These include project type categories of habitat enhancement (7), research (5), habitat creation (2), restoration planning (1), and shell recycling (1). These projects received a combined total of $62,432,195. Projects secondarily focused on oysters included one (#25) promoting local seafood consumption (project type: outreach) and another (#26) on living shoreline design and permitting (project type: planning). These two projects received a total of $331,314.

Of the 14 total projects, four (#18, 22, 24, 27) were completed between 2011 and 2020. The earliest of these (#27) was a research project funded by GoMRI ($337,631) to study the pre- and post-oil spill demographics and diversity of oysters in Florida estuaries. Two other projects involved enhancement of 1.28 km^2 (317 acres) of oyster habitat (#22) and creation of 0.48 km (0.3 miles) of oyster living shorelines (#24), for a total cost of $5,077,120. The final completed project (#18) was the planning phase of an oyster restoration effort in Pensacola Bay. The remaining nine active projects, and one approved but not yet begun (#28), include six focused on habitat enhancement (#15, 16, 17, 20, 21, 28) and one on habitat creation (#19). Together these projects will enhance or create more than 5.36 km^2 (1,324 acres) of oyster reef and 11.26 km (7 miles) of reef structures, as well as address additional objectives such as research and monitoring, for a total cost of $55,189,500.

Louisiana

Eight projects (#29-36) were awarded to Louisiana through the DWH settlement funds, seven of which focused primarily on oysters. Project types included habitat enhancement (3), aquaculture (2), planning (2), habitat creation (1), and research (1), with a total award value of $45,094,860 from DWH funding and an additional $52,841,550 from other sources. Of the three that have been completed, two were planning projects (strategy for oyster restoration funding [#30] and design for a living shoreline [#36]), and the other was a habitat enhancement and research project (#34), which was funded by NFWF-ROFW ($291,800) and outside contributions ($389,206). Project #34 created high resolution bathymetric data and planted 0.10 km^2 (25 acres) of cultch on optimal habitat, as revealed by the mapping. One of the habitat enhancement projects (#29) was to be completed in 2021; the project objectives involved placing cultch on 3.44 km^2 (850 acres) of public oyster reefs, but because of limitation in cultch availability, the area was reduced to 0.41 km^2 (100 acres), using 60% of planned cultch. The remaining funds were allocated to the second objective of the project, which was construction of a hatchery to generate larvae and seed for restoration. The second active habitat enhancement project (#31) was funded in 2020 and involves placing 1.62 km^2 (400 acres) of cultch at several public oyster seed areas to enhance oyster abundance and spawning stock. The habitat creation project (#32) will develop four broodstock reefs, covering a total area of 0.16 km^2 (40 acres) to improve and maintain oyster production. One project (#35) examined methods of assessing oil contamination in oysters and shrimp and was assigned a tertiary focus level. This was funded by GoMRI ($148,268) and completed in 2011.

Mississippi

Seventeen projects (#37-53) were awarded to Mississippi from the DWH settlement funds, and all were primarily focused on oysters, receiving a total of $61,397,285. These project categories included research (7), habitat enhancement (5), aquaculture (3), planning (2), habitat creation (1), shell recycling (1), and decision support (1). Of these, seven have been completed, and ten are active. Four of the completed projects were focused on research (#49-52), with the general objective of collecting data that would inform restoration efforts, for example, habitat mapping, hydrodynamic modeling, and ecological data collection. Two habitat enhancement projects (#46, 47) have been completed and together deployed cultch (oyster shell and/or limestone) on 6.20 km^2 (1,530 acres) of natural and artificial reefs in Mississippi Sound. The combined cost of these two

projects, which also included monitoring for the duration of the projects (#46 ended in 2015, #47 ended in 2020), was $13,350,000. Of the active projects, four (#39, 40, 42, 43) included habitat creation or enhancement and covered a range of approaches, including creating small-scale research reefs, expanding and deploying cultch on existing public reefs, and supplementing existing reefs with live adults (relayed from elsewhere) and spat from an aquaculture facility. These projects were all recently awarded (2019) with completion dates from 2022 to 2026. These projects will create or expand 0.12 km^2 (30 acres) of oyster reef and supplement an undefined area of existing reef with live oysters, for a total cost of $19,711,000, plus additional funding for project #39 of $49,270.

