SYNTHESIS REPORT SERIES MARCH 2017 WISR-002-2017

"This is your shield… this is your estuary"

Building community and coastal resilience to a changing Louisiana coastline through restoration of key ecosystem functions

THE WATER INSTITUTE OF THE GULF®

CITATION: Carruthers, T.J.B., Hemmerling, S.A., Barra, M., Saxby, T.A., Moss, L. 2017. "This is your shield… this is your estuary." Building community and coastal resilience to a changing Louisiana coastline through restoration of key ecosystem functions. WISR-002-2017. The Water Institute of the Gulf. 48pp.

SERIES: This report is part of The Water Institute of the Gulf Synthesis Report Series, available online at thewaterinstitute.org WISR-002-2017

FUNDING: FUNDING: Partial funding for this project was provided by Louisiana Sea Grant through Award Number NA14OAR4170099 subaward 98353. Additional funding was provided by the Coastal Protection and Restoration Authority and the Baton Rouge Area Foundation, as part of The Water Institute's Science and Engineering Plan.

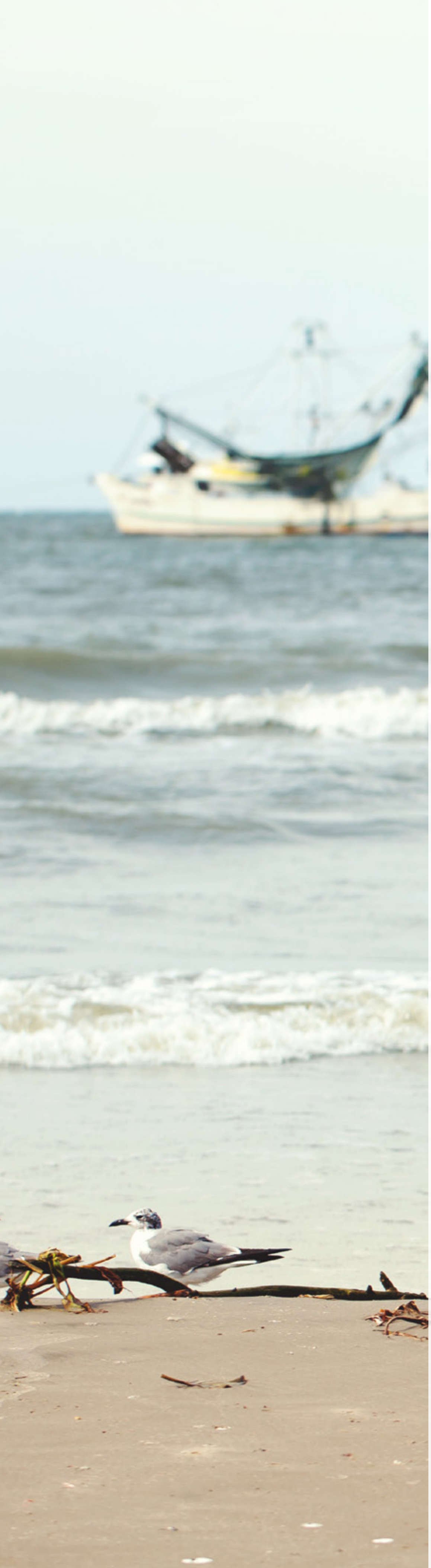
ACKNOWLEDGEMENTS: Phillip Lafargue, Emergent Method, provided input on layout and design; and Amy Wold assisted with photo sourcing and text editing.

SCIENCE COMMUNICATION, DESIGN, & LAYOUT: Tracey Saxby, Integration & Application Network, University of Maryland Center for Environmental Science ian.umces.edu

PHOTO CREDITS:
Cover: CRCL
Page 3: Dollarphoto
Page 4: Monica Barra (top), U.S. Army Corps of Engineers (bottom)
Page 6: FEMA (top), The Water Institute of the Gulf (middle), Louisiana Sea Grant College Program (bottom)
Page 8: Chincie Mouton (top & bottom)
Page 9: Monica Barra (top), Tim Carruthers (middle & bottom)
Page 11: Wendell Verrett
Page 12: Louisiana Sea Grant College Program (bottom)
Page 13: FEMA (bottom)
Page 15: FEMA (top), FEMA (middle),Louisiana Sea Grant College Program (bottom)
Page 16: Erik Zobrist, NOAA Restoration Center
Page 17: U.S. Army Corps of Engineers (bottom)
Page 18: Leland Moss (top), Tim Carruthers (bottom)
Page 19: Adobe Stock
Page 21: Dollarphoto
Page 23: Brett Patton
Page 25: Tim Carruthers
Page 27: John Cub, Wikimedia Commons
Page 29: Dollarphoto
Page 31: Tim Carruthers
Page 33: Dollarphoto
Page 34: CRCL (left), D. Todd Baker (middle), The Water Institute of the Gulf (right)
Page 35: CRCL (left), CRCL (middle), Denise Reed (right)
Page 36: CRCL (all)
Page 38: CRCL (left), CRCL (middle), Denise Reed (right)
Page 43: The Water Institute of the Gulf
Page 44: Dollarphoto

THE WATER INSTITUTE OF THE GULF®

University of Maryland CENTER FOR ENVIRONMENTAL SCIENCE



CONTENTS

RESTORING ECOSYSTEMS TO HELP COMMUNITIES OUTSIDE OF

THE LEVEE SYSTEM

BACKGROUND

The coastal communities of Louisiana are highly vulnerable to coastal change, yet the population has remained steady in the midst of highly dynamic environmental, social, and economic conditions.[1] Adaptations in the form of social networks, mobility, and ingenuity have enabled Louisiana's coastal communities to remain viable, although changed over time. Locally-based capacities to cope with disruption represent inherent resilience strategies and are retained in the social memory of residents when faced with extreme events.[2] This reservoir of capabilities, combined with the wealth of ecosystem services delivered from the productive range of coastal habitats, has enabled Louisiana's coastal residents to endure. Much of Louisiana's coastal zone is outside of the current system of hard infrastructure (primarily levee) protection. Therefore, the potential benefits of protecting, restoring, and enhancing intact ecosystems—including the potential benefits in terms of providing protection from waves and surge, and provision of fisheries and livelihoods—is particularly important to the highly vulnerable communities of the region.

Amongst the broader stakeholder community, there is a current lack of synthesized information on potential benefits of ecosystem-based restoration options at a parish, basin, or coastwide scale. Strategic partnerships and scientific synthesis can be effective in bridging the gap between science and a broader stakeholder group.[3,4]

PROJECT AIM

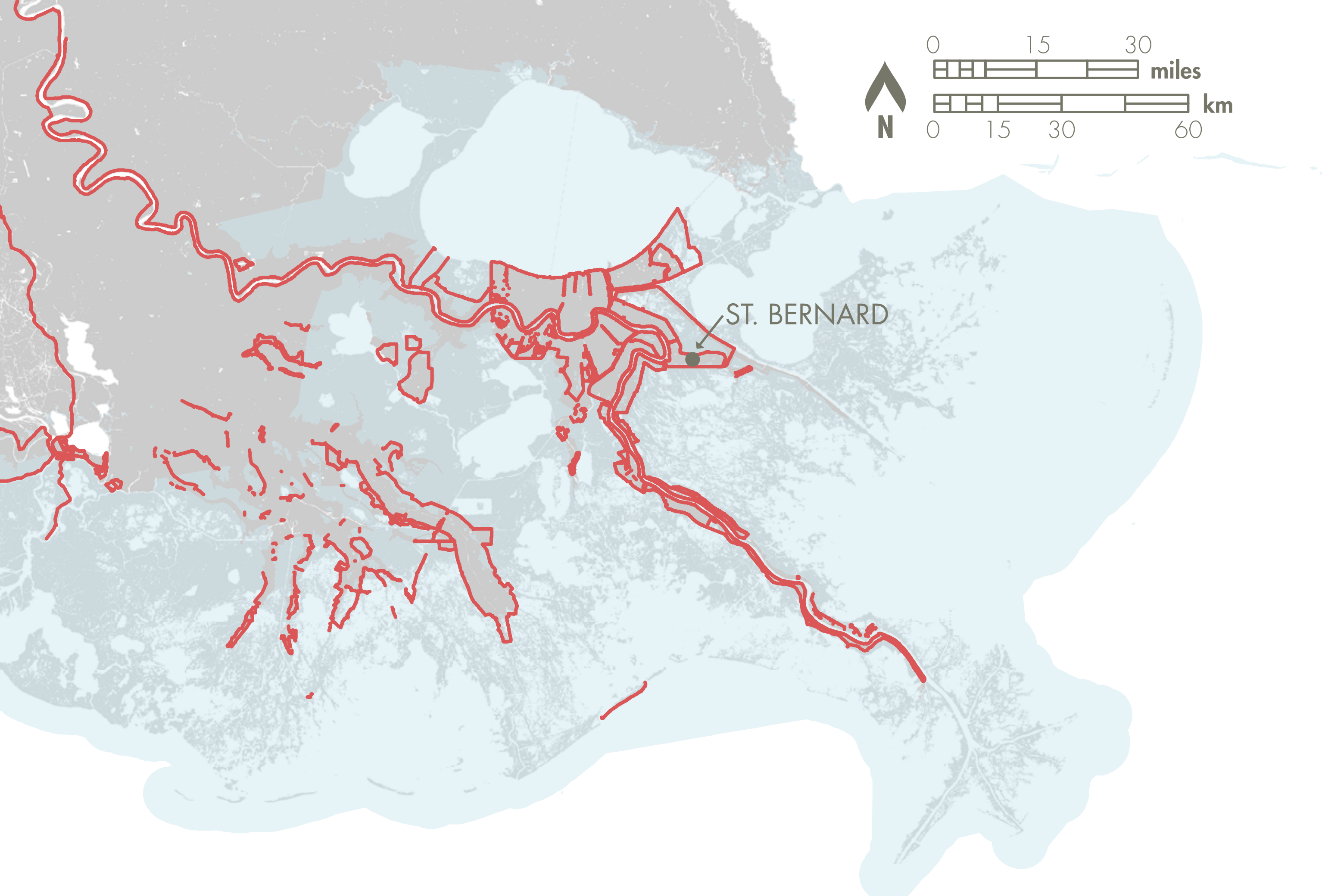
This document aims to provide key insights and communication tools that can assist in filling this knowledge gap through development of synthesized information on the potential of ecosystem-based adaptation approaches to build community resilience in coastal Louisiana, combining both technical scientific and community input.

"If we rebuild the coastal marsh, the more protection we have here."

Delcambre workshop participant, April 2016

Top: Flood wall in St. Bernard, built after 2005 by the U.S. Army Corps of Engineers as part of the Hurricane and Storm Damage Risk Reduction System (HSDRRS);

Bottom: Levee operated by the U.S. Army Corps of Engineers.



ECOSYSTEM-BASED RESTORATION

Maintenance and restoration of intact coastal ecosystems is considered globally to have high potential for supporting community resilience,[5] which can also be applied to coastal communities of Louisiana. Ecosystem services provided by intact ecosystems can increase community resilience through: reducing direct impacts of waves, storm surge, and marginal erosion; providing essential habitat for juvenile and adult fisheries species, ducks, and other hunted species; and potential revenue raising functions such as nutrient and carbon sequestration.[6,7,8,9] The 2012 Master Plan for coastal Louisiana focuses both on structural or engineered protection and restoration.[10] Ecosystem-based approaches that can restore or enhance intact natural ecosystems such as barrier islands, marshes, mangrove stands, aquatic vegetation, oyster reefs, and forested wetlands are an important component of current restoration efforts.[11,12] These approaches can be cost effective and often provide increased ecosystem services over time, with minimal maintenance or replacement costs.[13] Ecosystem-based approaches also provide additional protection that has the potential to enhance community resilience in some of the most vulnerable parishes where hard structural protection options aren't feasible due to local conditions or cost.[14]

HOW TO USE THIS REPORT

This report is specifically designed to assist in the integration of formal technical scientific knowledge with accumulated traditional knowledge and experience to identify sites and options for ecosystem restoration to build community resilience. For this reason, the report contains citations from peer reviewed literature alongside insights, quotations, and maps from residents and community members, many of whom have spent their entire lives living and working in the changing habitats of coastal Louisiana. To assist in synthesizing the wealth of information available on the functions, threats, and potential restoration options for coastal Louisiana, the information was divided into seven major habitat types across the coast which have been color-coded throughout in diagrams, maps, and tables. Two communities were approached to provide examples of linkages between community and formal scientific knowledge, applied within a local context.

THREATS TO COASTAL HABITATS INCREASE VULNERABILITY OF
COMMUNITIES

MULTIPLE THREATS TO HABITATS

The Mississippi River delta and the Chenier Plain, that make up coastal Louisiana, are naturally dynamic areas that have undergone many changes with movements of the mouth of the Mississippi River over the past eight thousand years.[15] However, the past decades have seen very high rates of land loss and rapid transitions of habitat types as a result of rapid relative sea level rise from land subsidence and climate change, saltwater intrusion, reduced sediment flow, increasing eutrophication, large storm events, and habitat clearing and alteration due to infrastructure development along the coast.

STORMS

Coastal Louisiana commonly has mild winters, meaning storm impacts are dominated by tropical storms and hurricanes.[16,17] The largest impact of Louisiana's hurricanes is the associated storm surge which floods coastal ecosystems.[16,17,18] Storm waves and wind also heavily erode coastal habitats[19] including inshore freshwater marshes.[17,20]

SEA LEVEL RISE

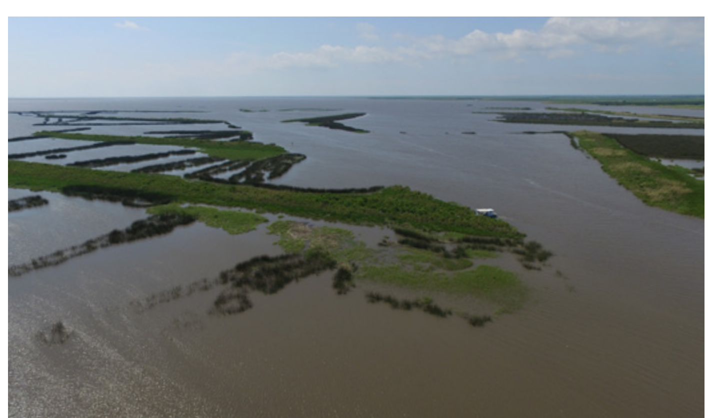
Relative sea level rise (RSLR) incorporates not only the rising ocean levels but the subsiding (sinking) land which is happening rapidly in deltaic Louisiana.[21] Coastal habitats that cannot accrete sediment and build land at least at the same rate as relative sea level rise will continue to deteriorate and become open water.[11,18,21]

HABITAT ALTERATION

Anthropogenic alteration and conversion of wetlands to other land uses has been occurring for centuries along the Louisiana coast for agriculture, coastal infrastructure, and flood protection.[11,18] Clearing and development of wetlands and subsequent protective actions can result in the reduced connectivity of the marsh, for example, reducing river flow over the marshes which has resulted in lower rates of sediment accretion.[11] Canal dredging impacts marshes by expanding storm surge effects, altering water flow and drainage, and increasing saltwater intrusion.[11,22]

"All agricultural lands are being sold for commercial development. The families cannot keep up anymore, not with the floods, drought, and costs. The way of life is too hard of work for most."

Delcambre workshop participant, April 2016



Top: Home in St. Bernard, damaged by hurricanes in 2005;

Middle: Erosion of marshes in Breton Sound;

Bottom: Habitat alteration in Vermilion Bay.

THREATS TO HABITATS IN COASTAL LOUISIANA*

Category	Threat	FORESTED WETLANDS	MARSH	AQUATIC VEGETATION	OYSTER REEFS	OPEN WATER	MANGROVE STANDS	BARRIER ISLAND COMPLEX
Climate change	Relative sea level rise	23, 24, 25, 26	19, 27, 6, 16, 28	6, 29	16, 30		16, 31, 32, 33	16, 34, 35
	Ocean acidification							
	Changes to rainfall patterns and cold-temperature stress			29			36	35
	Salination and tree death	23, 24, 25, 26, 37, 38						
Natural events	Hurricanes, storms, and high energy events	24	16, 19, 27, 39, 40	29	16, 30, 41		16, 42	16, 34, 35, 43, 44
	Fire	45	40					
Habitat alteration	Groundwater extraction accelerates subsidence and coastal structure, hard stabilization		16, 46					46
	Channelization, canals, backfilled canals, and fragmentation	24, 25, 45, 47, 48, 49	6, 11, 16, 19, 22, 27, 39		16	16, 22		107
	Reduced sediment delivery from Mississippi	25	11,27				31‡	16
	Agricultural and urban expansion, industrial development, solid structures	45, 47, 48	6, 11,16, 39, 46				6‡, 16	46, 50, 51
	Hydrologic alteration							
	Changes to flooding frequency	23, 24, 25, 26, 48, 49					32, 33, 52	
	Dredging		11, 22, 40	22, 29	16, 30, 43	22, 53		
	Vessel disturbance							
Pollutants	Pollution from vessels and communities, oil and gas extraction, oil spills	25	11, 22, 27, 40					50, 51
	Wastewater and septic inputs results in eutrophication/water quality		6, 16	6, 29, 54	30, 55	16, 29, 56		
	High algae cover and fouling of oyster reefs by competitors such as boring sponges				30, 57			
Pest species	Introduced species		6, 16			16		
	Invasive animals and plants, e.g., nutria, hogs	23, 25, 58	16, 28, 40					51
	Herbivory or predators	23, 25	6, 28, 40		30, 41, 55, 57, 59			35
	Disease	58‡			16, 30, 41			35
Over-exploitation	Clearing and unsustainable harvest of trees	24, 25, 45, 47, 48		6			6‡, 31‡	
	Overexploitation of natural resources e.g., crayfish, overfishing							

* Numbers = citations ‡ Citation not from Louisiana

A NOVEL APPROACH

INTEGRATING SCIENTIFIC & TRADITIONAL KNOWLEDGE

Developing syntheses across audiences and management perspectives can help to achieve consensus on solutions to the challenges of ecosystem change.[60,61] This project used two approaches: firstly a science synthesis workshop that used conceptual diagrams of different habitats to combine the technical knowledge of social and natural scientists to synthesize current understanding of community vulnerability and its linkages to ecosystem functions and ecosystem services for each habitat.[61] Secondly, community workshops that relied on participatory mapping to assess "traditional ecological knowledge" within coastal communities, building on conceptual diagrams developed during the science synthesis workshop were carried out.[61] The results of both technical scientific and community workshops are highlighted throughout the report.