Note: In 2020, two additional oyster-related projects were funded through the Mississippi RESTORE Act Center of Excellence (RESTORE Act Bucket 5). Projects were: 1) Impacts of Water Quality on Oyster Development to Inform Oyster Reef Restoration and Sustainability on the Mississippi Gulf Coast (Gochfield et al., University of Mississippi; $442,924), and 2) Optical Observation for Oyster Larvae (Zhang and Powell, University of Southern Mississippi; $449,907). These were supposed to run from 2020-2022 but were delayed by Covid and extended to 2023. These projects are not in the Deepwater Horizon Tracker Database, and no details are available beyond the proposal abstracts. These projects were therefore not included in the database. Project abstracts can be found at https://mbrace.usm.edu/current-funded-projects.

Texas

A total of $17,505,345 was awarded to Texas for 10 projects (#59-68). Three of these were primarily focused on oysters (#59-61), and for the remaining seven (#62-68) oysters/oyster habitats were incidental to the primary objectives, which focused on other coastal habitats. Three projects have been completed: One was for habitat enhancement (#60), one for decision support (#64), and the other (#65) planning for coastal restoration. The seven active projects included an oyster restoration planning project (#59); five habitat creation projects, one of which is focused on oysters (#61); four are constructing breakwaters (#62, 63, 66, 68); and one habitat enhancement of a coastal ecosystem (#67). The oyster habitat creation project (#61) was funded by NWFW-GEBF ($2,500,000) and plans to deploy 40 acres (0.16 km^2) of vertical structures in Galveston Bay to restore degraded oyster habitats. The majority of the restored area (0.1 km^2/25 acres) will

be open to harvest two years after construction, but the remaining 0.06 km^2 (15 acres) will be indefinitely restricted to harvest by the Texas Parks and Wildlife Department. A habitat creation project (#68) was awarded in 2018 but had not begun at the writing of this report. The project objective is to create 3.3 miles (5.31 km) of breakwater to prevent erosion of coastal habitats, including oyster reefs.

Multiple States

Only five (#54-58) of the total 68 projects involved multiple states, and four of these have already been completed. Project types included two decision support (#54, 58); one planning (#55), which is still active; one research (#57); and one habitat creation project (#56) that constructed 1.37 km (0.85 miles) of oyster reefs in Louisiana and Alabama. This project received $1,100,000 from the NFWF-ROFW funding, and an additional $272,026 from grants awarded to the project lead organization (The Nature Conservancy) by the American Recovery and Reinvestment Act and the Gulf of Mexico Foundation (see report attached to the restoration database, obtained from project lead). The decision-support projects included a comprehensive review of grant proposals and reports (#54) funded by NFWF ($70,000) to identify common problems and solutions associated with oyster restoration programs. The second decision support project (#58) created a guide to science-based management of several coastal ecosystems, including oyster reefs. The final reports for both projects are available through the link in the database. Total funding allocated to multi-state projects from DWH settlement funds was $2,093,496. The NRDA regionwide TIG recently released a draft plan (DWH oil spill TIG, 2021) that will fund restoration of up to 30 acres (0.12 km^2) of oyster habitat each Gulf state, for an estimated cost of $35,819,974.

Project Outcomes

Completed projects

One of the goals of this oyster restoration assessment is to understand how much funding has been committed to oyster restoration and the overall success of those efforts. Most of the projects in the database are still active, therefore final outcomes are not available yet. The database contains eight completed habitat enhancement (#1, 22, 34, 46, 47, 60) or habitat creation (#56, 24) projects that were focused on oysters (Table 5). Most of the information on the project summaries in this document can be found in the restoration database, either in the spreadsheet columns, project links,

or ancilliary PDF files. Any information not available through the database is cited in the references list at the end of this document.

Table 5. Brief summaries of completed oyster enhancement and creation projects. See the restoration database for additional detail.

#	Project Title	Dates	Funding	Project Activities	Accomplishments
1	Restoration and Enhancement of Oyster Reefs in Alabama	2013-2020	$3,716,355	Deployed cultch, spat on shell and seed, monitored sites	Cultch goals exceeded, monitoring goals met, oyster goals not met
22	Apalachicola Bay Oyster Restoration - Planning and Implementation	2017-2020	$4,680,000	Deployed cultch, mapped and monitored sites	Cultch goals exceeded, monitoring goals met, oyster goals not met
24	Yellow River Aquatic Preserve Shoreline Restoration	2011-2014	$397,120 NFWF-ROFW $110,000 additional funding	Constructed living shoreline	Construction goals met
34	Evaluation and Creation of Alternative Gulf Oyster Habitat	2011-2013	$291,800	Mapped and deployed cultch	Mapping goals met, cultch goals exceeded
46	Mississippi Artificial Reef Habitat Project	2012-2015	$2,350,000	Planned project, deployed cultch, monitored sites	Cultch goals met, oyster goals not met
47	Mississippi Oyster Cultch Restoration Project	2012-2020	$11,000,000	Planned project, deployed cultch, mapped and monitored sites	Cultch, mapping and monitoring goals met, oyster goals not met
56	Oyster Restoration in the Gulf of Mexico	2010-2012	$1,100,000 NFWF-ROFW 272,026 additional funding	Constructed oyster reefs, monitored sites, outreach	Construction goals met, monitoring and oyster goals met
60	Oyster Reef Restoration in East Bay, Texas	2013-2016	$840,000 NFWF-GEBF $2,500,555 additional funding	Deployed cultch, monitored sites	Construction goals exceeded, monitoring and oyster goals unknown

Project #1: Restoration and Enhancement of Oyster Reefs in Alabama (2013-2020; $3,716,355 NFWF-GEBF). Lead agency: Alabama Dept. Conservation and Natural Resources (ADCNR). This project deployed 46,256 m^3 (60,501 yd^3) of cultch material (oyster shell and limestone) over 3.2 km^2 (794 acres), which substantially exceeded the project goal of 38,228 m^3 (50,000 yd^3) over 2.43 km^2 (600 acres). With this final volume and area, the estimated material depth would be approximately 1.5 cm (0.6 in). The project also deployed spat-on-shell and seeded areas with more than 41 million larvae, spat, and sub-legal oysters to enhance productivity. The restoration efforts showed spatially and temporally variable abundance in spat, sub-legal, and legal oysters on natural and planted reefs. Water quality (high and low salinities) and predator abundance impacted different sites, in different years, so there was no clear trend in the data, but consistent recovery was not occurring. The final report included lessons learned for each of the major project components. For the cultch deployment section, the authors commented that adverse environmental conditions played a role in the variable success of the restoration efforts, and the deployment of *in situ* instruments to monitor water quality is critical to project planning.

Project # 22: Apalachicola Bay Oyster Restoration - Planning and Implementation (2017-2020; $4,680,000 RESTORE Act Bucket 2). Lead agency: Florida Dept. Environmental Protection (FDEP). This project deployed 73,014 m^3 (95,500 yd^3) of limerock aggregate over 1.3 km^2 (317 acres) of degraded historical oyster reef. This material was distributed over 14 reefs and exceeded the original target of 38,425 m^3 (50,258 yd^3) by 1.02 km^2 (251 acres). The project also mapped the restored areas using side-scan sonar. The fourteen sites were deployed in September-November 2017 and monitored annually in 2018, 2019, and 2020 (2021 monitoring report attached to the database). The density of live oysters was calculated and used to determine success of the restoration effort. The reefs were mapped using side-scan sonar after year 1 and year 2 to assess reef footprint and persistence, and showed that each reef diminished in footprint between mapping periods, with some sites silted over.

Results of monitoring showed the majority of live oysters were < 25 mm in all sampling rounds. Very few (<10) legal-sized (≥ 75mm) oysters were observed on any of the sites after the second sampling round, but the average size increased from 17.33 to 31.30 mm by round 3. Sampling rounds 1 and 2 showed almost no adults; but by round 3, adult oysters were documented at several sites, predominantly on the eastern part of the Bay. Live oyster density was highest in

the eastern part of the bay, and two years after deployment (round 3 sampling), three sites (Cat Point spur, Hotel Bar sites 1 and 2) had reached the restoration goal of > 300 oysters/m^2, and size class data coupled with density estimates indicated that three sites (Cat Point spur, Peanut Ridge and Monkey's elbow) had also reached levels capable of sustaining harvest (> 400 bags/acre).