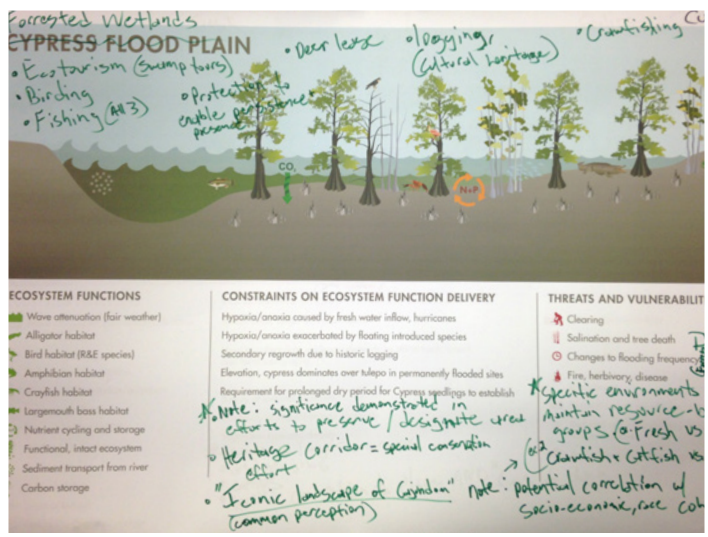
SOCIAL & ECOSYSTEM SCIENCE WORKSHOP

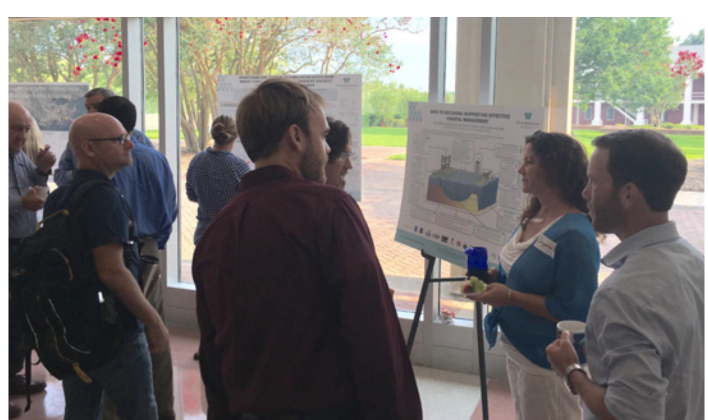
In October 2015, a one-day technical scientific workshop included 44 natural and social scientists with expertise in the diverse ecologies, economies, and socio-cultural histories of coastal Louisiana. The workshop focused on gathering information on the ecological and socio-cultural functions, constraints, and values of seven coastal habitats: forested wetlands, marsh, aquatic vegetation, oyster reefs, open water, mangrove stands, and barrier island complex. Information from the workshop is synthesized in the coastal habitat sections.

The workshop also provided a valuable opportunity for cross-disciplinary exchange. In a follow-up survey, several participants acknowledged that cross-disciplinary conversations help to pull science "out of silos," recontextualizing ecological restoration projects within the context of how they "affect people and communities, and not just as things made of sediment, water, plants, and animals" *(Science workshop participant, October 2015).*

"The benefits of this type of workshop are that scientists from many disciplines share multiple perspectives and work off each other's knowledge to better inform potential action."

Social + ecosystem science workshop participant, October 2015





Workshop to gather information on ecosystem functions and ecosystem services of seven coastal ecosystems (top + bottom); Example input from natural and social scientists on each coastal ecosystem (middle).

Participatory mapping workshops in Delcambre (top + middle) and in St. Bernard (bottom).

COMMUNITY WORKSHOPS & PARTICIPATORY MAPPING

In spring 2016, four community and participatory mapping workshops were conducted in two coastal communities: Delcambre (Iberia/Vermilion Parish) and St. Bernard (St. Bernard Parish). Approximately 60 participants from each community were engaged in these workshops, and data was collected through facilitated small group discussions and participatory mapping exercises.

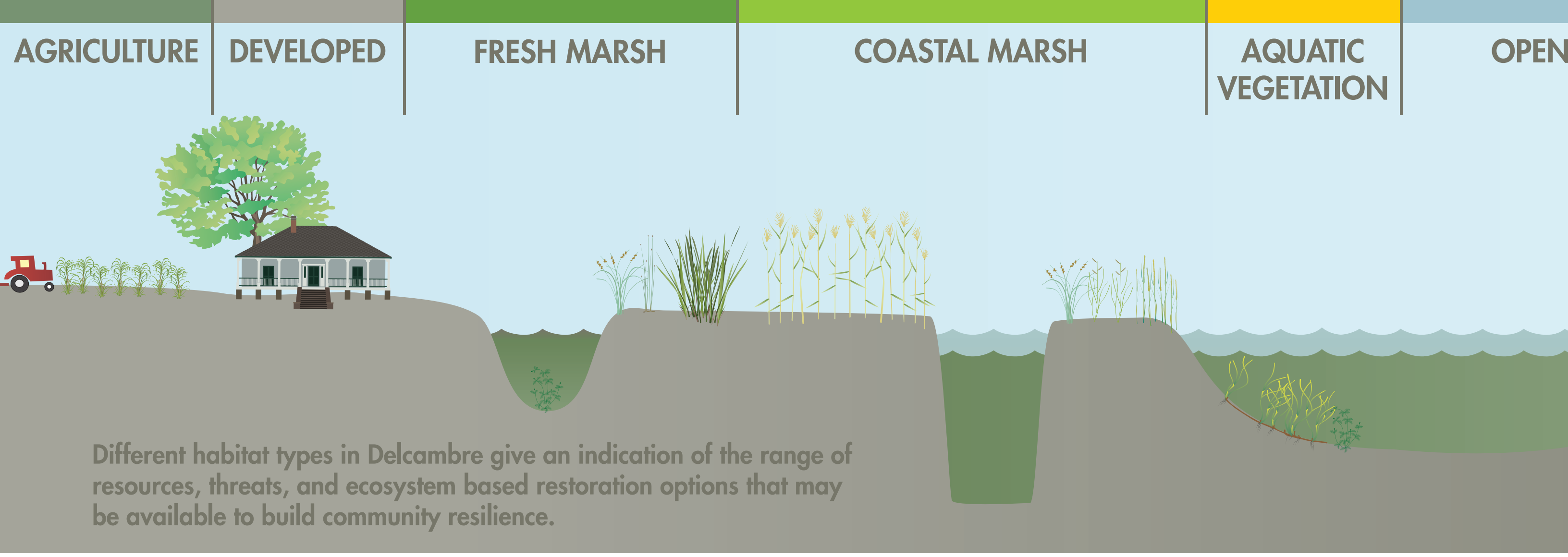
Small group meetings provided the opportunity for in-depth discussion with residents about the meaning and possible protection functions of different coastal ecosystems in addition to mapping places of value and risk. Mapping tables set up at the Delcambre Seafood and Farmer's Market and at the Sippin' on the Bayou Festival in St. Bernard further facilitated input by an audience from the immediate area and the wider coastal region, capturing input on ecosystem services and mapping places of value and risk from a diverse range of participants.

Participatory mapping is a technique that encourages participants to identify areas and places of value that are not readily identifiable through traditional quantitative and cartographic methods.[62,63] For the two communities, this included public facilities such as schools, roadways, and levees, as well as more personalized locations such as family lands, fishing grounds, or other places with specific social and cultural values.

Hand drawn features were integrated into ArcGIS to create eight "hotspot" maps of values and threats (see pages 10–17). This method is a powerful way to integrate qualitative input into quantitative data sets that can support understanding and decision making in regard to coastal restoration and protection. Workshops were also audio recorded with participants' consent, transcribed, and coded to locate frequency, cross-coding, and context within the community workshops. This multi-method approach can ground outputs in the experiences and voices of specific coastal communities.

"We've been through community meetings before…it all falls on deaf ears and goes by the wayside the next day. We are so fed up we don't even want to come to these things. We need to do something with this information that you are going to get."

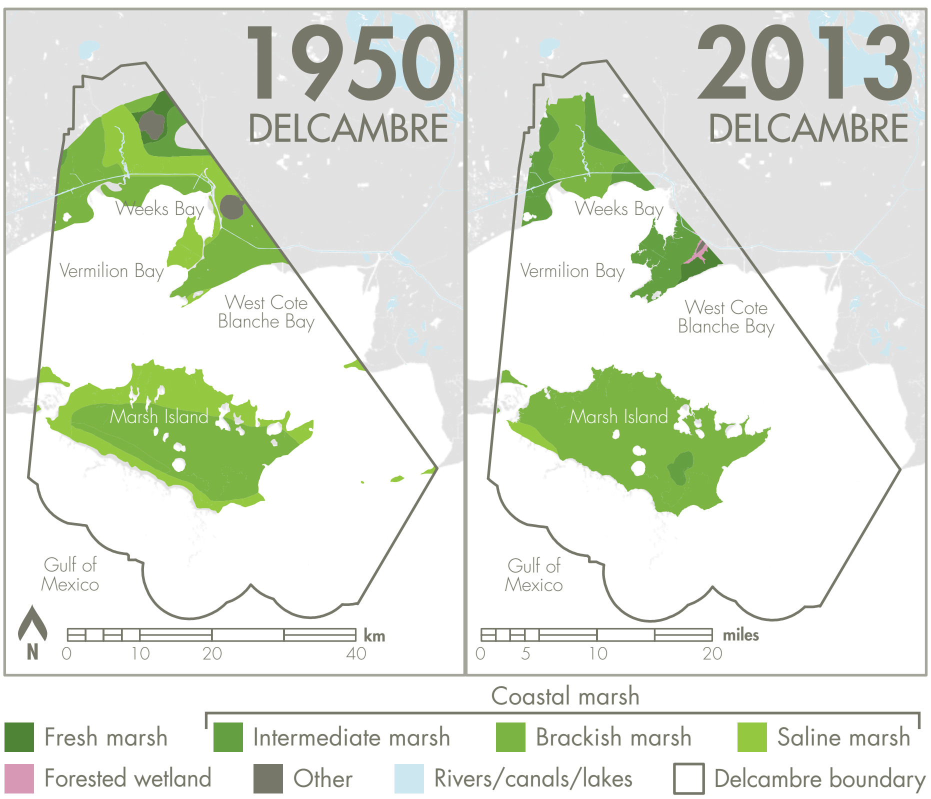
St. Bernard workshop participant, May 2016



Different habitat types in Delcambre give an indication of the range of resources, threats, and ecosystem based restoration options that may be available to build community resilience.

GATEWAY TO ACADIANA

DELCAMBRE



Wetland types directly accessible to the Delcambre community in 1950 and 2013.

> *"I've lived in Delcambre for 54 years, and was in a boat by the time I was 3 months old. I was raised on the bayou, and I've seen a lot of changes. It worries me that when I was younger the bayou was full of shrimp boats and now there are none."*
>
> *Delcambre workshop participant, April 2016*

The town of Delcambre is located in south central Louisiana, west of the Atchafalaya River and north of Vermilion Bay, and has a long history connected to coastal habitats. The diagram above is a conceptualization of the coastal habitats from Delcambre down through Vermilion Bay, shown in the maps to the left. Crossing several habitats (each color coded), the maps show the coastal marshes becoming fresher between 1950 and 2013.

For the community mapping workshops in Delcambre, the local port director and Sea Grant Extension agent assisted in engaging a diverse cross-section of residents from the area. Through facilitated conversations and mapping exercises at two events in Delcambre in April and May 2016, we spoke directly with approximately 60 residents who told us how they use the local environment, what they feel are the greatest threats to their communities, and what prospects for ecological restoration and building community resilience they find most relevant.

The town has recently rebuilt much of its local infrastructure and housing after damage from Hurricane Rita in 2005, and Hurricane Ike in 2008. As of 2016, it is home to approximately 1,800 residents and a recovering seafood

industry encompassing two shrimp processing plants and a rebounding group of local commercial fishermen and shrimpers. Many of the residents trace their roots to the Cajun traditions of Acadiana and the industries that sustained them, including: commercial fishing, agriculture (rice, sugar cane, and soy), cattle raising, crawfish farming, trapping, and the oil and gas industry. This region is more recently home to a growing community of southeast Asian and Latino immigrants who work and live among generations of Cajun communities.

Delcambre is situated between what was historically bottomland hardwood forest and the beginnings of freshwater marsh. The Delcambre Canal runs through the middle of town, connecting Vermilion Bay and the Gulf of Mexico to the inland communities of the region. Commercial and recreational boats are kept along this main waterway. The most prevalent concern for residents was the threat of another storm surge like the one experienced in 2005 during Hurricane Rita. That hurricane brought a seven meter (23 feet) storm surge into areas surrounding Delcambre and Vermilion Bay, destroying almost all of the structures in Delcambre and rendering much of the public infrastructure, such as schools, unusable.

Top: Buying fresh shrimp at the Delcambre market;

Middle: Many Delcambre residents trace their roots to the Cajun traditions of Acadiana;

Bottom: Delcambre Shrimp Festival Queens.

DELCAMBRE

CIVIC FACILITIES & FAMILY HOMES

Reflecting the resident's experiences during the aftermath of Hurricane Rita in 2005, the areas of highest value for participants were public facilities and private homes. The closing of local schools, the loss of family homes and camps, and the destruction of critical amenities such as the local grocery store after Hurricane Rita were consistently discussed among residents. These structures are a priority for protection as they are perceived as important in making Delcambre a desirable place to live as well as appealing to visitors from around Louisiana and the rest of the country. Delcambre's rebuilding efforts have focused on building public facilities and spaces, such as the Port of Delcambre and public boat launches, and plans to rebuild the town's only grocery store are currently underway.

VERMILION BAY

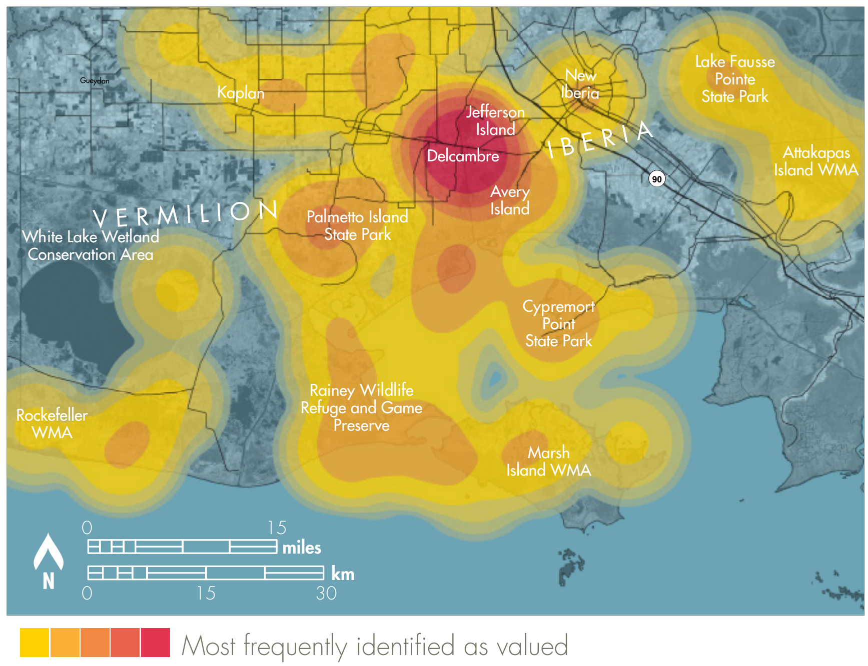
Vermilion Bay is highly valued by local residents, as it provides opportunities for fishing, recreation, and family trips. Southwest Pass connects the bay to the Gulf of Mexico, which provides access for boats in the smaller bayous and the Gulf Intracoastal Waterway in south Vermilion Parish to open water. Numerous family camps are located in proximity to Vermilion Bay, resulting in historical connections and memories of growing up on the water, learning to fish, crab, and hunt, and spending time with family.

JEFFERSON & AVERY ISLANDS

Avery Island, famous for the McIlhenny family that owns the Tabasco hot sauce factory and Jungle Gardens onsite, and Jefferson Island, are both located on salt domes that characterize the geology of this section of the Louisiana coast. They are named islands due to their relatively high elevation, becoming "islands" during extreme high tides or flooding conditions. Neither of these sites are active salt mines today, but both are thriving recreational areas that draw tourists and locals alike. With sprawling gardens, a lake, restaurant, and bed & breakfast, these "islands" are host to weddings, family gatherings, and destinations for visitors and locals alike.

"Sometimes we go fishing or boating around in Vermilion Bay…you eat the fish that folks come in with…shrimping, crabbing….in the Intracoastal we get a lot of travelers and they stop in Delcambre as a destination…we get people from all over… tourism and ecotourism…."

Delcambre workshop participant, April 2016



Top: Hotspots of community-identified places of value, indicated by Delcambre residents during two workshops in spring 2016.

Bottom: People lining up to buy shrimp and other seafood at the Delcambre fish market.

COMMUNITY IDENTIFIED THREATS & CHALLENGES
DELCAMBRE

NUISANCE FLOODING

Delcambre is not protected by any federal or local levee system. Storm surges and strong south winds often push water into Delcambre and adjacent agricultural lands via the Delcambre canal. This creates a situation where roads become impassable and saltwater intrusion destroys agricultural lands. Surface flooding from high rainfall events is also problematic.

CIVIC INFRASTRUCTURE CLOSURES

Prolonged rainfall from hurricanes and tropical storms also induce flooding that can shut down highways, public schools, grocery stores, and government complexes, creating logistical obstacles for communities attempting to organize rebuilding after environmental disturbances.

COASTAL EROSION

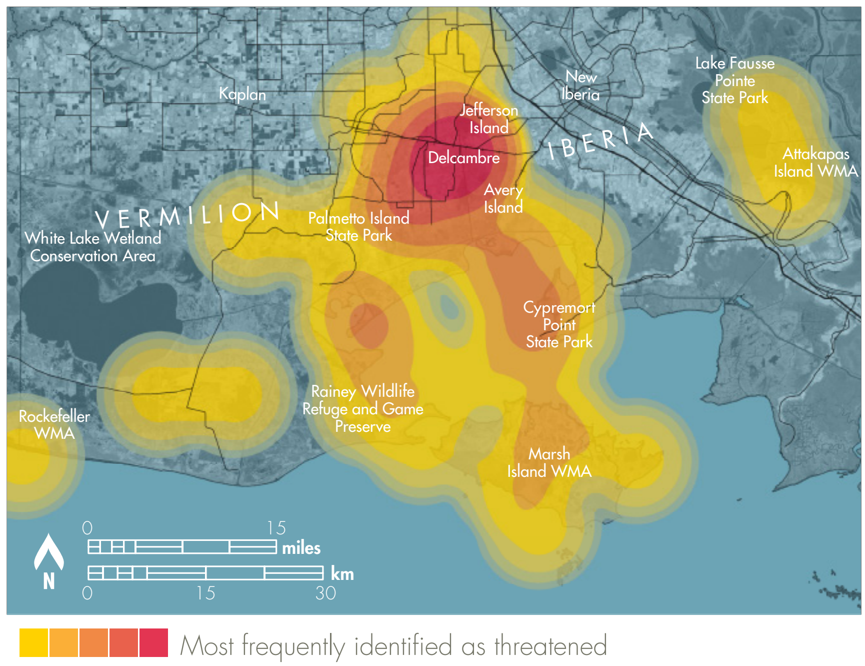
Land loss and the disappearing coast were also noted—through erosion and subsidence—as making the community more vulnerable to powerful storms from the Gulf. Community members have seen marshlands disappear, channels widen, and fisheries change, due to the transformation of the local coastline and the changing salinity of coastal waters. The potential threat imposed by predictions of future sea level rise were also of concern for several residents.

CHANGING ECONOMIES

One of the most significant barriers to creating community resilience for residents is the changing economy. Of particular concern was the decrease of family farms and agriculture and the downturn of local commercial fishing and shrimping in the region due to changes in global seafood markets. The loss of local jobs has translated into younger generations moving away from Delcambre and the gradual depopulation of the area.

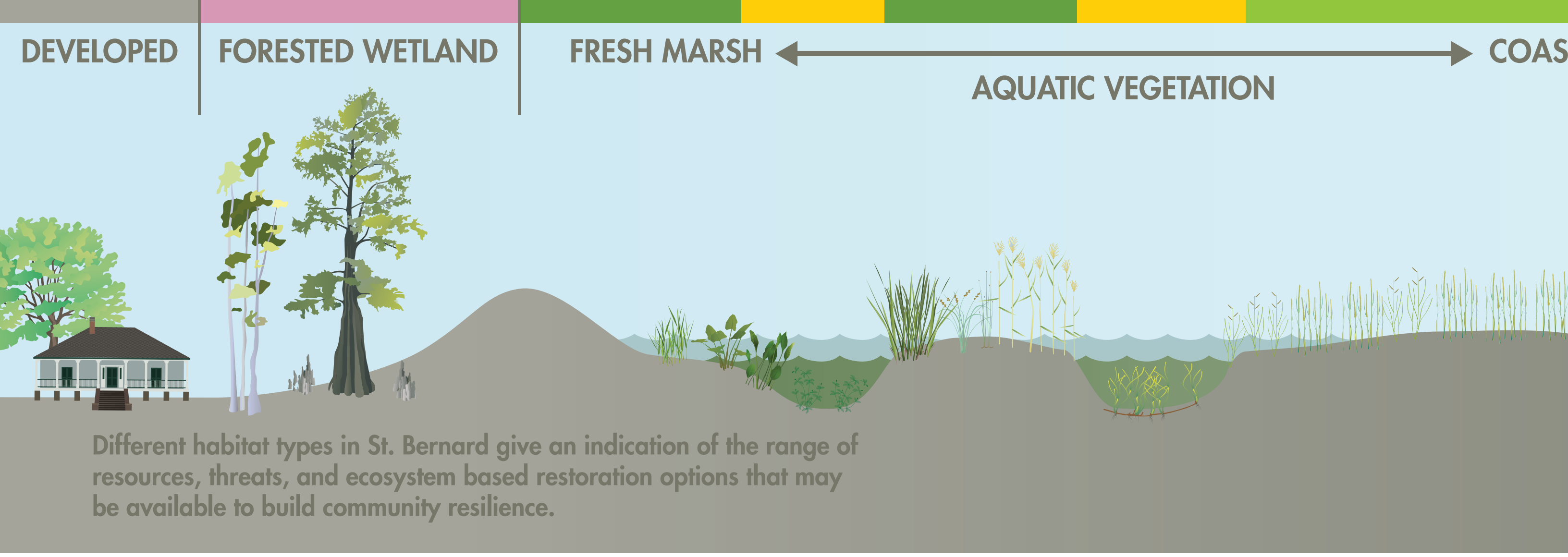
"Storm surge comes up Bayou Tigre and up the canal and up and down the town roads. Rita was a tidal wave. Ike was a gradual rise. I remember picking up people on roofs, and the next day I took pictures with the National Guard who flew over. Afterwards I couldn't talk…"

Delcambre workshop participant, April 2016



Top: Hotspots of community identified threats and challenges, indicated by Delcambre residents during two workshops in spring 2016.

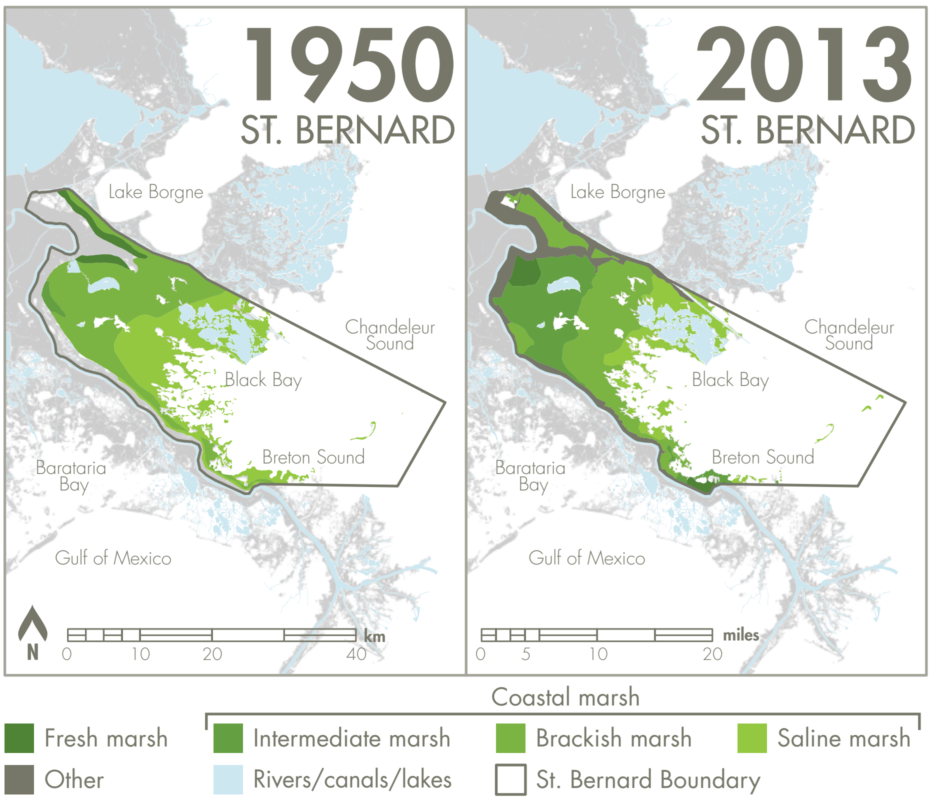
Bottom: Sandbags at Delcambre City Hall following Hurricane Rita in 2005.



Different habitat types in St. Bernard give an indication of the range of resources, threats, and ecosystem based restoration options that may be available to build community resilience.

GATEWAY TO THE GULF

ST. BERNARD



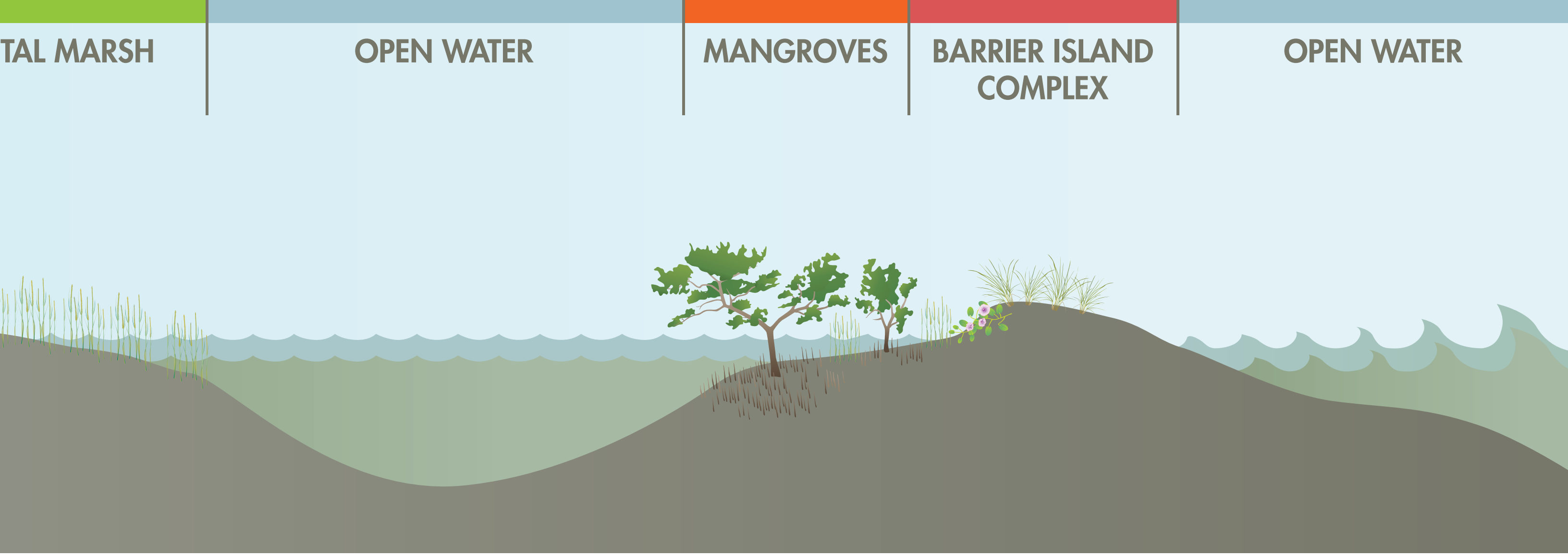
Main wetlands directly accessible to the St. Bernard community in 1950 and 2013.

"Erosion, the economy, and hurricanes have all contributed to moving people out. Delacroix used to be all family, where ancestors settled...there used to be a Native American village in Bayou La Loutre... everyone would fish in the waters."

St. Bernard workshop participant, May 2016

Approximately 30 kilometers (17 miles) east of New Orleans towards Breton Sound, east St. Bernard Parish is at the front lines of coastal land change in Louisiana. The diagram above is a conceptualization of the coastal habitats from St. Bernard down through Breton Sound, shown in the maps on the left. Crossing several habitats (each color coded), the maps show the coastal marshes becoming fresher between 1950 and 2013.

To engage residents who have fished and worked in the Breton Sound area for many years, two mapping workshops were held with assistance from the Los Isleños Culture and Heritage Society. At the invitation of a local parish council member, a participatory mapping exercise was also held to engage the wider community at a small festival in St. Bernard. Both events were held in May 2016. Approximately 60 local residents were directly engaged, including: community leaders, fishermen, and teachers. Participants spoke about specific areas within the Breton Sound estuary used by residents, observations on successful and unsuccessful restoration projects, and their reflections on the challenges of navigating the bureaucracy associated with constructing restoration and protection projects.



"We've had this place since before the flood wall came in... four generations of families... it's home."

St. Bernard workshop participant, May 2016

St. Bernard Parish has a population of residents with deep ancestral, cultural, and economic ties to the coastal marshes and bayous, and therefore has high potential to better understand the connections between socio-economic and ecological resilience. In the wake of immense damage from Hurricane Katrina in 2005, the majority of residents now live within a 100-year federal hurricane flood protection system. However, the far eastern portion of the parish—including the fishing villages of Delacroix, Ycloskey, and Hopedale—still remain outside federal flood protection. A significant commercial fishing industry still exists in the parish despite the damage incurred during hurricane Katrina, and many of the commercial fisherman have previously been engaged in efforts to advise local and state restoration projects. Despite challenges from multiple hurricanes and the Deepwater Horizon oil spill in 2010, residents of St. Bernard have a strong commitment to sustaining their culture and livelihoods, and the ecosystem that supports these.

Top: Opening of the St. Bernard fire station which was rebuilt following Hurricane Katrina;

Middle: Los Isleños Heritage and Cultural Society Museum;

Bottom: Shell Beach.

COMMUNITY IDENTIFIED PLACES OF VALUE
ST. BERNARD

FISHING VILLAGES

The fishing communities that follow the winding bayous out into the sound, including Ycloskey, Hopedale, Woodland, Delacroix, and Shell Beach, are of high socio-cultural, historic, and economic importance to the people of St. Bernard. They are home to multiple generations of subsistence and commercial fishing families, some descending from European settlers including migrants from the Spanish Canary Islands known as Isleños as well as Native American groups that have long occupied coastal areas in the Gulf South.

BRETON SOUND ESTUARY

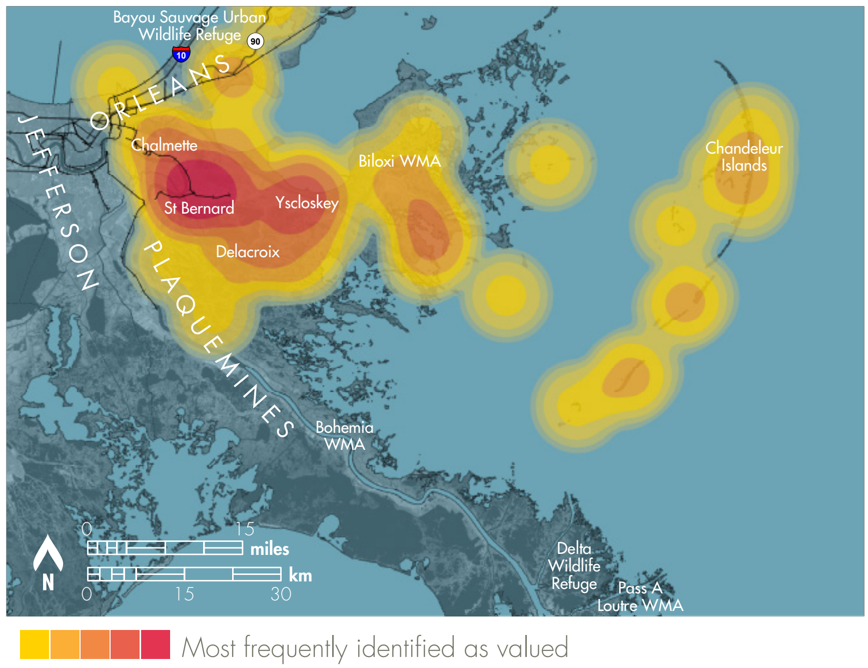
Many St. Bernard residents emphasized the ecological, economic, and historical importance of the Breton Sound estuary. Residents pointed out places where their grandparents and great-grandparents fished, trapped, or owned land, giving these places almost as much importance as their individual homes. These areas are closely tied to memories of family and cultural traditions, such as boat blessings and learning how to fish, as well as other historic sites such as Native American mounds and villages, and first settlements of European immigrants. Not all of these places are gone today, but many of them have changed or moved due to the loss of cypress and bottomland hardwood forests and alluvial ridges (forested wetland habitat) that were historically common in this area.

CHANDELEUR ISLANDS

The Chandeleur Islands were consistently identified as one of the most valuable and important places in the region. This is both due to the biophysical protection they provide (or historically provided) and the abundance of historic sites on the island chain. These sites include Native American settlements, outposts for colonial settlers, locations of sunken ships, and personal memories of shrimping, fishing, and recreating on the barrier islands. Currently encompassed within a federal wildlife management area, these islands are still used for charter fishing operations, but have been reducing in size with successive hurricanes.

"My great-grandpa owned all of Woodland…I own 80 acres here but it's 80 acres of water now…it was wetlands where my grandpa trapped and had a grocery store, bar room, and a seafood dock…right here."

St. Bernard workshop participant, May 2016



Top: Hotspots of community identified places of value, indicated by St. Bernard residents during two workshops in spring 2016.

Bottom: Aerial photo of the Chandeleur Islands in June 2001.

COMMUNITY IDENTIFIED THREATS & CHALLENGES
ST. BERNARD

UNINTENDED CONSEQUENCES OF LANDSCAPE ALTERATION

The loss of marshland resulting from human actions was a major concern for workshop participants. Several long-term residents reported changes in water flow and loss of marshes surrounding eastern St. Bernard Parish after the Mississippi River Gulf Outlet (MRGO) opened in 1965, and suggested this loss of marshland increased damage during Hurricane Katrina.

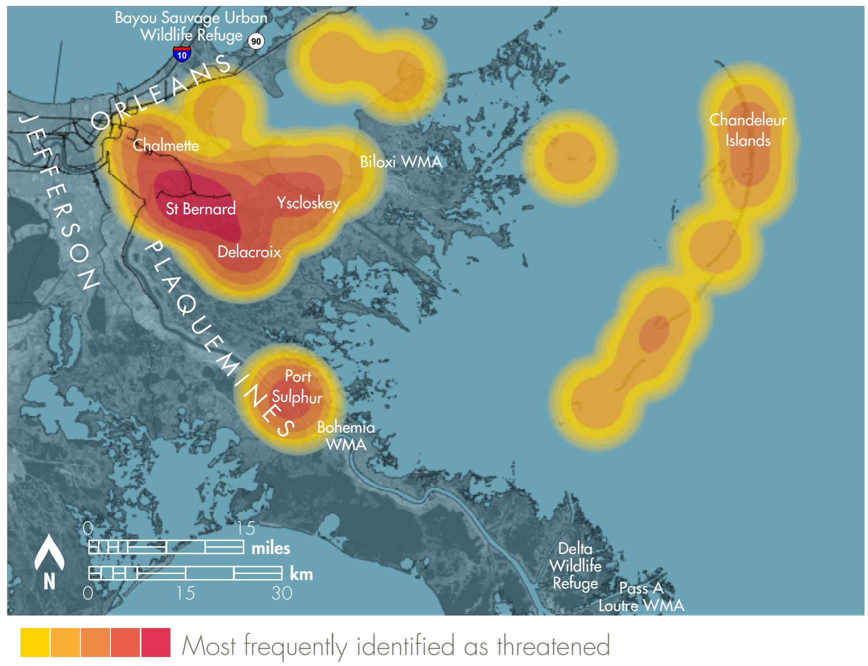
While many participants recognized the need for increased protection and restoration action, they expressed concern that the land created by freshwater and sediment diversions may be particularly vulnerable during storm events, exposing communities to greater risk of storm damage. Participants observed that the freshwater marshes built below Caernarvon Diversion (opened in 1991) were highly impacted by the hurricane winds and storm surge during Hurricane Katrina.

RESTORATION PLANNING PROCESS & PUBLIC ENGAGEMENT

Subsidence and erosion of coastal wetlands and barrier islands were acknowledged by workshop participants as the greatest threat to the region, with many noting that without restoration projects the communities of St. Bernard Parish would be increasingly vulnerable to future storm events. Recognizing this, a commonly identified challenge in St. Bernard Parish was related to the process of how restoration projects are nominated, prioritized, and selected; and where restoration efforts and funds are spent. Residents noted the challenging bureaucracy of getting projects on the ground. Overall, many residents felt fatigued, ignored, and frustrated by repetitive and ambiguous public engagement processes that left them feeling disenfranchised. New, meaningful, and actionable ways of accounting for and integrating community input into the management planning and decision making process was seen as necessary to increase local support of restoration projects.

"You lose the estuary, you lose everything that comes with it...now it's all open water, and when it's all open water you have no estuary."

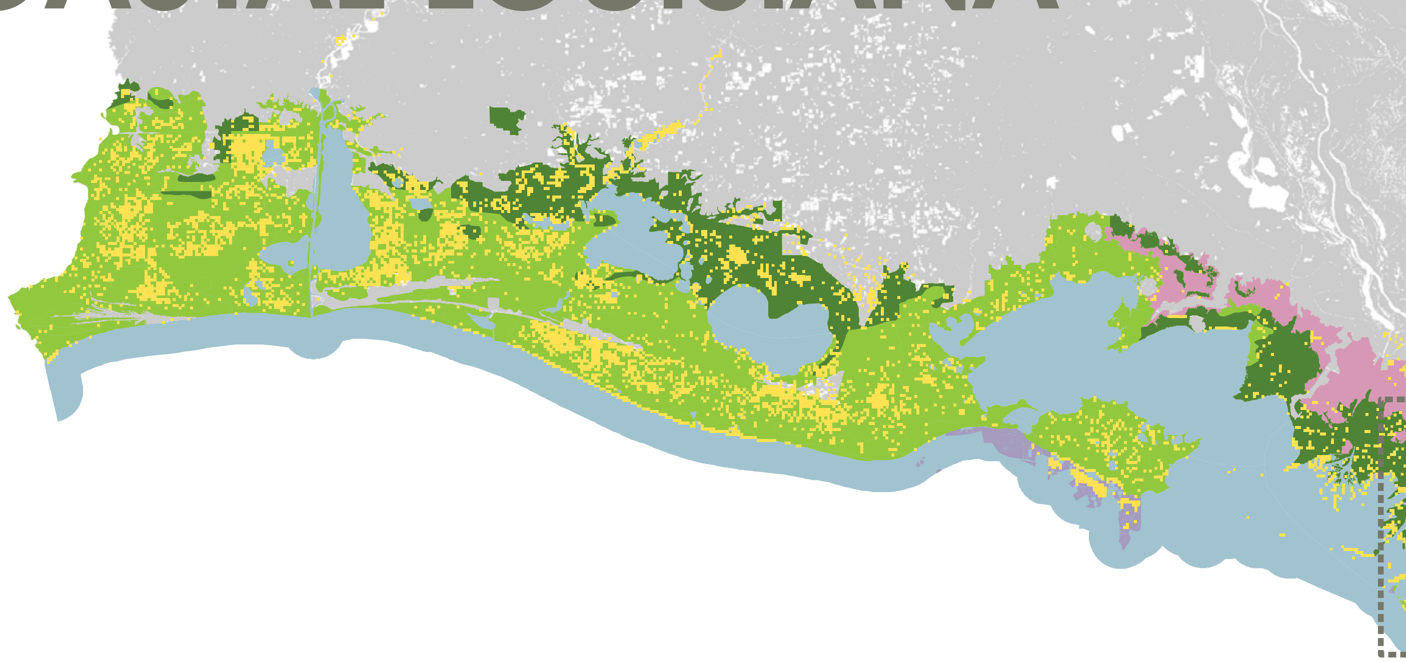
St. Bernard workshop participant, May 2016



Top: Hotspots of community identified threats and challenges, indicated by St. Bernard residents during two workshops in spring 2016.