Project # 24: Yellow River Aquatic Preserve Shoreline Restoration (2011-2014; $397,120 NFWF-ROFW, $110,000 additional funding). Lead agency: FDEP. This was one of the earlier DWH projects (2011-2014), with the objective of creating 0.48 km (0.3 miles) of living shoreline within the Yellow River Marsh Aquatic Preserve State Park. The project coordinator confirmed the materials have been deployed, and there may have been limited post-construction monitoring, but data is not available.

Project # 34: Evaluation and Creation of Alternative Gulf Oyster Habitat (2011-2013; $291,800 NFWF-ROFW, $389,206 additional funding). Lead agency: Environmental Defense Fund. This project involved mapping 13.8 km^2 (3,400 acres) of sub-tidal habitat using side-scan sonar and sub-bottom profiling, which resulted in identification of 1.1 km^2 (275 acres) of optimal oyster restoration area. These maps were used to place 0.1 km^2 (25 acres) of cultch material (limerock and oyster shell), which is greater than the original 0.06 km^2 (15 acres) in the original project proposal. Volume of material used was not reported. There is no final report available for this project, but a paper was published [18] that detailed the mapping outcomes, and a poster that included the cultching was provided by the project lead (A. Freeman, pers. comm) for inclusion in the database. Louisiana Department of Wildlife and Fisheries monitored the cultch post-deployment as part of their statewide monitoring program (A. Freeman, pers. comm). This project concluded that mapping was a necessary step in the restoration process as it optimized material placement.

Project # 46: Mississippi Artificial Reef Habitat Project (2012-2015; $2,350,000 NRDA-ERPI). Lead agency: Mississippi Dept. Environmental Quality (MDEQ). This project focused on placement of 22,172 m^3 (29,000 yds^3) of limestone on 47 artificial reefs to enhance or create 0.43 km^2 (100 acres) of oyster habitats. The project was monitored for two years after deployment, but the focus was non-bivalve infauna and epifauna. Depth was measured to determine whether reef

material remained in place, and according to the reports, the material persisted. The target biomass was 84 grams of wet weight of invertebrates per m^2 (g ww/m^2), which was exceeded (263 g ww/m^2) at the end of year 1 but had diminished (41 g ww/m^2) by the end of year 2. This was most probably due to a severe hypoxia event in year 2 (2015).

Project # 47: Mississippi Oyster Cultch Restoration Project (2012-2020; $11,000,000 NRDA-ERPI). Lead agency: MDEQ. This project restored and enhanced approximately 5.79 km^2 (1,430 acres) of the oyster cultch areas within Mississippi Sound. Cultch material (oyster shell and limestone) was deployed at a rate of 76.5 m^3 (100 yds^3) per 4,046 m^2 (1 acre). Post-construction monitoring included side-scan sonar for physical structure, dredge and quadrat sampling for oyster metrics, and secondary productivity sampling using baskets. Oyster density was measured annually in years 1-7, except years 2 and 6. The target metric was 4 oysters/m^2, but this target was not attained, possibly due to hypoxia events. Secondary productivity sampling was done twice in years 1, 2, 5, and once in year 4, and exceeded the target metric.

Project #56: Oyster Restoration in the Gulf of Mexico (2010-2012; $1,100,000 NFWF-ROFW, $272,026 additional funding). Lead agency: The Nature Conservancy. This was one of the earliest DWH projects, funded in 2010 and completed in 2012. This project installed 1.37 km (0.85 miles) of different types of artificial reef structures in Louisiana and Alabama, building on reef constructed previously in Mobile Bay, AL, and Vermilion Bay, LA. The original proposal listed 1.6 km (1 mi) of reef, so the project did not reach its original goals in terms of linear feet, but the permits necessitated changing the configuration of the reefs to make them a little wider than planned, which increased their area. A detailed final report was obtained directly from the project lead as there is no public report available. This report is attached to the restoration database. This project accomplished its biological goals and metrics, although some oyster mortality was observed in Louisiana in the earlier phase due to low salinities, but by the end of the project, good oyster growth was observed. Among the lessons learned from this project were the need for pre-construction baseline data and post-construction monitoring to understand ecosystem responses to the deployments.

Project #60: Oyster Reef Restoration in East Bay, Texas (2013-2016; $840,000, NFWF-GEBF, $2,500,000 additional funding). Lead agency: Texas Parks and Wildlife Dept. This project planned to plant 0.12 km^2 (30 acres) of cultch in a 0.53 km^2 (130 acre) restoration area, but with additional funding ($2 million from the Coastal Impact Assessment Program and $500,000 from the Coastal Conservation Association), was able to plant 0.20 km^2 (50 acres) at Middle Reef, Pepper Grove and Hanna's Reef. The project included post-construction monitoring to evaluate the success of the project, but there is no publicly available final report.