Bottom: Junction of the Gulf Intracoastal Waterway, Mississippi River Gulf Outlet, and Inner Harbor Navigation Canal.

DIVERSE HABITATS OF COASTAL LOUISIANA



DIVERSITY OF HABITATS & ECOSYSTEM FUNCTIONS IN COASTAL LOUISIANA

Coastal Louisiana is a highly dynamic landscape and is recognized as a global hotspot of change, with multiple processes contributing to the observed rapid land loss rate of 42.9 km^2 per year (1985–2010 average).[64,65,66,67,68] The coastal area of Louisiana, including the Mississippi River Delta and the Chenier Plain, has abundant fresh and coastal wetlands, and includes 37% of the estuarine herbaceous (grass) marshes in the contiguous United States.[69] The different coastal habitats within this area support many important ecosystem functions,[70] such as: nutrient regulation, mammal and alligator production, recreation, reduction of storm effects, carbon sequestration, and nursery habitat for fish, however these ecosystem functions vary greatly between habitats.[70,71] For example, the importance of marsh habitat for fish changes depending on both the fish species and the physical structure of the marsh.[72,73,74]

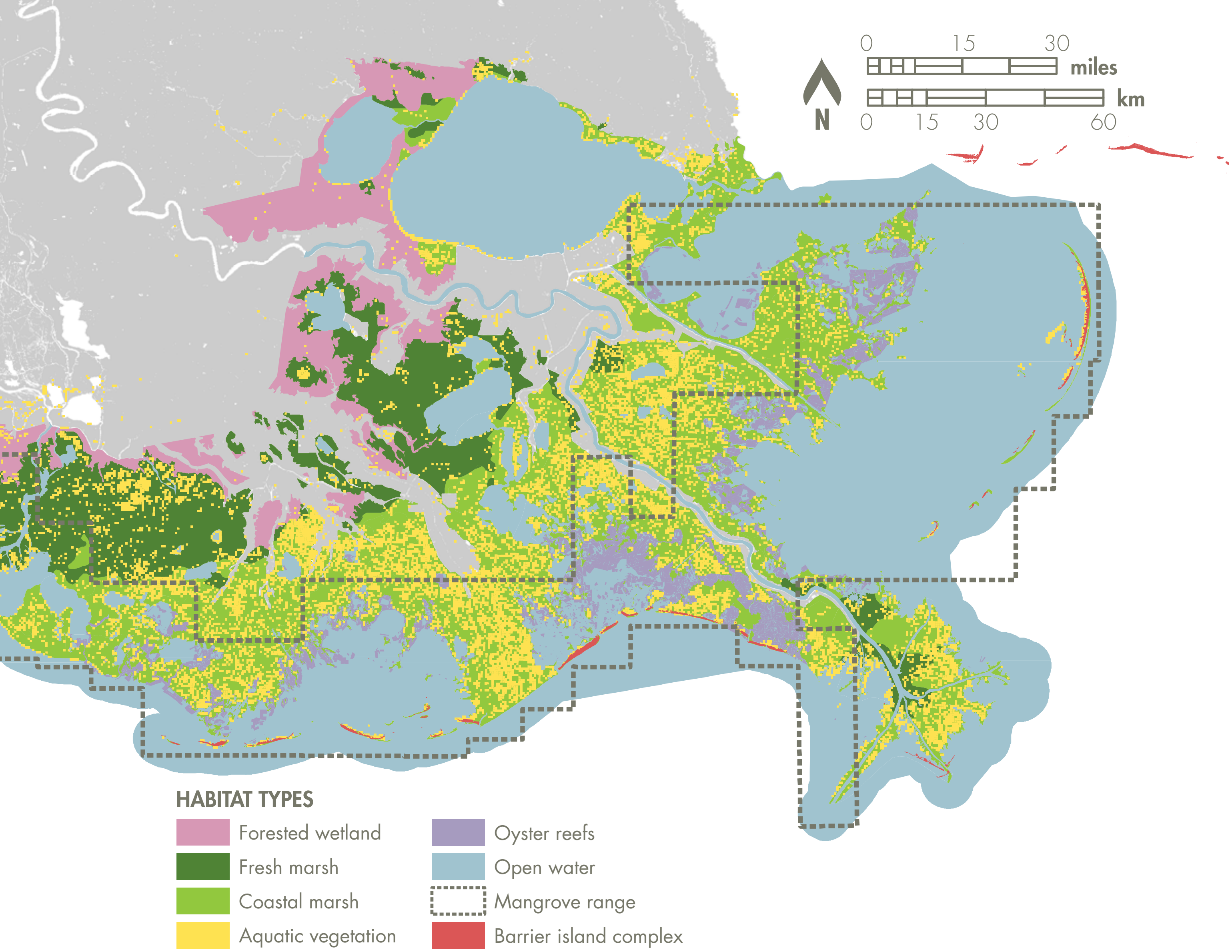
COASTAL HABITATS: A WAY TO LINK DATA, MANAGEMENT, & COMMUNITIES

The coastal area of Louisiana was classified into seven different habitats: forested wetlands (fresh), marsh, aquatic vegetation, oyster reefs, open water, mangrove stands, and barrier island complex. The following pages (pages 20–33) summarize the output of the social and ecosystem science workshop where key ecosystem functions were identified for each habitat type, and linked to protective, social/cultural, and economic ecosystem services that each habitat potentially provides to nearby communities.

Top: Marshes provide essential nursery habitat for fish and birds (ecosystem functions) which supports fishing and hunting (ecosystem services);

Bottom: Alligator production is a key ecosystem function;

Opposite page: Oyster reefs provide protective, social/cultural, and economic ecosystem services.



Restoration approaches that build key ecosystem components, referred to as "ecosystem-based restoration," were identified for each coastal habitat, along with constraints that potentially limit delivery of resulting ecosystem services reaching communities.

COMPARING ECOSYSTEM FUNCTIONS & ECOSYSTEM SERVICES

Ecosystem functions are natural processes (non-monetized), such as providing a nursery habitat for fish, that can potentially be used by communities as an ecosystem service, such as supporting a viable fishery that has both economic and socio-cultural benefits.[75] Ecosystem functions are highly dependent upon habitat type and include such features as; reduction of direct impacts of waves, storm surges and marginal erosion, the provision of essential habitat for juvenile and adult fish and shellfish species, avian and mammal species, and the storage of carbon and nutrients.[6,7,8,76] The associated ecosystem services include commercial fishing, tourism, hunting, cultural practices, recreation, water use, and transport.

"Oysters give protection for the inner land too, in addition to eating. Protection for water services and stopping erosion... and charbroiled..."

Delcambre workshop participant, April 2016

FORESTED WETLANDS

<table>
<tr><th rowspan="2">ECOSYSTEM FUNCTIONS</th><th colspan="3">ECOSYSTEM SERVICES</th></tr>
<tr><th>PROTECTIVE</th><th>SOCIAL/CULTURAL</th><th>ECONOMIC</th></tr>
<tr><td>Intact landscape and ecosystem (45,48,49)</td><td>Flood and wave protection for coastal communities and infrastructures outside of levees</td><td>Aesthetic value, cultural identity and heritage of diverse coastal communities, educational value, historical value, maintenance of fisheries and ecotourism</td><td>Provides food, jobs, and support to local communities, potential for agriculture</td></tr>
<tr><td>Reduces wave height in fair weather which protects natural ridges</td><td>Flood and wave protection for coastal communities and infrastructures outside of levees</td><td></td><td rowspan="3">Avoided cost of infrastructure damage</td></tr>
<tr><td>Vegetation reduces wind strength</td><td>Wind protection for coastal communities and infrastructures outside of levees</td><td></td></tr>
<tr><td>Stores excess waters (48,58)</td><td>Flood protection for coastal communities and infrastructures outside of levees</td><td></td></tr>
<tr><td>Sediment retention and storage from river results in land building (49,58)</td><td rowspan="2">Flood and wave protection for coastal communities and infrastructures outside of levees</td><td></td><td>Avoided cost of infrastructure damage, supports mineral and energy industry</td></tr>
<tr><td>Plant growth, organic production, land building, & carbon storage (26,48,77)</td><td></td><td>Avoided cost of infrastructure damage, timber, carbon market</td></tr>
<tr><td>Nutrient storage and cycling (48,58,77)</td><td></td><td>Maintenance of fisheries and ecotourism potential</td><td>Nutrient markets, avoided cost of poor water quality</td></tr>
<tr><td>Habitat for migratory and wading birds (23,48,49,58,78)</td><td></td><td rowspan="3">Supports hunting and ecotourism, intrinsic value</td><td rowspan="4">Provides food, jobs, and support to local communities</td></tr>
<tr><td>Habitat for alligators, snakes, turtles, and frogs (48,49)</td><td></td></tr>
<tr><td>Habitat for black bears, mink, deer, and otters (49)</td><td></td></tr>
<tr><td>Habitat for fish, crabs, crayfish, and freshwater mussels (9,23,48,49,58)</td><td></td><td>Supports commercial, recreational, and subsistence fishing</td></tr>
<tr><td>Sustainable waterways (49)</td><td></td><td>Historical value and access for recreational use, ecotourism, commercial, recreational, and subsistence fishing</td><td>International ports, jobs, and transportation</td></tr>
</table>

CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: Water level,[25,49] flow, and quality are essential in supporting intact forested wetlands that can deliver ecosystem functions. Alterations to water flow[23,24,25,48,49] can cause water stagnation and low oxygen,[26,38] as well as limiting drying to allow growth of new tree seedlings.[24] In addition, altered water flow can increase water salinity.[23] All of these changes degrade the structure of forested wetlands[24] and delivery of ecosystem functions. Other constraints include changes to forest structure due to historic logging[24,25,45,48] and hurricanes resulting in tree loss.[24]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

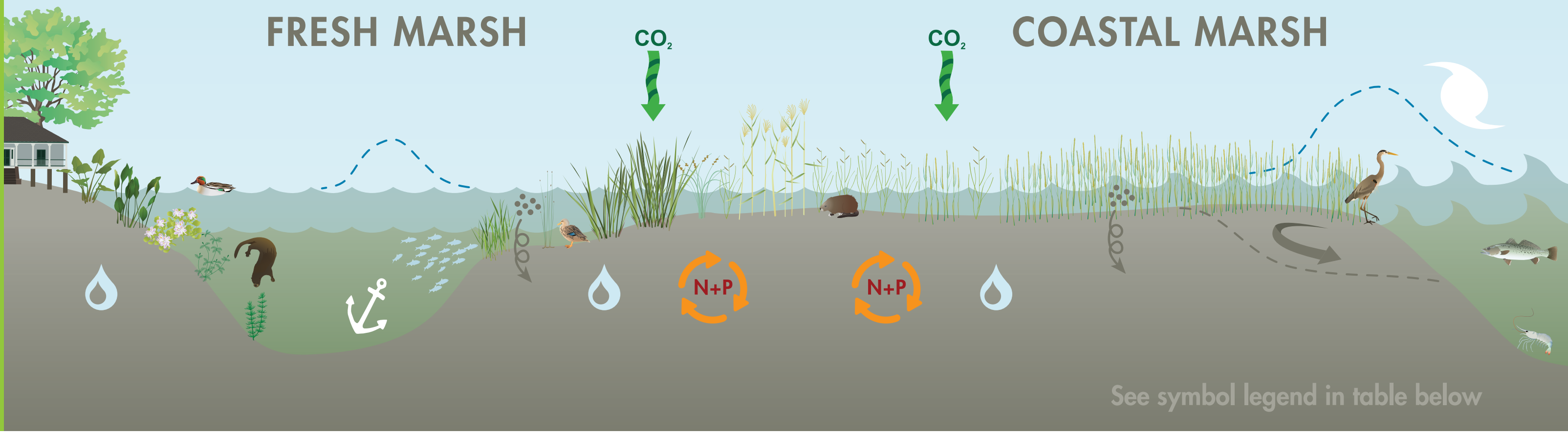
- Restore natural water flow and hydrology
- Strategic use of water control structures
- Bank and shoreline stabilization
- Replant forested wetland species e.g., cypress
- Sustainable forestry use
- Restore existing and historic ridges with clay sediments

HOW CAN RESTORATION HELP BUILD COMMUNITY RESILIENCE?

A community perspective: The maintenance and restoration of forested wetlands provides valuable storm surge and wind protection for low-lying coastal communities. They can store floodwaters from hurricanes and frequent flooding events from sustained eastern or southerly winds that periodically flood communities. Secondly, forested wetlands are deeply connected to fishing, foraging, and hunting traditions and subsistence practices that flourish with the biodiversity this ecosystem sustains. Numerous diverse coastal communities are descended from peoples who used the forested wetlands in this manner. Restoring these lands has the potential to sustain these social/cultural and economic ecosystem services and facilitate the maintenance of cultural traditions and histories that are connected to the resources of forested wetlands. Finally, many of the historic ridges that follow bayous are sites where generations of coastal families have established homes and camps. On naturally higher ground, these areas are historically and currently desirable sites to build homes for families who live off the resources of forested wetlands and surrounding marshes.

> *"Years and years ago this was a cypress freshwater swamp. Then they came in and dug the channel, letting all the saltwater in, saltwater that killed all the cypress and oak trees. The whole system changed from forested wetlands to a brackish marsh."*
>
> *St. Bernard workshop participant, May 2016*

MARSH



ECOSYSTEM FUNCTIONS	ECOSYSTEM SERVICES: PROTECTIVE	ECOSYSTEM SERVICES: SOCIAL/CULTURAL	ECOSYSTEM SERVICES: ECONOMIC
Intact landscape and ecosystem (11,27,39,79)	Flood and wave protection for coastal communities and infrastructures	Historic and cultural value for diverse coastal communities, aesthetic value, educational value, supports tourism and ecotourism	Provides food and jobs for local communities; sustains commercial fishing, hunting, and ecotourism; supports onshore and offshore natural resource extraction and economies
Reduces wave height in fair weather and storm conditions which protects interior marshes (6,18,19,27,39,79,80,81,82)	Flood and wave protection for coastal communities and infrastructures		Avoided cost of infrastructure damage, supports mineral and energy industry
Surge reduction protects interior marshes (6,18,19,27,39,79,81,82)			
Reduced shoreline erosion (6,27,39,79)			
Increased sedimentation and accretion results in land building (27,39)			
Increased infiltration/ temporary water storage (27,39,83)	Flood protection for coastal communities		Avoided cost of infrastructure damage
Plant growth, organic production, land building, and carbon storage (6,27,84,85)	Flood and wave protection for coastal communities and infrastructures		Avoided cost of infrastructure damage, carbon market
Nutrient storage and cycling (6,27,40,84,85)		Healthy fisheries and good water quality	Nutrient markets, avoided cost of poor water quality
Nursery habitat for juvenile fish, alligators, snakes, shrimp, blue crab (6,11,16,27,53,56,79)		Supports commercial, recreational, and subsistence fishing, hunting, and ecotourism	Provides food, jobs, and support to local communities
Habitat for wetland birds, migratory birds, and waterfowl (11,16,27)		Supports hunting and ecotourism	
Sustainable waterways (6,27,39)		Historical value and access for recreational use, ecotourism, commercial, recreational, and subsistence fishing	International ports, jobs, and transportation

CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: Marshes within coastal Louisiana are not uniform: there are large differences in physical structure and dominant plant species of fresh, intermediate, brackish and saline marshes,[86,87,88,89] which results in large differences in the ecosystem functions provided by these different marsh types. In this document, coastal marshes includes intermediate, brackish, and saline marshes. Reduced sediment delivery to large areas of these marshes has resulted in increased marsh loss.[27] Hurricanes directly damage marsh,[16,19,27,39,40] and both the track and strength of storms has a large influence on how effective marsh areas are in providing wave and surge attenuation.[19,39]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

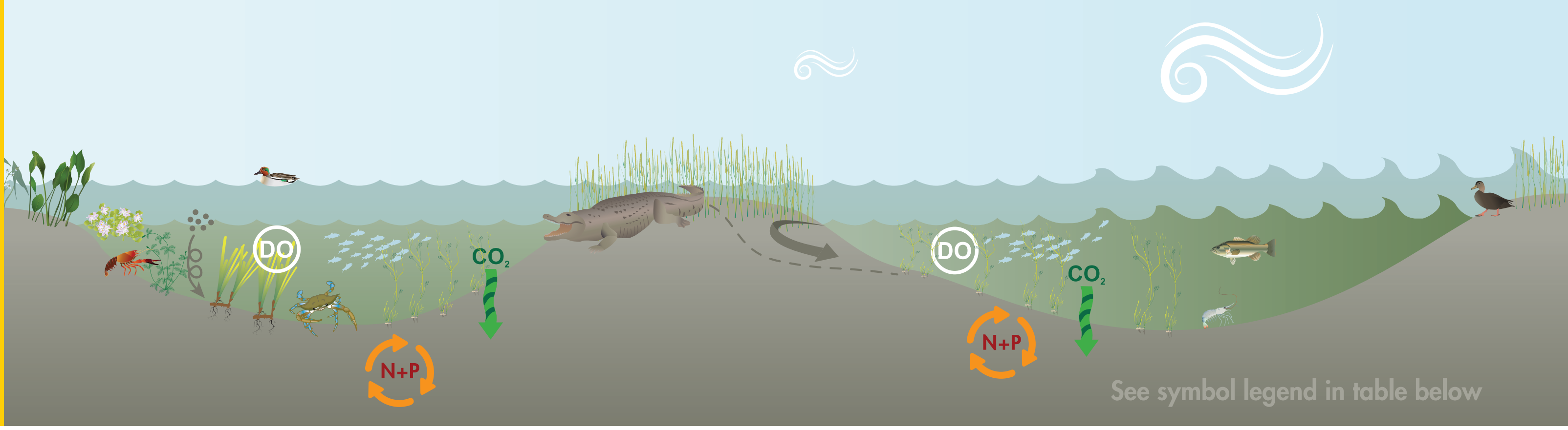
- Plant vegetation
- Restore ridge and bayou
- Long-term maintenance of restoration and planting projects
- Sediment and river diversions
- Terracing
- Dredging
- Remove nutria and hogs
- Stop shoreline erosion using fences and Christmas trees
- Backfill canals
- Invasive plant control

HOW CAN RESTORATION HELP BUILD COMMUNITY RESILIENCE?

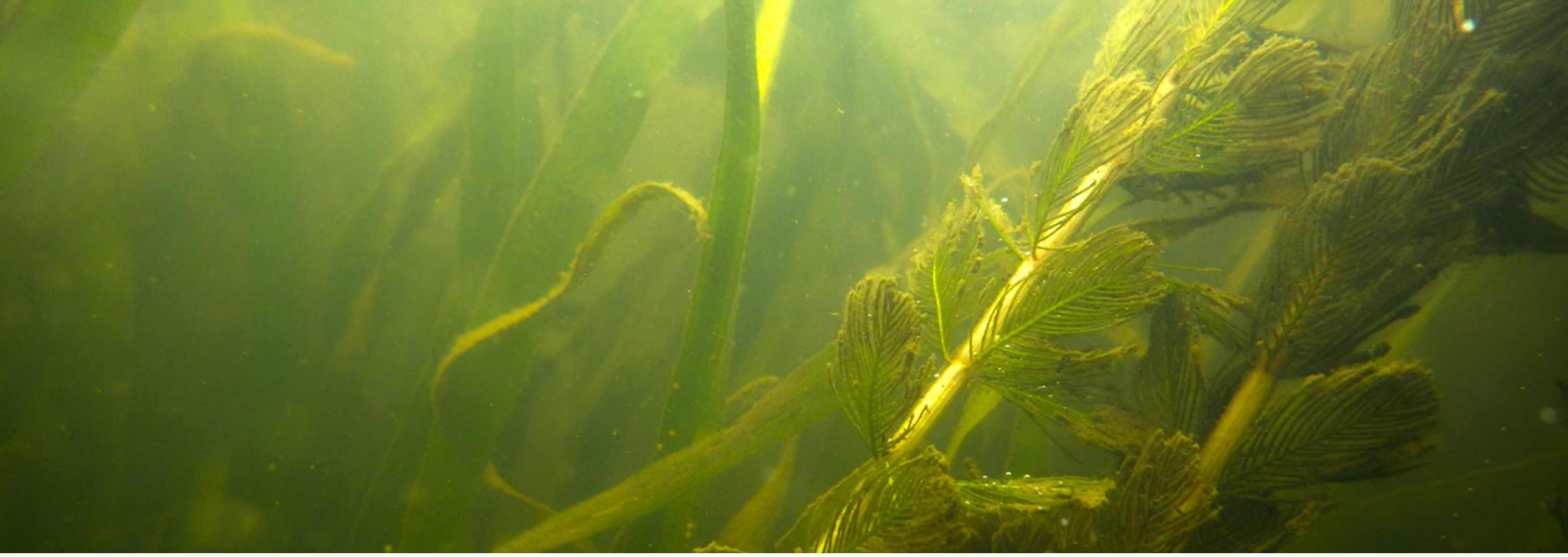
A community perspective: Coastal marshes are the backbone of social-cultural, economic, and physical resilience in coastal Louisiana. For many, the marsh is simply "home." The range of marsh ecosystems in Louisiana support diverse cultural traditions and economies directly tied to the range of fresh to saltwater coastal marshes. Fishing, hunting, shrimping, and foraging in these landscapes have provided sources of income, sustenance, and recreation for Louisianans for multiple generations with histories that easily predate the establishment of the state of Louisiana. Many community members would like to continue these traditions that marsh restoration could potentially sustain. Different marsh landscapes also provide significant protection as buffers between community settlements and hurricane storm surge and wind damage. There is agreement between residents and policy makers that these marshes are important for the protection and sustainability of coastal communities.

> *"If we rebuild the coastal marsh…the more we have out there, the more protection we have here. That is the whole reason we are flooding more…because the coastal marsh is gone."*
>
> *Delcambre workshop participant, April 2016*

AQUATIC VEGETATION



ECOSYSTEM FUNCTIONS	ECOSYSTEM SERVICES: PROTECTIVE	SOCIAL/CULTURAL	ECONOMIC
Intact landscape and ecosystem (29)	Stabilizes adjacent marsh	Maintenance of fisheries and ecotourism potential	Provides food, jobs, and support to local communities
Stabilize sediment (6,29,80)	Stabilizes adjacent marsh		Avoided cost of marsh loss, supports mineral and energy industry
Increased sediment deposition (6,29)			
Reduced wind fetch reduces shoreline erosion (6,29)			Reduces threat of marsh loss
Plant growth, organic production, land building, & carbon storage (6,90,91)			Carbon market
Nutrient storage and cycling (6,29)			Nutrient markets, avoided cost of poor water quality
Increased dissolved oxygen (29)		Maintenance of fisheries and ecotourism potential	Avoided cost of lost fisheries
Nursery habitat for fish (6,29,54,72,91,92)		Supports commercial, recreational, and subsistence fishing, and ecotourism	Provides food, jobs, and support to local communities
Habitat and food for waterfowl (29,54,91)		Supports hunting	
Supports invertebrate and vertebrate growth within the habitat and in adjacent areas (29,91,92)		Supports commercial, recreational, and subsistence fishing, and ecotourism	



CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: Submerged aquatic vegetation is often patchy and varies from winter to summer and from year to year.[29] It can also only grow in shallow and protected areas of water. Hurricanes and storms can remove aquatic vegetation and they are susceptible to poor water quality, such as reductions in oxygen. Different aquatic plants provide different ecosystem functions[29] and the distribution of these species is influenced by: water salinity, nutrient content of the water, sediment type, and amount of fair weather disturbance.[29]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

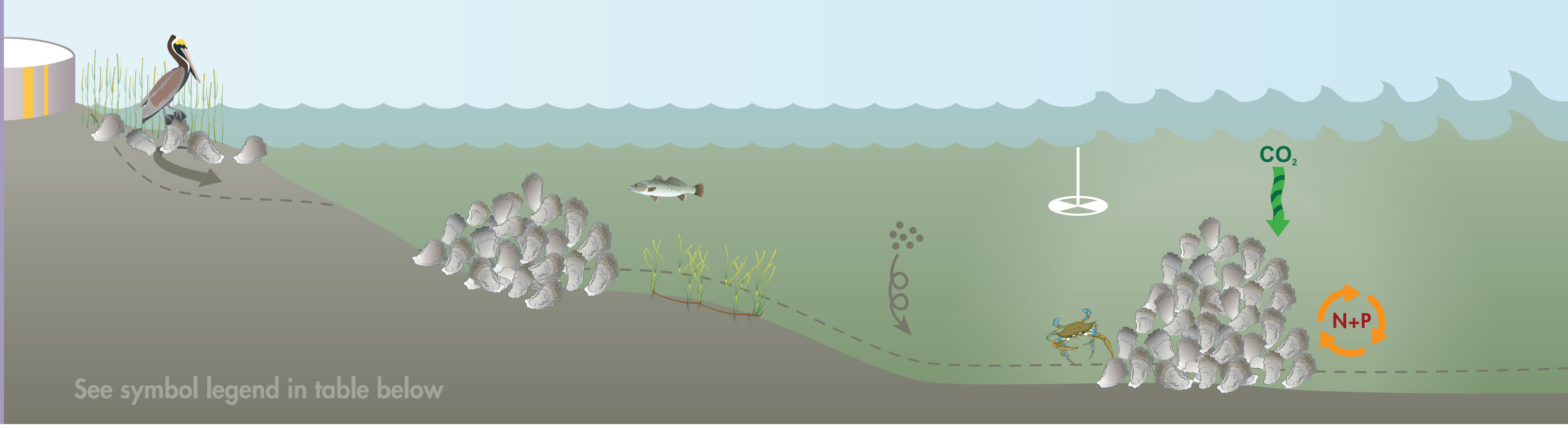
- Terracing
- Seed spreading
- Replant seagrasses (plants and rhizomes)
- Restore upstream marsh habitat
- Sediment and river diversions
- Best management practices—streams
- Establish oyster reefs or other protection from waves
- Improve water quality

HOW CAN RESTORATION HELP BUILD COMMUNITY RESILIENCE?

A technical perspective: Numerous coastal communities rely upon aquatic vegetation which provides nursery habitat for commercial and recreational fishery species as an ecosystem function. While aquatic vegetation is not always at the forefront of conversations about community resilience and restoration, they are vital to sustain key ecosystem functions and the associated economies and cultures of adjacent communities. In a changing coastline with increasing marsh fragmentation,[93] submerged aquatic vegetation growing in newly created shallow water areas has the potential to maintain the important nursery habitat function of marsh edges.[94]

> ***"The marsh are good nurseries for fish. The wetlands also clean the water —natural filtration, natural pollution removal."***
>
> *Delcambre workshop participant, April 2016*

OYSTER REEFS



ECOSYSTEM FUNCTIONS / ECOSYSTEM SERVICES

ECOSYSTEM FUNCTIONS	PROTECTIVE	SOCIAL/CULTURAL	ECONOMIC
Intact landscape and ecosystem (55)	Wave protection for coastal communities, infrastructure and other habitats	Cultural heritage and identity, educational value, historical value, maintenance of fisheries and ecotourism	Provides food, jobs, and support to local communities, maintained viable leases
Offshore reefs reduce wave height in fair weather (43,83)	Wave protection for coastal communities, infrastructure and other habitats		
Generates new carbonate sediment and traps sediment (accretion) which results in land building (55)	Maintains land for coastal communities and infrastructure		Avoided cost of infrastructure damage, supports mineral and energy industry
Inshore reefs reduce shoreline erosion (16,30,55)			
Water filtration by oysters enhances water quality (16,30,55)			Avoided cost of poor water quality
Nutrient cycling and storage			Nutrient market
Carbon storage			Carbon market
Vertical habitat structure for estuarine dependent fish & invertebrate species, mammals, and birds (16,30,55)		Maintenance of fisheries protects livelihoods of coastal inhabitants, Recreational fishing, family heritage (familial lines), cultural value & identity	Provides food and income through oyster harvest, commercial fishing
Habitat for oysters (larval source) (30,41,55,57)		Supports commercial, recreational, and subsistence fishing, family heritage (familial lines), cultural heritage & identity, particularly intergenerational ties in the oyster industry	Provides food, jobs, and support to local communities
Habitat for wading birds and pelicans (16)		Supports hunting and ecotourism	

CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: The age of oyster reefs affects the width, elevation, and roughness of oyster reefs, as well as the density and size of oysters,[30,41] all of which influence the amount and type of ecosystem functions delivered. While intertidal reefs primarily reduce shoreline erosion,[30,55,83] subtidal reefs can reduce wave height. Formation of oyster reefs is affected by availability of cultch for the oysters to grow on,[30,57] as well as proximity to live reefs for natural recruitment of new oysters.[30]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

- Create artificial reefs: subtidal vs. tidal
- Fisheries management—designate areas, change regulation of open/closed season, make restrictions, establish brood stock sanctuaries
- Cultch plants
- Utilize hatchery based larvae

HOW CAN RESTORATION HELP BUILD COMMUNITY RESILIENCE?

A community perspective: Oysters provide an important commercial fishing industry for Louisiana, and the oyster reefs also provide habitat for shrimp—another staple commercial industry in coastal Louisiana. Consuming and selling oysters is central to the culture of several different coastal communities, particularly Native American tribes and Croatian groups. Oysters and the associated businesses are embedded deep into the cultural, economic, and environmental fabric of south Louisiana and support some of the communities most heavily impacted by coastal change as well as those communities affected by the 2010 Deepwater Horizon oil spill. Restoration of oyster reefs and the creation of new oyster reefs can break up violent waves before they can reach fishing villages and coastal communities and provide a sustainable income source. Overall, sustaining oyster reefs can provide several key ecosystem functions to create community resilience environmentally, economically, and culturally.

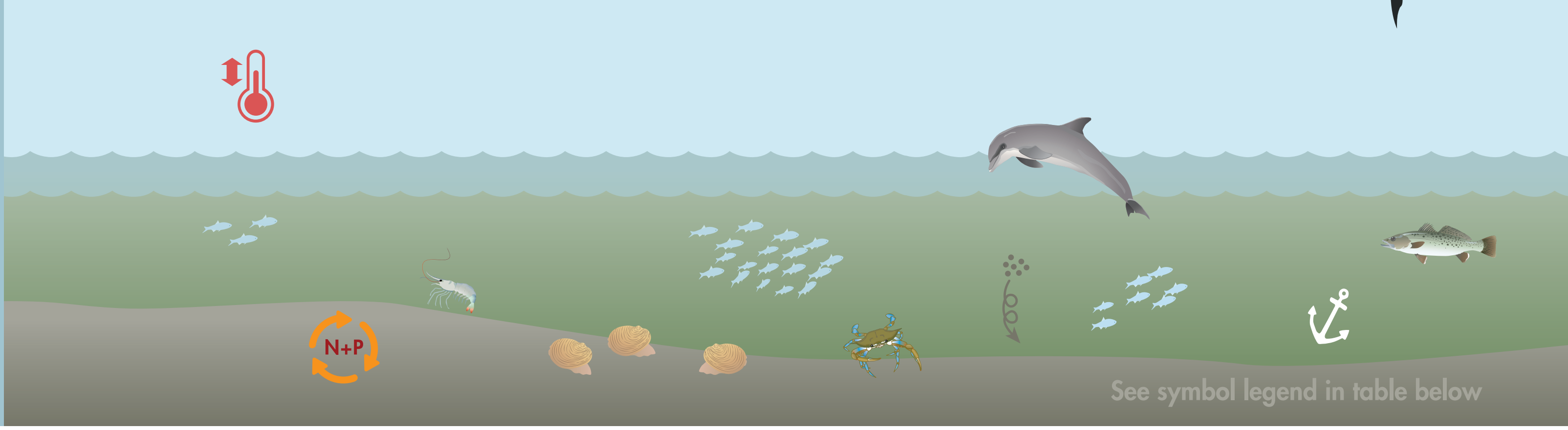
"Oysters can slow down storm surge. They need to keep rebuilding the reefs. That helps fishing, which helps everything. Recycling oyster shells is a way to build reefs."

Delcambre workshop participant, April 2016

"Oystermen and shrimpers, we use the same ecosystem. Without oyster reefs we don't have shrimp that go around reefs. It's an ecosystem. When you have a dead reef, you have no ecosystem."

St. Bernard workshop participant, May 2016

OPEN WATER



ECOSYSTEM FUNCTIONS	ECOSYSTEM SERVICES: PROTECTIVE	SOCIAL/CULTURAL	ECONOMIC
Intact landscape and ecosystem		Aesthetic value, cultural heritage, educational value, maintenance of fisheries and ecotourism	Provides food, jobs, and support to local communities; supports transportation and navigation; connection to global economies
Deposition of sediment and organic matter	Can provide a sediment source for restoration and protection projects		Avoided cost of infrastructure damage, supports mineral and energy industry, restoration economy, Supports on and off shore natural resource extraction
Moderates rapid air temperature changes			Provides food, jobs, and support to local businesses and agriculture (citrus)
Nutrient cycling and storage			Nutrient markets, avoided cost of poor water quality
Habitat for pelagic fish, shrimp, benthic species, invertebrates (36,53,56,92)		Supports commercial, recreational, and subsistence fishing, ecotourism	Provides food, jobs, and support to local communities
Feeding ground for pelagic birds		Supports hunting and ecotourism	Provides food, jobs, and support to local communities
Habitat for marine mammals		Supports ecotourism	Provides jobs, and support to local communities
Sustainable waterways		Historical value and access for hunting, recreational use, ecotourism, and commercial, recreational, and subsistence fishing	International ports provide jobs and transportation; supports international business, particularly oil and gas

CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: Areas of open water are very different from each other,[36,56] resulting in large differences in the ecosystem functions that they support. Proximity to adjacent habitats, water depth, salinity, areas of very low oxygen, very high nutrient inputs, water turbidity, and underlying sediments all influence the potential ecosystem function of open water areas in coastal Louisiana.[22,36,56]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

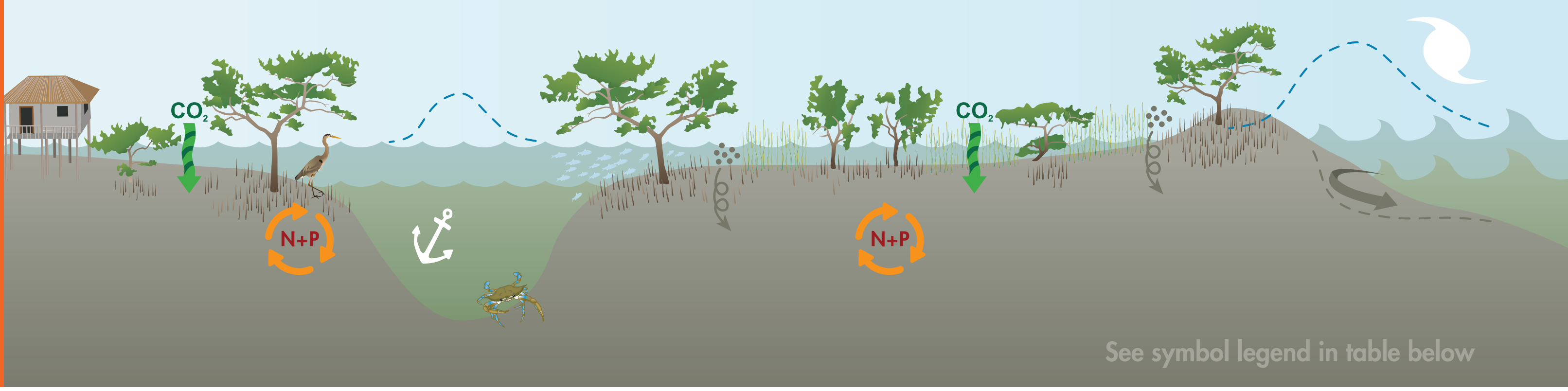
- Improve water quality
- Restore other habitats (e.g., marshes, oyster reefs, mangroves)
- Hydrological restoration (e.g., dredging/canal filling)
- Best management practices—streams
- Establish fish hatcheries

HOW CAN RESTORATION HELP BUILD COMMUNITY RESILIENCE?

A community perspective: Open water in coastal Louisiana is both a resource and potential threat to communities. On the one hand, the Gulf of Mexico supports an abundance of natural resource industries that sustain coastal communities and are embedded into the social fabric and histories of many of these communities. On the other hand, the increasing area of open water as marsh fragments and is lost transforms open water into a conduit for storm surge and nuisance flooding closer to inhabited coastal areas. Furthermore, the increase in open water reduces the amount of marsh edge and occurrences of slack tide, which are key for fisheries, allowing the tide further inland and up into estuaries. Loss of both marsh and barrier islands to open water makes communities more vulnerable to increased water and wave action from tides, hurricanes, and strong south winds. With these threats in mind, options for building community resilience rely on maintaining the current coastlines and marsh to open water ratios.