Summary

Most of the completed projects were funded shortly after the 2010 spill and were of relatively short duration (two to three years). The projects generally accomplished or exceeded their goals in terms of materials deployed (Table 6), for a total cost of $27,646,507 ($24,375,275 from DWH settlement funds, and the remainder from additional funding). The exception was project #56, which did not quite meet the reef creation goal of 1.6 km (1 mi). Despite the construction success, the projects often did not reach their target metrics in terms of oyster population recovery. Failures to recover were often due to environmental conditions (extreme freshwater events, hypoxia, sedimentation) that caused oyster mortality. With few exceptions, baseline mapping, monitoring, or modeling data were not used to guide the construction or deployment. Some pre-construction planning could possibly have mitigated or avoided placing material in sub-optimal locations. All cultching efforts placed a thin layer of material over a large area. This is a traditional approach but in cases where the reef habitats are severely depleted it may be more effective to create a higher reef with a smaller footprint to avoid sedimentation and hypoxia. Few of the projects discussed reef height as a necessary consideration in project planning.

Table 6. Summary of target and actual enhancement (km^2) or creation (km) of oyster habitat for completed projects.

Project #	Project type	Target (km^2)	Actual (km^2)	Difference (km^2)	Target (km)	Actual (km)	Difference (km)
1	Enhancement	2.43	3.20	0.77			
22	Enhancement	1.02	1.30	0.28			
34	Enhancement	0.06	0.10	0.04			

46	Enhancement	0.41	0.41	0.00			
47	Enhancement	5.79	5.79	0.00			
60	Enhancement	0.12	0.20	0.08			
24	Creation				0.48	0.48	0.00
56	Creation				1.60	1.37	-0.23
Total		**9.83**	**11.0**	**1.17**	**2.08**	**1.85**	**-0.23**

Active Projects

The database contains 12 active (#5, 6, 15, 16, 17, 20, 21, 29, 31, 40, 42, 43) and one approved (#28) habitat enhancement, plus five habitat creation (#8, 19, 32, 39, 61) projects that were primarily focused on oysters. The 13 enhancement projects proposed to place materials on more than 10.1 km^2 (2,471 acres) of oyster habitat and enhance 1.6 km (1 mi) of degraded reef. Four of these projects (#6, 15, 17, 40) will have a small footprint (< 0.5 km^2, 123 acres), seven (#5, 16, 20, 21, 28, 29, 31) will have a medium footprint (0.5-5 km^2 or 1-10 km). None of the active projects with a primary focus on oysters have a large footprint (>5 km^2/1,235 acres or 10 km/6.21 mi). The remaining two enhancement projects involved placing an undefined quantity of adult oysters (#42) or spat on cultch (#43) on existing reefs. The habitat creation projects will construct 0.36 km^2 (90 acres) and 9.6km (6 mi) of new reefs. These projects are in the early stages of development (pre-construction or unfinished construction, and pre-construction monitoring) and there is little information available on their status.

Of the active enhancement projects, seven have already completed the construction phase (#5, 6, 15, 17, 20, 21, 29) and are currently monitoring and/or addressing other aspects of the project objectives. Outcomes so far are detailed below. The oyster relay project (#42) is underway, and the remaining projects are either in the planning phase, or there is no status information.

Project #5: Alabama Oyster Cultch Restoration (2015-2025; $3,239,485 NRDA-ERPIII). Lead agency: ADCNR. In May 2015, 10,088 m^3 (13,197 yds^3) of oyster shell and 40,020 m^3 (52,344 yds^3) of limestone were placed over 2.1 km^2 (519 acres) of subtidal oyster reef habitat, exceeding the original goal of placing ~23,000 - 30,500 m^3 (30-40,000 yd^3) cultch on 1.3 km^2 (319 acres). Quadrat surveys of oyster density, size distribution, and mortality were conducted using scuba during the summers of 2015-2019 on planted and adjacent natural reefs. Recruitment was also

monitored in 2016-2017 using recruitment tiles. Quadrat surveys and recruitment monitoring will continue annually until 2025, but monitoring data is not currently available.