> ***"We go back far... we can tell you the stories of where our grandfathers used to fish at... now we're fishing where they used to have their camps... it was all trees... it was all forests..."***
>
> *St. Bernard workshop participant, May 2016*

MANGROVE STANDS



<table>
<tr><th>ECOSYSTEM FUNCTIONS</th><th colspan="3">ECOSYSTEM SERVICES</th></tr>
<tr><th></th><th>PROTECTIVE</th><th>SOCIAL/CULTURAL</th><th>ECONOMIC</th></tr>
<tr><td>Intact landscape and ecosystem (16,33,52,95)</td><td>Flood and wave protection for coastal communities and infrastructures</td><td>Educational value, maintenance of fisheries and ecotourism</td><td>Provides food, jobs, and support to local communities</td></tr>
<tr><td>Reduced wave height in fair weather and storm conditions (up to 1m waves) (6,16,31,33,80,96,97)</td><td rowspan="3">Flood and wave protection for coastal communities and infrastructures</td><td></td><td rowspan="2">Avoided cost of infrastructure damage</td></tr>
<tr><td>Reduction of storm surge prevents erosion and increases sedimentation (6,16,31,33,96)</td><td></td></tr>
<tr><td>Vegetation stabilizes soil and traps sediment, resulting in land building (6,31,33,98)</td><td></td><td>Avoided cost of infrastructure damage, supports mineral and energy industry</td></tr>
<tr><td>Nutrient storage and cycling (6,31,95)</td><td></td><td></td><td>Nutrient markets</td></tr>
<tr><td>Carbon storage (6,16,31,42,85,95,99)</td><td></td><td></td><td>Carbon markets</td></tr>
<tr><td>Habitat for shrimp, crab, fish (6,16,31,33,42)</td><td></td><td>Supports commercial, recreational, and subsistence fishing</td><td rowspan="2">Provides food, jobs, and support to local communities</td></tr>
<tr><td>Habitat for nesting, roosting, wading birds, pelicans, frigates, secretive marsh birds (16,31,33)</td><td></td><td>Supports hunting, ecotourism, aesthetic value</td></tr>
<tr><td>Sustainable waterways (6)</td><td></td><td>Historical value and access for recreational use, ecotourism, commercial, recreational, and subsistence fishing</td><td>International ports, jobs, and transportation</td></tr>
</table>

CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: Mangroves grow along the warmer and more saline areas in southern coastal Louisiana[16,31,32] They are highly susceptible to extended freezes and these trees have historically died off during occasional harsh winters.[31,52,100] The density and height of mangroves, as well as the topography where they grow, influences delivery of ecosystem function.[32,33,52] The small seedlings are dispersed by water and need to sit on dry soil for days to establish, which can limit the extent of where they can establish.[33,52]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

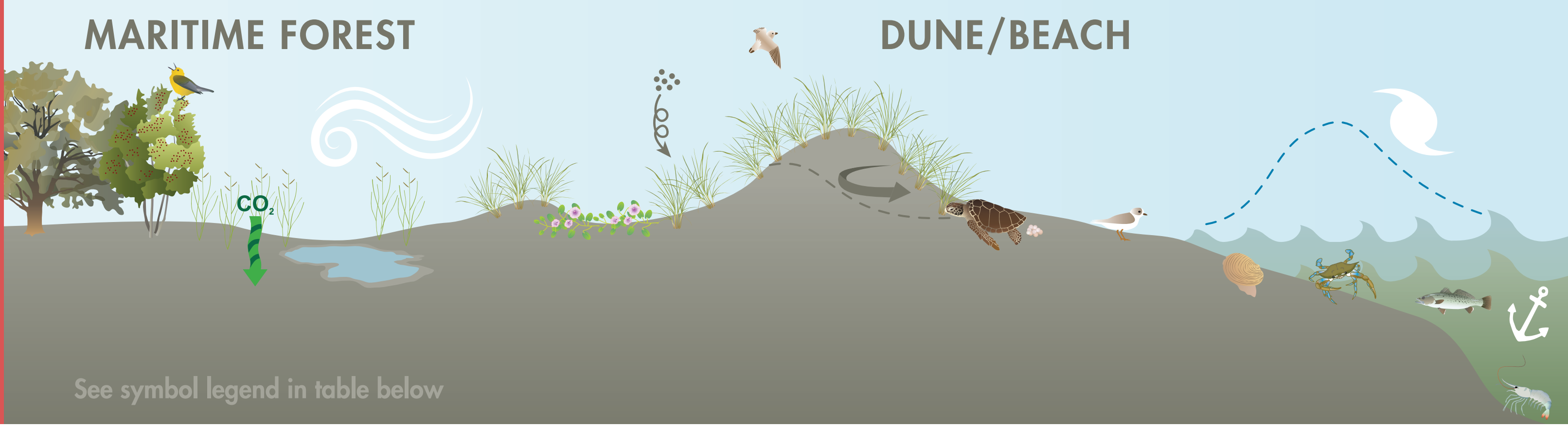
- Maintain mature mangrove stands
- Maintain hydrology, appropriate elevation
- Occasional marsh planting, particularly at various life stages
- Assisted dispersal of propagules

A NEW POTENTIAL TO HELP BUILD COMMUNITY RESILIENCE?

A technical perspective: The vegetation in much of the brackish and saline marsh areas are currently dominated by the emergent marsh grass, *Spartina alterniflora*. However, native black mangrove trees, *Avicennia germinans*, are also found in the most southerly coastal areas of Louisiana and have the potential to expand northerly as a result of predicted reductions in freezing temperatures over the next 20 to 30 years.[100] Planting mangroves could serve as a means for local managers to protect shorelines and levee systems from wave attack as has been reported in other systems.[108] As mangroves have not historically been a major component of coastal habitats in Louisiana, they are less familiar to coastal residents and the ecosystem functions provided are less recognized. With the continued changes in a transforming Louisiana coastal ecosystem, new species such as the black mangrove are likely to alter the balance of marsh plant species. Based on observations and data from other locations, some of these, such as the increase in mangrove trees, have potential to increase community resilience.

> *"...relatively small changes in the intensity and frequency of extreme winter events could cause relatively dramatic landscape-scale ecosystem structural and functional change in the form of poleward mangrove forest migration and salt marsh displacement."*
>
> *Osland et al 2013*

BARRIER ISLAND COMPLEX



ECOSYSTEM FUNCTIONS	ECOSYSTEM SERVICES: PROTECTIVE	SOCIAL/CULTURAL	ECONOMIC
Intact landscape and ecosystem (34,35,43)	Flood and wave protection for coastal communities and infrastructures, barrier against salt water intrusion	Aesthetic value, cultural identity and heritage, educational value, historical value, maintenance of fisheries and ecotourism, recreation for visitors and residents	Provides jobs and support to local communities; supports commercial and recreational fisheries
Reduced wave height in fair weather. Dunes are the first line of defence (6,16,35,43,44,80,83)	Flood and wave protection for coastal communities and infrastructures, barrier against salt water intrusion		Avoided cost of infrastructure damage
Maritime forest vegetation helps to stabilize beach and dune sediment and prevent shoreline erosion (83)			Avoided cost, supports mineral and energy industry
Beach/dune reduces surge (18,34,43,44)			Avoided cost of infrastructure damage
Soil retention by vegetation (34,44)			
Maritime forest vegetation reduces wind strength (50)	Wind protection for coastal communities and infrastructures		
Plant growth, organic production, land building, and carbon storage (35)	Flood protection for infrastructure		Avoided cost of infrastructure damage, timber, carbon market
Nutrient storage and cycling (35)		Maintenance of fisheries and ecotourism potential	Nutrient markets, avoided cost of poor water quality
Habitat for shorebirds and migratory birds (16,34,50)		Supports ecotourism	Provides jobs, and support to local communities
Habitat for turtle nesting (16)		Supports ecotourism	
Sustainable waterways		Historical value and access for recreational use, ecotourism, commercial, recreational, and subsistence fishing	Provides jobs, transportation, Supports international ports and other international business, particularly oil and gas, and commercial fishing

CONSTRAINTS ON DELIVERY OF ECOSYSTEM FUNCTIONS

A technical perspective: Structure and shape of the beach and dunes, including dune height[44] and width, as well as sediment grain size and supply of new sediment, all influence delivery of ecosystem functions.[34] Both in the dunes and the maritime forest the delivery of ecosystem function is changed by: vegetation height and density, range of species present, and the size of the vegetated area.[35]

WHAT ARE THE ECOSYSTEM-BASED RESTORATION OPTIONS?

- Restore/maintain barrier islands, modifying hydrology
- Nearshore sediment placement (beach response plan)
- Dune restoration with sand fencing
- Plant upland vegetation
- Invasive plant control
- Scarp reduction (shape for birds / turtles)
- Beach nourishment
- Land use restrictions / upslope protection (migration corridors) / conservation easement risk reduction
- Vehicular use restrictions

HOW CAN RESTORATION HELP BUILD COMMUNITY RESILIENCE?

A community perspective: Through restoring and maintaining the barrier island complex, the resilience of coastal communities can be reinforced culturally, economically, and physically. In certain locations, maintaining or restoring the barrier island complex can provide protection from hurricanes and accompanying storm surge and violent winds that can cause severe and extensive damage to public infrastructure, private property, and coastal marshes. Furthermore, barrier islands also function as historic and recreational sites for many locals and visitors to the region.

"We lose the barrier islands that is it. This is the buffer zone."

St. Bernard workshop participant, May 2016

"We don't have the barrier islands to catch the wind."

Delcambre workshop participant, April 2016

ECOSYSTEM-BASED RESTORATION IN COASTAL LOUISIANA

Over the past century, coastal Louisiana has experienced a globally high rate of land loss from many causes including sea level rise, subsidence, saltwater intrusion, and reduced sediment flow.[54,101,102] Despite decades of planning and investment in a diversity of projects through to the early 2000s, continued high rates of land loss indicated a need for an integrated and systems-scale approach to coastal restoration planning.[103] In 2005, communities and ecosystems of coastal Louisiana were heavily impacted by two major hurricanes, Katrina and Rita, providing the impetus for establishment of the state Coastal Restoration and Protection Authority (CPRA) to coordinate an integrated and coastwide plan to achieve a safe and sustainable coast.[10,103,104] The development of a Coastal Master Plan for coastal Louisiana provides a framework for identification, prioritization, and tracking of restoration and protection projects and efforts across the coast.[10,105,106] The need to be coastwide, include large scale projects, and result in sustainable communities, infrastructure, and ecosystems has highlighted the need to consider a range of approaches, with a strong focus on a diversity of ecosystem-based approaches including coastal forest conservation, crevasses and river diversions, marsh creation, vegetation planting, oyster reef establishment, and barrier island restoration.

Coastal forest conservation

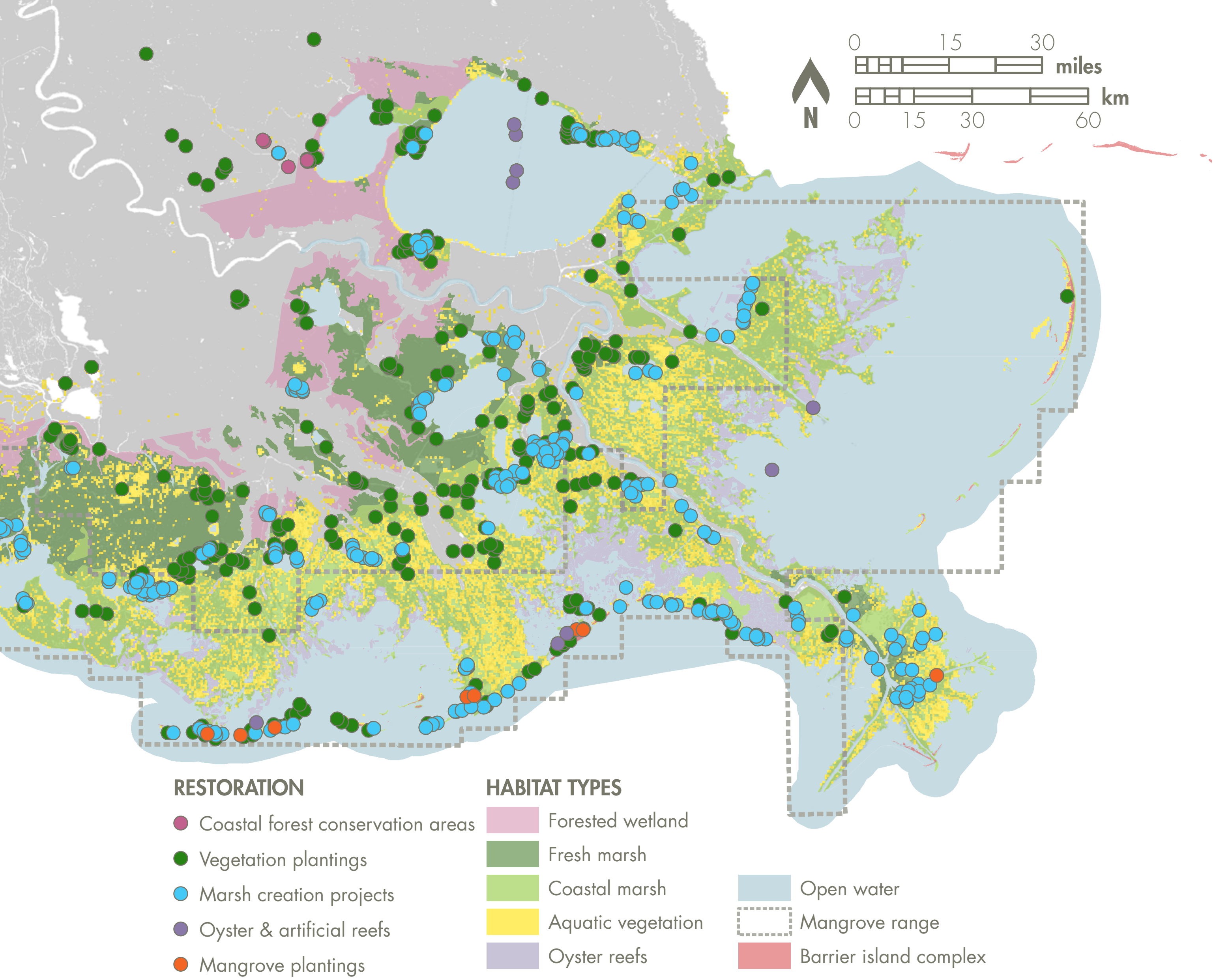
Protecting areas of coastal wetland that are still intact, such as large areas of the Atchafalaya River Basin, to maintain the freshwater resources, flood protection and wildlife habitat of these areas.

Crevasses + river diversions

The establishment of openings or channels through the banks of the river (crevasses) or developing built structures (diversions) to distribute river water and sediment into adjacent basins, to restore natural processes of sediment deposition and fresh marsh growth.

Marsh creation

Marsh creation through use of dredged sediment into bays, ponds, and canals, frequently using a pipeline conveyance for sediment placement. Also includes development of "marsh terraces," the creation of bare soil segmented ridges and emergent marsh with excavated subtidal sediment from the adjacent area.[107]



Vegetation planting

In areas where coastal vegetation has become degraded or areas of active marsh creation, coastal forest trees, marsh grass, and mangrove trees can be planted to stabilize soil and encourage sedimentation, as well as providing additional habitat for fish and shellfish.

Oyster reef establishment

Various bioengineering approaches establish a structure for the establishment of oysters, with the potential for these reefs to expand and be self-sustaining, providing shoreline protection as well as other ecosystem services.

Barrier island restoration

Restoration projects protect and restore island topography, ecosystems, and natural processes. Strategies include placement of dredged sediment to nourish beaches, build dunes, fill breaches, or increase elevation; placing structures such as breakwaters to reduce wave impact along shorelines; planting vegetation; or building sand fencing to trap sediment.

*Data sources: Coalition to Restore Coastal Louisiana; Louisiana Coastal Protection and Restoration Authority; NOAA Restoration Center.

DELCAMBRE

FUTURE RESTORATION & PROTECTION: IDENTIFIED OPTIONS AND SITES

Despite most residents living inland, 15–30 km (9–19 miles) from the coast, they consistently suggested that forms of marsh restoration and shoreline stabilization were key for protecting their communities. They noted places along several canals adjacent to Vermilion Bay that have been reinforced by concrete or rock barriers that abate erosion from storms and passing boats. Regularly dredging and using dredge material to help rebuild coastal marsh was mentioned numerous times, as well as the success of volunteer planting programs that restored parts of the coast around Vermilion Bay (particularly those initiated by the Coalition to Restore Coastal Louisiana). Alongside these suggestions, residents also emphasized putting flood control structures on existing canals—such as Bayou Tigre and the Delcambre Canal—that could be used to help block storm surge from backing up into communities farther upland.

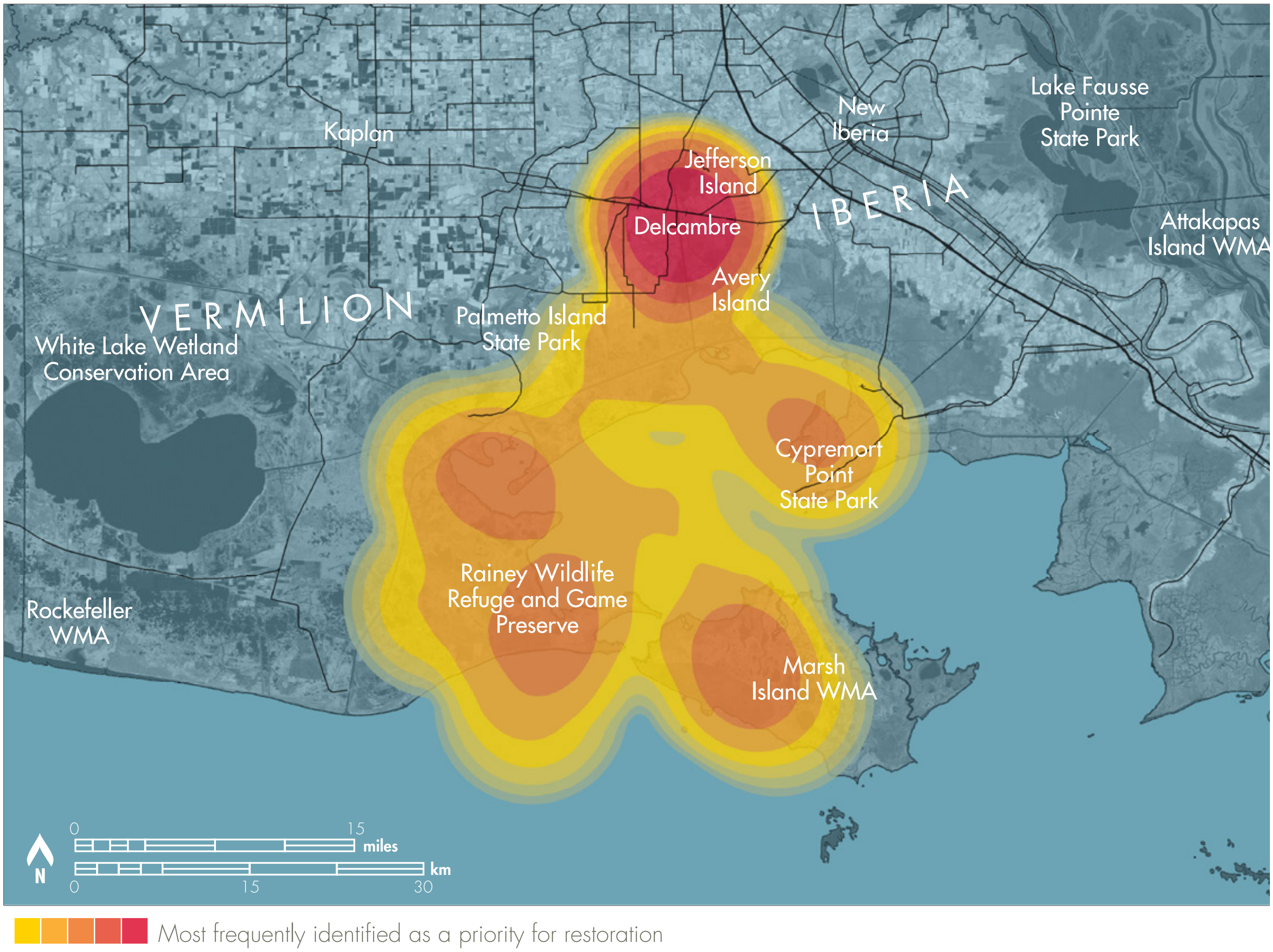
TOP 5 LOCATIONS OF CONCERN

LOCATION	FREQUENCY
Local bayous and canals	23
Area schools	19
Vermilion Bay	15
Town of Delcambre + Port of Delcambre	14
Avery and Jefferson Islands	6

"Some shoreline protection projects have worked, especially those in Little Vermilion Bay. Little Bay is the place we always get caught in the mud flats."

Delcambre workshop participant, April 2016

Coalition to Restore Coastal Louisiana (CRCL) volunteers planting 7,200 smooth cordgrass plants on terraces near Cole's Bayou in Vermilion Parish on September 6th, 2013 (left, middle, right).



Hotspots of community identified locations for restoration, indicated by Delcambre residents during two workshops in spring 2016.

EXISTING AND ANTICIPATED RESTORATION PROJECTS

	TYPE OF PROJECT	NUMBER OF PROJECTS	ORGANIZATION
	Tree planting	2	CRCL
	Marsh planting and restoration	5	CPRA, CRCL, CWPPRA
	Sediment and nutrient trapping (including terracing)	5	CPRA, CWPPRA
	Bank stabilization/ shoreline protection	3	CPRA, CWPPRA

CRCL = Coalition to Restore Coastal Louisiana

CPRA = Coastal Protection and Restoration Authority

CWPPRA = Coastal Wetlands Planning, Protection and Restoration Act

"Vermilion Bay and Little Bay have changed over the years. It's so overgrown! I didn't recognize it. That's what they planted...looks like it's growing and filling up since the hurricane. Planting programs are good."