Project #6: Oyster Cultch Relief and Reef Configuration (2018-2024; $480,262 NRDA-post settlement). Lead agency: ADCNR. This project deployed a series of experimental reefs to test the efficacy of different materials and cultching methods. The overall goal is to inform and increase the success of future restoration efforts. Cultch material included 192.15 m^3 (251.32 yd^3) of oyster shell and 206.42 m^3 (270 yd^3) of #4 limestone and were used to study the effects of cultch relief (three oyster shell mounds, three limestone mounds, and two controls of each material were deployed using traditional low relief methods) and configuration (three elongated mounds of mixed shell and limestone and two controls of each material). Monitoring is ongoing and includes deployment of water quality dataloggers and annual assessment of oyster mortality, density, and size distribution.

Project #15: Apalachicola Bay Oyster Restoration Phase I (2013-2021; $4,189,400, NFWF-GEBF). Lead agency: Florida Fish and Wildlife Conservation Commission (FWC). This project placed cultch on approximately 0.07 km^2 (18 acres) of degraded oyster reef habitat across a range of salinity levels. The objective of this study was to better understand optimal conditions for oyster reef development to inform future restoration efforts. The sites are monitored quarterly using scuba for oyster density, predator density, and water quality. The final report for this project is not yet available, but the monitoring data so far indicate that oysters have not recovered, and despite good juvenile recruitment, very few oysters have survived to market size (project lead personal communication)

Project #17. Oyster Reef Habitat Restoration in St. Andrew Bay (2014-2025; $1,973,500 NFWF-GEBF). Lead agency: FWC. This project was divided into four phases, with the overall objective of restoring/creating approximately 16,187 m^2 (4 acres) of oyster reef in West Bay (St. Andrew Bay), to improve water quality, enhance fisheries, and increase coastal resiliency. The project also promoted expansion of seagrass beds that were lost or degraded as a result of a former shrimp farm operation and wastewater discharge. The pilot phase deployed ~3,035 m^2 (0.75 acres) of cultch material in bags. The implementation phases (II and III) deployed loose shell and limerock

to create 12,140 m^2 (3 acres) of reef. Phase IV will involve transplanting seagrass to enhance recovery. Annual monitoring includes reef area and height, oyster density, percent cover and size distribution, assessment of resident and transient invertebrates and fishes, and percent seagrass cover. Water quality was measured monthly or quarterly from 2014-2019 (project lead personal communication). Reports for each phase are in progress and planned for release from 2021-2025.

Project #20: Recovery and Resilience of Oyster Reefs in the Big Bend of Florida (2016-2024; $8,334,400 NFWF-GEBF). Lead agency: University of Florida. This project restored 22 degraded intertidal oyster reefs, covering a total of 1.6 km (1 mile) in Suwannee Sound in the Big Bend area of Florida. Elevation and stability were added using Ocala limestone base material, with oyster shell placed on top. One of the project objectives is to improve salinity regulation by containing freshwater from coastal rivers within the Suwannee Sound and improving oyster reef resiliency to the long-term effects of sea level rise. A manuscript [19] comparing live and dead oysters on restored vs. unrestored reefs indicated that the restored areas were becoming more similar to the unrestored reefs, but that overall, intertidal oyster populations were declining over time.

Project #21: Florida Oyster Cultch Placement Project (2015-2027; $5,370,596 NRDA-ERPIII). Lead agency: Florida Department of Environmental Protection (FDEP). This project deployed ~ 46,716 m^3 (61,103 yds^3) of cultch materials over ~1.23 km^2 (302 acres) of degraded oyster reefs in three Florida estuaries: Pensacola Bay (0.36 km^2 / 89 acres), St. Andrews Bay (0.34 km^2 / 84 acres), and Apalachicola Bay (0.53 km^2 /131 acres). Note: There is discrepancy among the project reports in the quantities of material deployed in Apalachicola Bay. This report used the as-built construction reports. Construction of all three sites was completed by 2016, and monitoring was scheduled bi-annually for five years post-construction and annually for the subsequent five years. Each of the project components had a target metric of 100 bags of harvestable oysters per acre two years post-construction. The monitoring reports are very detailed, but in summary, very few of the sites in each of the bays have reached their targets. Each year shows recruitment and initial survival, but very few (if any) harvestable oysters are present in the populations.

Project #29: Louisiana Oyster Cultch Project (2016-2021; $15,582,600 NRDA-ERPI). Lead agency: Louisiana Department of Wildlife and Fisheries (LDWF). This project intended to place

cultch material onto 3.44 km^2 (850 acres) of Louisiana public oyster seed grounds. The second portion of the project involves constructing an oyster hatchery to provide a source of oyster larvae and seed to supplement cultch placement. In 2018, 12,351 m^3 (16,155 yd^3) of oyster shell was spread across 0.4 km^2 (100 acres) of existing oyster habitat to increase reef height by approximately 3 cm (1.2 in). No additional material was available after this initial deployment. Funds remaining for the cultch deployment ($1,032,910) were used for the oyster hatchery operations. Post-construction monitoring includes annual dredge sampling (Q1, Q3, Q4 2019; Q1, Q2, Q4 2020) and quadrat surveys (Q4 2018, Q2 2019, Q3 2020). Target metrics are unclear, but the numbers of live oysters are consistently low and may have been impacted by extreme freshwater floods in 2019. The hatchery produced 40 million spat-on-shell, which were deployed on nine oyster reefs in the area during 2019. Monitoring data for these reefs is not available through the project website, but reports are submitted to the LDWF, and are incorporated into their annual stock assessment reports (https://www.wlf.louisiana.gov/resources/category/oyster).

CONCLUSIONS AND OBSERVATIONS

The data compiled and summarized for the restoration database and this report were originally sourced through the Deepwater Horizon Project Tracker, which is the primary repository for information on projects funded under the DWH settlement funds. This report includes oyster restoration and related projects completed or active as of December 31, 2020, with the caveat that some relevant projects may not be included if adequate information was unavailable at the time of writing.

This database may be used to query a number of parameters associated with the projects and to locate reports and information that may not readily be found through traditional search engine queries. These may include monitoring protocols for specific restoration efforts, total spatial footprint of restoration efforts by region or funding agency, amount of funding expended by state, costs of different restoration approaches per unit area, and many others. In addition to these simple database searches, more detailed analyses of project outcomes may be performed. For example, resource management agencies may be interested in the outcomes of different restoration techniques, which can be obtained by reviewing monitoring reports and lessons learned from individual projects that in combination might identify common problems. Additionally, in calculating the amount of material deployed per unit area, it became clear that the standard

approach to cultching has been to apply a thin layer over a large area. Although most completed projects met or exceeded their construction goals, the oysters have not responded as expected and production goals have generally not been met. The cultching approach used therefore may not be the most effective in areas where reef structure has been badly diminished.

Since 2010, $141,811,939 of DWH settlement funds has been spent on 26 oyster habitat creation or enhancement projects across the Gulf states. The total projected area of enhanced habitat is 23.86 km2 (5,896 acres) and 3.45 km (2.14 miles) of new habitat; however, some of these projects are ongoing so the actual areas may be slightly different than projected.

Several projects did not reach their production goals, and most of these sub-optimal outcomes were attributed to environmental conditions, including hypoxia. In the future it may be beneficial to incorporate a research component to identify optimal placement, materials, and configuration of restoration efforts prior to deployment.

The report details examples of the application of the database, and the information derived from different queries and manipulations of the data. Reporting requirements differ among funding entities; the NFWF-GEBF does not post project reports so the outcomes of this important funding source are not readily available. In contrast, all documents associated with the NRDA projects include budget expenses, and all reports are available through the project web links. Standardizing reporting requirements across funding entities would help in assessing project success.

Since several of the funding sources for this work are ongoing, the database will almost certainly become outdated over time. It is our hope that this initial effort will create a foundation for additional updates as more oyster restoration work is conducted under these, and potentially other, funding initiatives. Examples are state and local government, non-profit and community groups, or federal fishery disaster relief, though these funding sources are less centralized than the DWH funding and may be more challenging to capture the information for the database. This report and database can be used to analyze effectiveness of oyster restoration in the Gulf to date, as well as be used to refine restoration practices to better ensure long-term success of achieving biological and ecological goals.