Delcambre workshop participant, April 2016

ST. BERNARD

FUTURE RESTORATION & PROTECTION: IDENTIFIED OPTIONS AND SITES

Past and potential restoration projects were a significant topic of conversation throughout both workshops. Dredging and pumping sediment was a critical technique many participants emphasized as a strategy that could produce desired results in a short time frame. The ability to do strategic and controlled marsh restoration was highly valued by many participants. Others also emphasized the need to rebuild and revegetate ridges following the historic bayous that meander out towards Breton Sound, emphasizing Bayou La Loutre Ridge and the ridge following Bayou Terre Aux Boeufs in particular. Participants discussed efforts to replant cypress trees on historic ridges and the significance of the ridges for the marsh ecosystem. Participants also pointed out the need for reductions in clear cutting of existing forested wetlands for development, with particular emphasis on forested wetlands on private property.

Another area identified as significant for restoration was the Chandeleur Islands. Rebuilding and sustaining these islands was considered key for making all the other projects on the coast more resilient over time. Describing them as the "roof" on the "house of coastal restoration," barrier islands are the first line of defense against hurricanes. However, because the Chandeleur Islands are federally regulated as part of the Breton National Wildlife Refuge, the ability of local and state authorities to initiate restoration projects is a challenge. This once again reinforces the myriad bureaucratic challenges that undermine the restoration projects that members of the coastal community would like to see built.

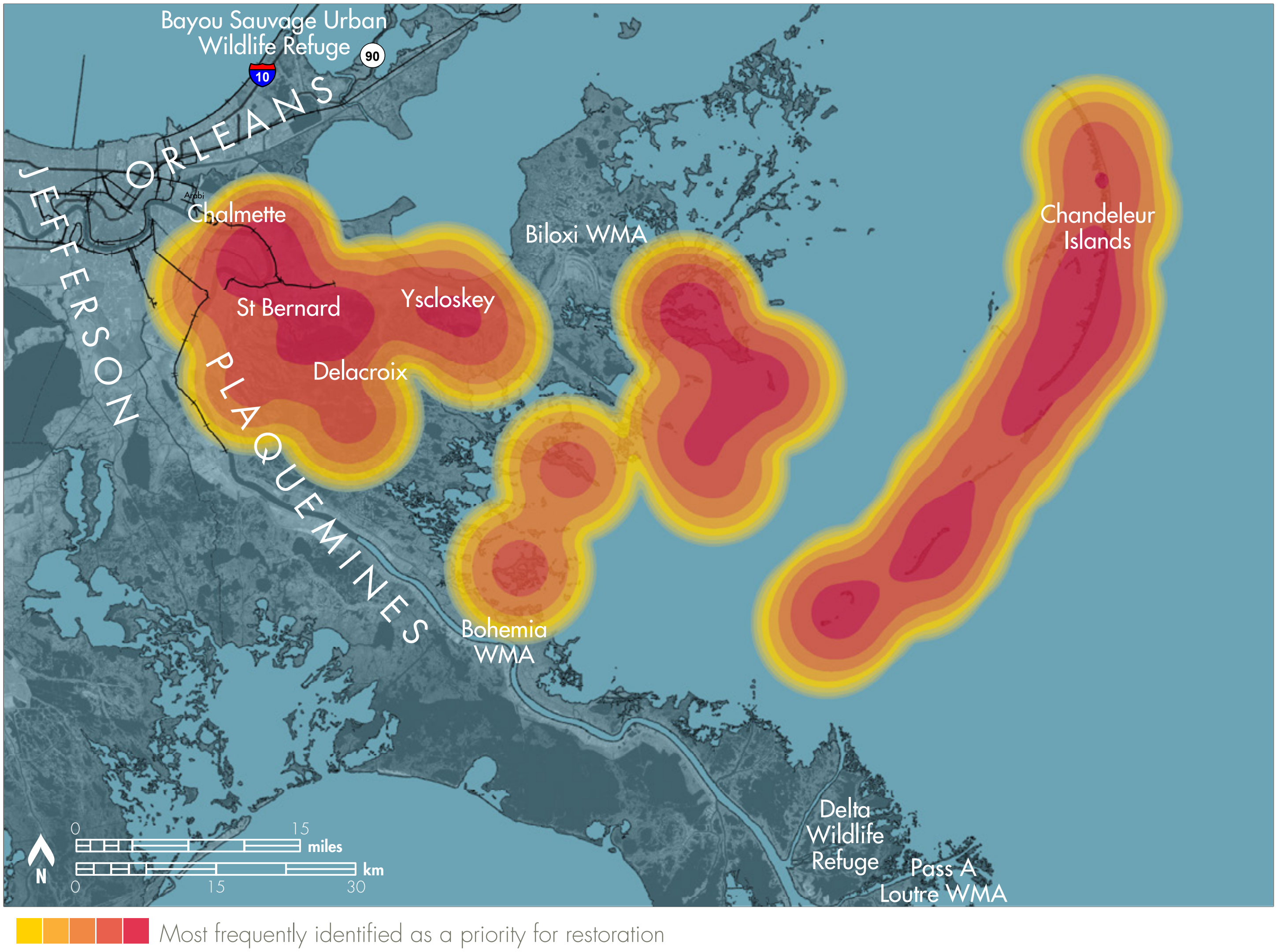
TOP 5 LOCATIONS OF CONCERN

LOCATION	FREQUENCY
Fishing villages	29
Breton/Chandeleur Sound	23
Caernarvon	14
Lake Lery + Big Mar	13
MRGO	12
Bayou La Loutre + Bayou Terre Aux Boeufs	11

"I shrimp for a living. And I shrimp out here where there are times when I don't even get a slack tide and the reason for that is because we lost all these little islands [Chandeleur Islands] and the tide just doesn't slow down…it just comes in and goes back out…we don't get a slack tide in the bayou."

St. Bernard workshop participant, May 2016

Coalition to Restore Coastal Louisiana (CRCL) and Lake Pontchartrain Basin Foundation worked to reforest coastal forest habitat near St. Bernard by planting 5,000 bottomland hardwood trees over 25 acres. Volunteers participate at a planting event on March 19-20th, 2015 (left, middle); restoring barrier islands (right).



Hotspots of community identified locations for restoration, indicated by St. Bernard residents during two workshops in spring 2016.

EXISTING AND ANTICIPATED RESTORATION PROJECTS

	TYPE OF PROJECT	NUMBER OF PROJECTS	ORGANIZATION
	Tree planting	10	CRCL
	Marsh planting and restoration	4	CPRA, CWPPRA
	Sediment and nutrient trapping (including terracing)	1	CWPPRA
	Bank stabilization/ shoreline protection	3	CPRA

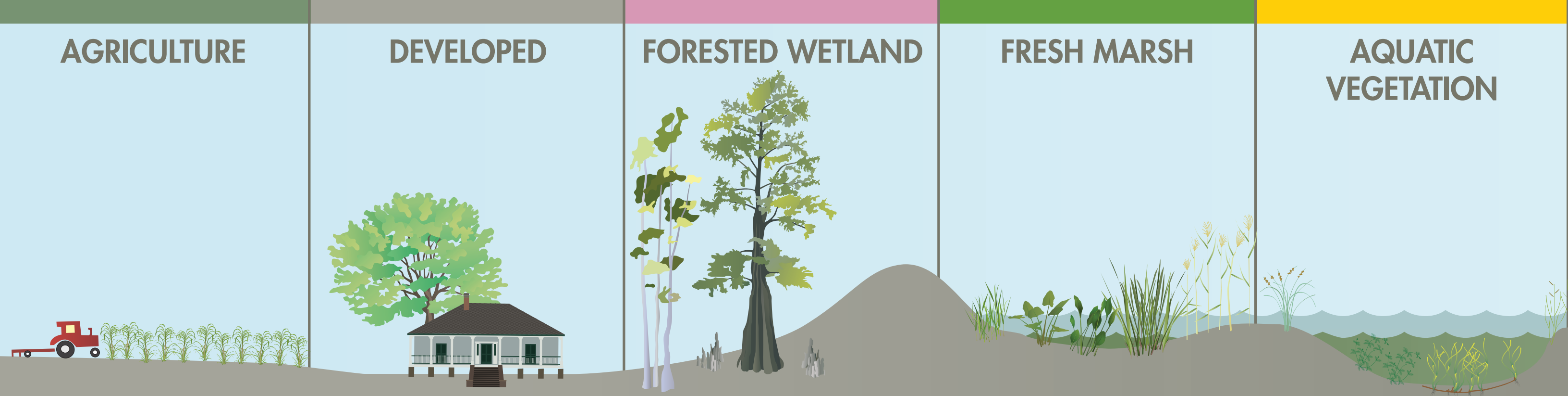
CRCL = Coalition to Restore Coastal Louisiana

CPRA = Coastal Protection and Restoration Authority

CWPPRA = Coastal Wetlands Planning, Protection and Restoration Act

"Dead oyster cultch can provide a foundation for restoration."

St. Bernard workshop participant, May 2016

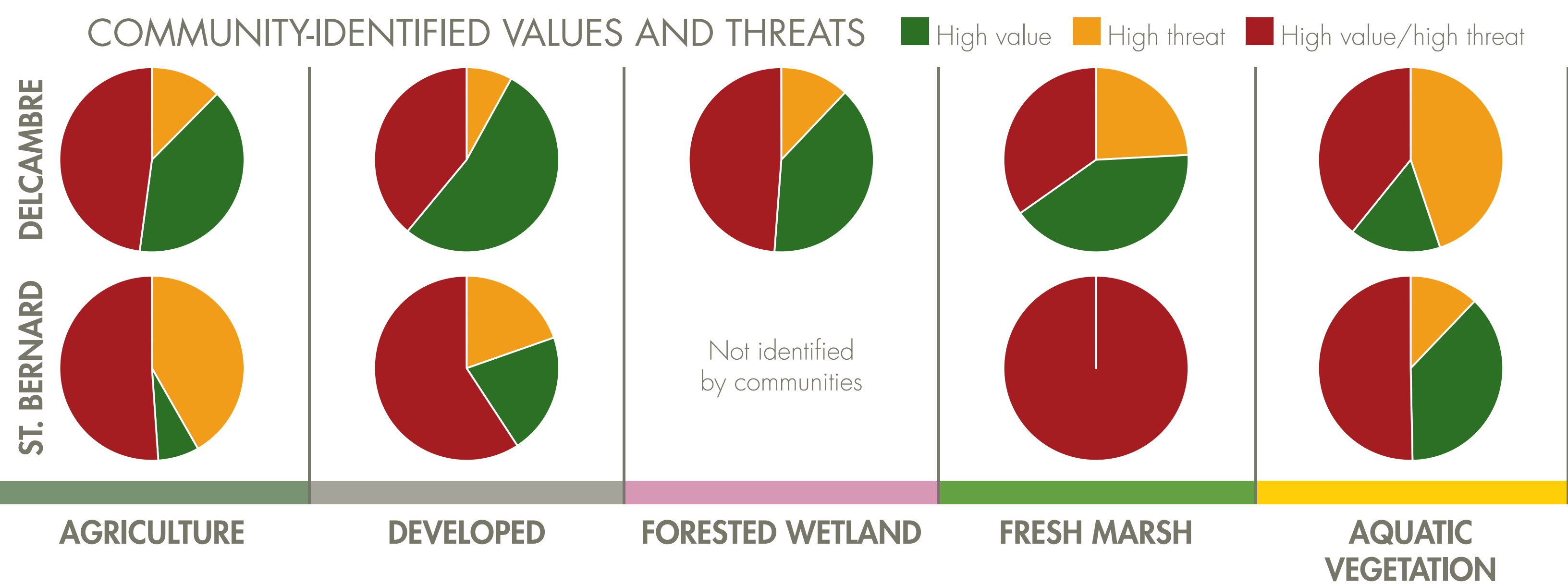


LINKING COASTAL HABITATS, COMMUNITY PRIORITIES & RESTORATION OPTIONS

ECOSYSTEM-BASED RESTORATION OPTIONS

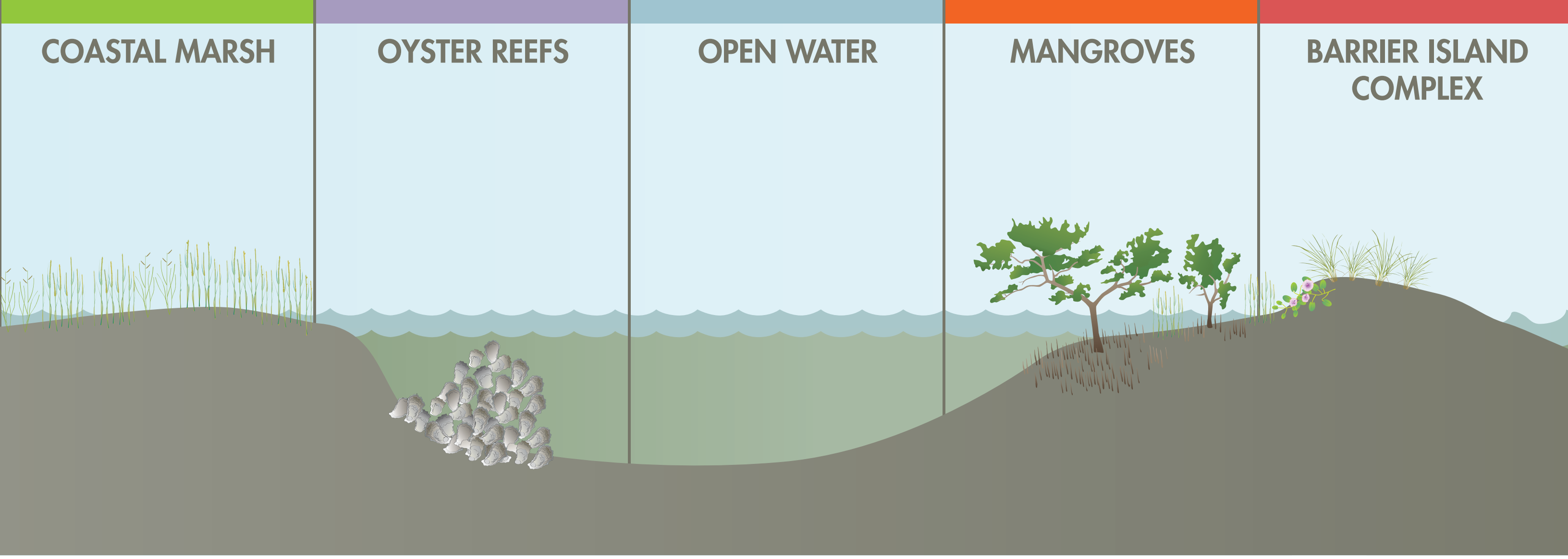
	Forested Wetland	Fresh Marsh	Aquatic Vegetation
Vegetation planting	■	■	■
Surface and river water control	■	■	■
Ridge & bank restoration	■	■	
Sand & mud for habitat creation		■	
Reef building			
Land and water management	■	■	■
Dune restoration and sand fencing			
Pest control		■	

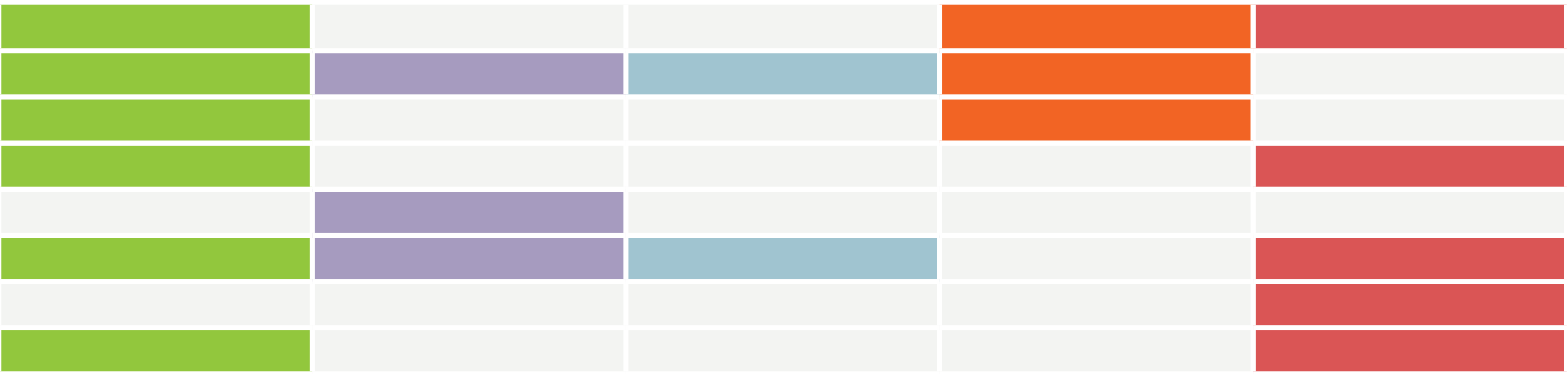
COMMUNITY-IDENTIFIED VALUES AND THREATS

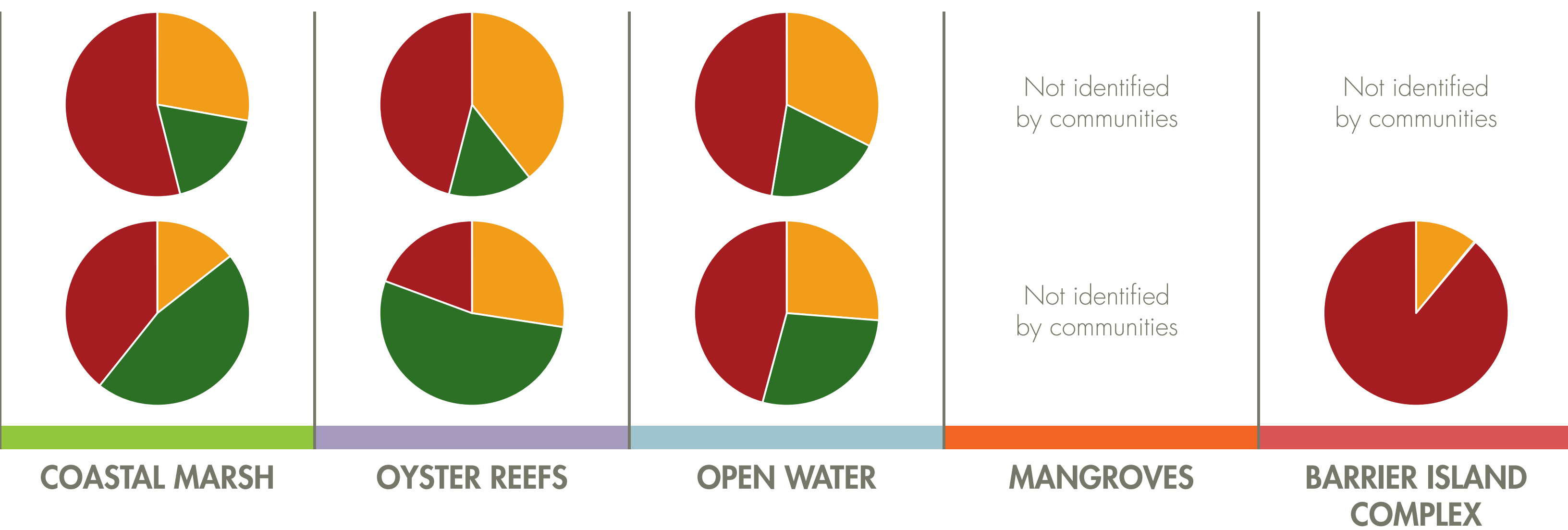


Linking community identified areas of value and threat to habitat types present within those areas has the potential to assist in prioritizing ecosystem-based restoration options in those locations. Applying locations of community identified values and threats to locations of mapped actual or potential habitats indicated that there were differences in identified value and threat between habitats and differences between Delcambre and St. Bernard. In the area of focus, fresh marsh occurs in areas identified as high value and high threat by St. Bernard residents, whereas in Delcambre large areas where fresh marsh occurs were identified by residents as high value but not currently as high threat. Similarly, where agricultural and developed areas were identified, in the St. Bernard area of focus they were consistently identified as high threat, whereas in Delcambre they were often classified as high value without additionally being identified as high threat.