REFERENCES

[1] Deepwater Horizon Natural Resource Damage Assessment Trustees. (2016). Deepwater Horizon oil spill: Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement. Retrieved from http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan

[2] On Scene Coordinator Report Deepwater Horizon Oil Spill (2011). Submitted to the National Response Team September 2011 pp244

[3] Environmental Protection Agency website https://www.epa.gov/enforcement/deepwater-horizon-bp-gulf-mexico-oil-spill

[4] National Oceanic and Atmospheric Administration DWH website https://www.noaa.gov/explainers/deepwater-horizon-oil-spill-settlements-where-money-went

[5] Reuters article on DWH costs January 2018 https://www.reuters.com/article/us-bp-deepwaterhorizon/bp-deepwater-horizon-costs-balloon-to-65-billion-idUSKBN1F50NL

[6] Introduction of the RESTORE Act to Congress https://www.congress.gov/bill/112th-congress/senate-bill/1400/actions

[7] Oil Spill Liability Trust Fund https://www.uscg.mil/Mariners/National-Pollution-Funds-Center/about_npfc/osltf/

[8] Gulf Coast Ecosystem Council Comprehensive Plan Update 2016 https://www.restorethegulf.gov/sites/default/files/CO-PL_20161208_CompPlanUpdate_English.pdf

[9] National Fish and Wildlife Foundation Recovered Oil Fund for Wildlife https://www.nfwf.org/restoration-gulf-coast-recovered-oil-fund-wildlife

[10] The RESTORE Act website https://www.restorethegulf.gov/history/about-restore-act

[11] The Deepwater Horizon Project Tracker https://dwhprojecttracker.org/

[12] Natural Resource Damage Assessment website https://oceanservice.noaa.gov/facts/nrda.html

[13] Natural Resource Damage Assessment Trustees website https://www.gulfspillrestoration.noaa.gov/co-trustees

[14] Deepwater Horizon Natural Resource Damage Assessment Trustees. (2016). *Deepwater Horizon oil spill: Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic Environmental Impact Statement.* Retrieved from *http://www.gulfspillrestoration.noaa.gov/restoration-planning/gulf-plan*

[15] Gulf of Mexico Research Initiative (GoMRI) website https://gulfresearchinitiative.org/about-gomri/

[16] GoMRI research awards https://research.gulfresearchinitiative.org/research-awards/

[17] National Academies of Science Engineering and Medicine website https://www.nationalacademies.org/gulf/about

[18] Freeman AM and HH Roberts (2013) A geological approach to the evaluation and creation of Gulf oyster habitat. Gulf Coast Assoc. of Geological Societies Transactions 63:227-234.

[19] Moore JF and Pine WE (2021) Bootstrap methods can help evaluate monitoring program performance to inform restoration as part of an adaptive management program. PeerJ 9: e11378.

LINKS TO DATABASES AND OTHER RELEVANT INFORMATION

1. Deepwater Horizon Project Tracker https://dwhprojecttracker.org/
2. National Fish and Wildlife Foundation Gulf Environmental Benefit Fund www.nfwf.org/gulf-environmental-benefit-fund/projects
3. National Fish and Wildlife Foundation Recovered Oil Fund for Wildlife https://www.nfwf.org/restoration-gulf-coast-recovered-oil-fund-wildlife
4. The RESTORE Act https://www.restorethegulf.gov/history/about-restore-act
5. Gulf Spill Restoration website www.gulfspillrestoration.noaa.gov
6. Gulf of Mexico Research Initiative https://research.gulfresearchinitiative.org/research-awards/
7. National Academies of Science Engineering and Medicine Gulf Research Program https://www.nationalacademies.org/gulf/gulf-research-program
8. The Mississippi Department of Environmental Quality www.msrestoreteam.com/ProjectStoryMap/

9. RESTORE Act Centers of Excellence websites
    - Alabama – Dauphin Island Sea Lab https://alcoe.disl.edu/
    - Florida – Florida Institute of Oceanography https://www.fio.usf.edu/programs/flracep/projects/
    - Louisiana – The Water Institute of the Gulf https://thewaterinstitute.org/la-coe
    - Mississippi – Mississippi Based RESTORE Act Center of Excellence https://mbrace.usm.edu/
    - Texas – Texas One Gulf Center of Excellence https://www.harte.org/project/texas-onegulf-center-excellence

APPENDIX: OYSTER RESTORATION DATABASE

The database is available as an excel spreadsheet. It contains project data, links to project summaries and reports, and ancilliary PDF files with additional information.