Refer to pages 20–33 for complete list of ecosystem-based restoration options. Refer to page 42 for maps showing value-threat matrix.





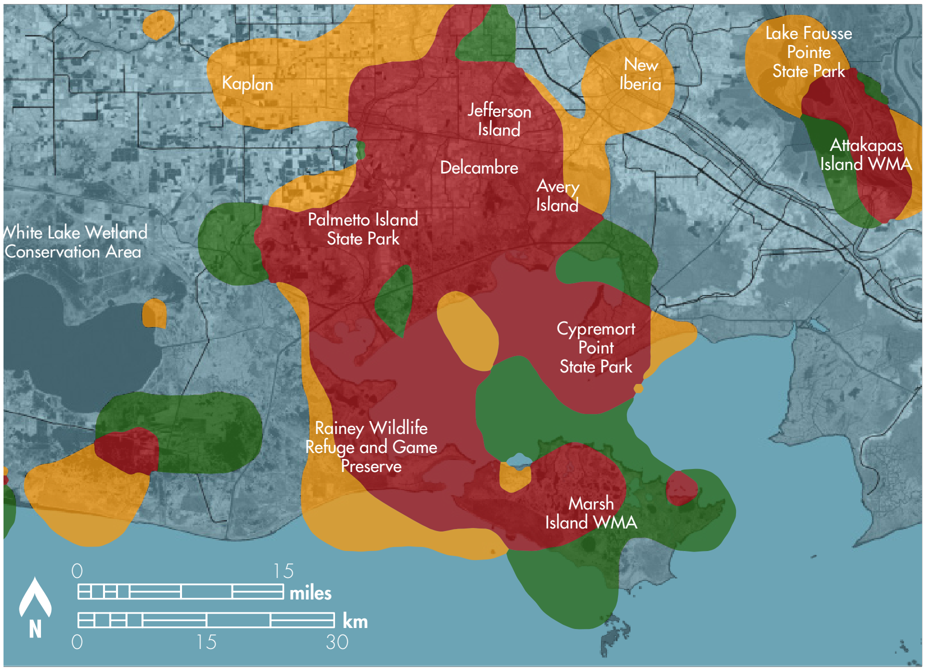


"There used to be a lot of land from our camp to the Intracoastal, but now it's just a hop, skip, and a jump to Vermilion Bay. In our current camp, we used to have marsh between us and the bay, but now the bay is right there. It's scary. Now we're worried about the hurricane because we don't have the land to protect us."

Delcambre workshop participant, April 2016

APPLICABILITY OF DOCUMENT & APPROACH

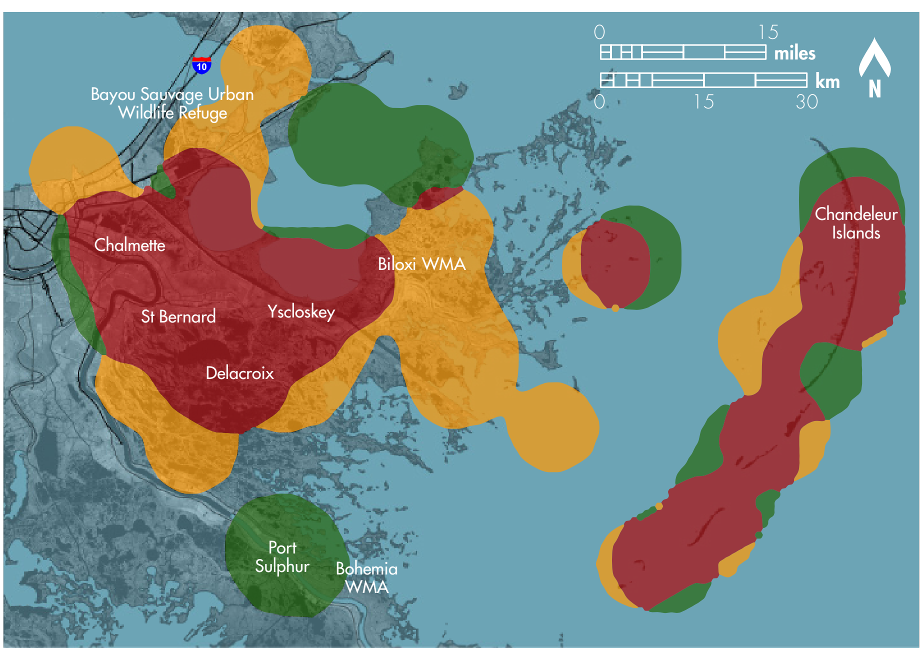
DELCAMBRE



High value | High threat | High value and high threat

Value-threat matrix map, developed using input from Delcambre residents, gathered during two workshops in spring 2016.

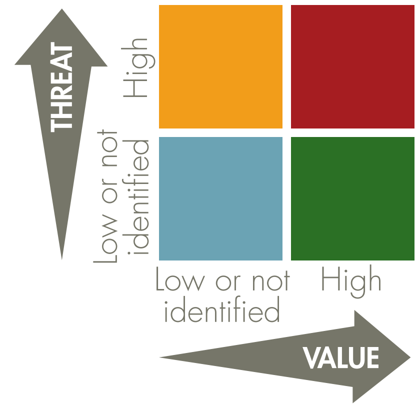
ST BERNARD



High value | High threat | High value and high threat

Value-threat matrix map, developed using input from St. Bernard residents, gathered during two workshops in spring 2016.

VALUE-THREAT MATRIX



COMBINING COMMUNITY IDENTIFIED VALUES & THREATS

The value-threat matrix is a framework for analyzing the outputs of community knowledge mapping in order to identify locations where coastal protection and restoration would be most valuable from the perspective of local residents. A map was developed from the interpolated knowledge maps for each community, using the categories in the "value-threat matrix," based upon the average number of times a site was mentioned by workshop participants. Locations that workshop participants identified more often as being both high value and high threat represent the greatest potential for restoration from a social impact perspective. This framework also identifies locations of high community value that are perceived as low threat, as well as those areas of high threat that are not identified as having high social or community value. Areas of high value that are not identified as being at threat could represent a source of perceived community strength.

The results should be interpreted with caution, as many locations identified rarely or not at all, may be locations which residents may not have any experience with, particularly those far away from the study site.

CONCLUSIONS	RECOMMENDATIONS
Community resilience in coastal Louisiana depends upon social, cultural, and economic wellbeing, which relies upon the wealth of natural resources that are provided by an intact and productive coastal ecosystem.	• Integrate local knowledge with accumulated technical scientific knowledge to fully understand the complex linkages of key ecosystem functions and protective, social/cultural, and economic ecosystem services.
Ecosystem functions are natural processes which can potentially be used by communities as an ecosystem service, for example, the support of abundant fish populations is an ecosystem function that provides potential economic and socio-cultural ecosystem services.	• Increase awareness and understanding about ecosystem functions in different habitats and their potential to provide protective, social/cultural, and economic ecosystem services for communities. • Better quantify ecosystem functions (non-monetized) delivered by different ecosystem-based restoration actions to assess potential delivery of protective, social/cultural, and economic ecosystem services (monetized and non-monetized).
Habitat-targeted ecosystem-based restoration can maximize delivery of ecosystem functions and associated ecosystem services.	• Build community and coastal resilience and sustainability through restoration of key ecosystem functions.
The success of ecosystem-based restoration projects varies with geographic location and habitat type.	• Recognize the external constraints (e.g., hurricanes and sea level rise) on realization of ecosystem functions following ecosystem-based restoration actions.
Many coastal residents feel that their local knowledge is not ultimately accounted for in the coastal restoration planning process within their own communities.	• Use coastal habitat types to support engaged discussion and feedback on prioritization and viability of coastal restoration options. • Develop a community derived value-threat matrix through participatory mapping and citizen engagement as part of the restoration planning process. • Link coastal habitat types and the value-threat matrix to help prioritize key locations for restoration and identify appropriate restoration actions to maximize community resilience.

Community and scientific workshops in Delcambre, St. Bernard, and Baton Rouge, in spring 2016.

REFERENCES

1. Adger, WN. et al. (2005). Socio-Ecological Resilience to Coastal Disasters. *Science,* 309: 1036–205.

2. Colten, CE. et al. (2012). Community Resilience & Oil Spills in Coastal Louisiana. *Ecology and Society,* 17 (3): 5.

3. Dennison, WC. and Wicks, CE. (2010). Environmental Campaigns: achieving a shared vision using research, monitoring, and management. In: Longstaff, B.J., Carruthers, T.J.B., Dennison, W.C., Lookingbill, T.R., Hawkey, J.M., Thomas, J.E., Wicks, E.C. and Woerner, J.L. (eds). *Integrating and applying science: a practical handbook for effective coastal ecosystem assessment.* Chapter 1. 244 pp. IANPress.

4. Murray L, Gurbisz C, Gibson D, Woerner J, Carruthers T. (2012). Collaborative parternships help bridge the gap between science and education. *EOS, Transactions American Geophysical Union.* Vol 93 (49): 510.

5. Travers, A., Elrick, C., Kay, R., and Vestergaard, O. (2012). *Ecosystem-based Adaptation Guidance: moving from principle to practice—working document.* United Nations Environment Programme.

6. Barbier, EB., Hacker, SD., Kennedy, C., Koch, EW., Stier, AC. and Silliman, BR. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs,* 81 (2): 169–193.

7. Chesney, EJ., Baltz, DM. and Thomas, RG., (2000). Louisiana estuarine and coastal fisheries and habitats: perspectives from a fish's eye view. *Ecological Applications,* 10: 350–366.

8. Gedan, KB., Kirwan, ML., Wolanski, E., Barbier, EB. and Silliman, BR. (2011). The present and future role of coastal wetland vegetation in protecting shorelines: answering recent challenges to the paradigm. *Climatic Change,* 106: 7–29.

9. Mitsch, WJ., and Gosselink, JG. (2008). *Wetlands.* Van Nostrand Reinhold, New York, New York, USA.

10. Coastal Protection and Restoration Authority. (2012). *Louisiana's Comprehensive Master Plan for a Sustainable Coast* . 188 pp. Baton Rouge, Louisiana: CPRA.

11. Boesch, DF., Josselyn MN., Mehta, AJ. Morris, JT. Nuttle, WK. Simestad, CA. and Swift, DJP. (1994). Scientific Assessment of Coastal Wetland Loss, Restoration and Management in Louisiana. *Journal of Coastal Research* Special Issue, 20: 1–103.

12. Boesch, DF. (2006). Scientific requirements for ecosystem-based management in the restoration of Chesapeake Bay and Coastal Louisiana. *Ecological Engineering,* 26: 6–26.

13. Rao NS., Carruthers TJB., Anderson P., Sivo L., Saxby T., Durbin, T., Jungblut V., Hills T., Chape S. (2012). *A comparative analysis of ecosystem–based adaptation and engineering options for Lami Town, Fiji.* A synthesis report by the Secretariat of the Pacific Regional Environment Programme.

14. Dalbom, C., Hemmerling, SA., and Lewis, J. (2014). *Community Resettlement Prospects in Southeast Louisiana* [White Paper]. Tulane Institute on Water Resources Law & Policy. New Orleans, LA.

15. Blum, MD., and Roberts, HH. (2009). Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise. *Nature Geoscience,* 2: 488–491.

16. Watson, A., Reece, J., Tirpak, BE., Edwards, CK., Geselbracht, L., Woodrey, M., LaPeyre, M., & Dalyander, PS. (2015). T*he gulf coast vulnerability assessment: Mangrove, tidal emergent marsh, barrier islands, and oyster reef.* 132 pp.

17. Morton, RA., & Barras, JA. (2011). Hurricane impacts on coastal wetlands: A half-century record of storm-generated features from southern Louisiana. *Journal of Coastal Research,* 275: 27–43.

18. Wamsley, TV., Cialone, MA., Smith, JM., Ebersole, BA., & Grzegorzewski, AS. (2009). Influence of landscape restoration and degradation on storm surge and waves in southern Louisiana. *Natural Hazards,* 51(1): 207–224.

19. Wamsley, TV., Cialone, MA., Smith, JM., Atkinson, JH., & Rosati, JD. (2010). The potential of wetlands in reducing storm surge. *Ocean Engineering,* 37(1): 59–68.

20. Howes, NC., FitzGerald, DM., Hughes, ZJ., Georgiou, IY., Kulp, MA., Miner, MD., Smith, JM., & Barras, JA. (2010). Hurricane-induced failure of low salinity wetlands. *Proceedings of the National Academy of Sciences,* 107(32): 14014–14019.

21. Smith, JM., Cialone, MA., Wamsley, TV., & McAlpin, TO. (2010). Potential impact of sea level rise on coastal surges in southeast Louisiana. *Ocean Engineering,* 37(1): 37–47.

22. Neill, C., & Turner, RE. (1987). Backfilling canals to mitigate wetland dredging in Louisiana coastal marshes. *Environmental Management,* 11(6): 823–836.

23. Allen, JA., Conner, W., Goyer, R., Chambers, JL., & Krauss, K. (1998). Freshwater forested wetlands and global climate change. In G. R. Guntenspergen & B. . Vairin (Eds.), *Vulnerability of coastal wetlands in the southeastern United States: Climate change research results, 1992–1997* (pp. 33–44). U.S. Geological Survey, Biological Resources Division Biological Science Report USGS/BRD/BSR-1998–0002.

24. Conner, WH., Krauss, KW., & Doyle, TW. (2007). Ecology of tidal freshwater forests in coastal deltaic Louisiana and northeastern South Carolina. In *Ecology of Tidal Freshwater Forested Wetlands of the Southeastern United States* (pp. 223–253). Springer.

25. Chambers, JL., Conner, WH., Keim, RF., Faulkner, SP., Day, JW., Gardiner, ES., Hughes, MS., King, SL., McLeod, KW., Miller, CA., et. al. (2006). *Towards Sustainable Management of Louisiana's Coastal Wetland Forests: Problems, Contraints, and a New Beginning.*

26. Krauss, KW., Whitbeck, JL., & Howard, RJ. (2012). On the relative roles of hydrology, salinity, temperature, and root productivity in controlling soil respiration from coastal swamps (freshwater). *Plant and Soil,* 358 (1): 265–274.

27. Batker, D., Torre, I. de, Costanza, R., Swedeen, P., Day, JW., Boumans, R., & Bagstad, K. (2010). *Gaining ground: wetlands, hurricanes, and the economy: the value of restoring the Mississippi River Delta.*

28. Gough, L., & Grace, JB. (1998). Effects of flooding, salinity, and herbivory on coastal plant communities, Louisiana, United States. *Oecologia*, 117: 527–535.

29. Cho, H. (2003). *Ecology of submersed aquatic vegetation in Lake Pontchartrain, Louisiana* (Dissertation). University of New Orleans, New Orleans, LA.

30. LDWF. (2013). *Oyster stock assessment report: of the public oyster seed areas of Louisiana seed grounds and seed reservations.* (No. 19).

31. Alongi. DM. (2015). The Impact of Climate Change on Mangrove Forests. *Current Climate Change Report,* 1: 30–39.

32. Alleman, L., & Hester, M. (2011). Refinement of the fundamental niche of black mangrove (Avicennia germinans) seedlings in Louisiana: Applications for restoration. Wetlands Ecology and Management, 19: 47–60.

33. Conner, WH., & Tolliver, JR. (1990). Long-term trends in the bald-cypress (Taxodium distichum) resource in Louisiana, USA. *Forest Ecology and Management*, 33/34: 543–557.

34. Coastal Protection and Restoration Authority. (2014) *Barrier island status report.* Baton Rouge, Louisiana: CPRA.

35. Day, FP., Crawford, ER., & Dilustro, JJ. (2001). Aboveground plant biomass change along a coastal barrier island dune chronosequence over a six-year period. *Journal of the Torrey Botanical Society*, 128(3): 197–207.

36. Thom, CSB., Peyre, MKGL., & Nyman, JA. (2004). Evaluation of nekton use and habitat characteristics of restored Louisiana marsh. *Ecological Engineering*, 23(2): 63–75.

37. Conner, WH., McLeod, KW., & McCarron, JK. (1997). Flooding and salinity effects on growth and survival of four common forested wetland species. *Wetlands Ecology and Management*, 5: 99–109.

38. Pezeshki, S. R. (1990). A comparative study of the response of Taxodium distichum and Nyssa aquatica seedlings to soil anaerobiosis and salinity. *Forest Ecology and Management*, 33/34(1–4): 531–541.

39. Shephard, CC., Crain, CM., Beck, MW. (2011). The protective role of coastal marshes: a systematic review and meta-analysis. *PLoS ONE*, 6(11).

40. McFalls, TB., Keddy, PA., Campbell, D., & Shaffer, G. (2010). Hurricanes, Floods, Levees, and Nutria: Vegetation Responses to Interacting Disturbance and Fertility Regimes with Implications for Coastal Wetland Restoration. *Journal of Coastal Research*, 265: 901–911.

41. Loftin, LB., Hoese, HD., & Konikoff, MA. (2011). Will Overfishing and Proposed Mississippi River Diversions Imperil Louisiana Oyster Fisheries? Commentary and Review. *Gulf of Mexico Science,* 1: 1–12.

42. Alongi, D. (2002). Present state and future of the world's mangrove forests. *Environmental Conservation,* 29: 331–349.

43. Stone, GW., Zhang, X., & Sheremet, A. (2005). The role of barrier islands, muddy shelf and reefs in mitigating the wave field along coastal Louisiana. *Journal of Coastal Research*, Special Issue No. 44: 40–55.

44. Pries, AJ., Miller, DL., & Branch, LC. (2008). Identification of structural and spatial features that influence storm-related dune erosion along a barrier-island ecosystem in the Gulf of Mexico. *Journal of Coastal Research*, 24(4C), 168–175.

45. Rentz, R. (2013). A Brief History of Reforestation and Restoration in Louisiana. 56(1).

46. Louisiana Ground Water resources commission. (2012). Managing Louisiana's groundwater resources with supplemental information on surface water resources.

47. Visser, J.M. and Sasser, C.E. (1995). Changes in tree species composition, structure and growth in a bald cypress - water tulepo swamp forest 1980–1990. *Forest Ecology and Management*, 72(2–3): 119–129.

48. Wharton, CH., Kitchens, WM., Pendleton, EC. and Sipe, TW., (1982). *The ecology of bottomland hardwood swamps in the southeast: A community profile.* FWS/OBS-8 l/37, US Fish and Wildlife Service, Biological Services Program, Washington, DC.

49. Keim, RF., Chambers, JL., Hughes, MS., Nyman, JA., Miller, CA., Amos, BJ., Conner, WH., John Jr, W., Faulkner, SP., Gardiner, ES., et. al. (2006). Ecological consequences of changing hydrological conditions in wetland forests of coastal Louisiana. *Coastal Environment and Water Quality*, 383–396.

50. LA CWCS (2005). Conservation Habitats and species assessments: Barrier island live oak forest.

51. Louisiana Department of Wildlife & Fisheries, & Louisiana Natural Heritage Program. (2009). *The Natural communities of Louisiana. 46 pp.*

52. Finney, W. (2011). *Comparative growth and propagule viability of Louisiana-harvested black mangrove,* Avicennia germinans. University of Louisiana at Lafayette. 42 pp.

53. Rozas, LP., Caldwell, P., & Minello, TJ. (2005). The fishery value of salt marsh restoration projects. *Journal of Coastal Research*, SI(40): 37–50.

54. Caldwell, AB. (2003). *Do Terraces and Coconut Mats Affect Seeds and Submerged Aquatic Vegetation at Sabine National Wildlife Refuge?* LSU Master's Theses.

55. Scyphers, SB., Powers, SP., Heck, KL., Byron, D. (2011). Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries. *PLoS One*, 6(8): e22396.

56. La Peyre, MK., Gossman, B., & Nyman, JA. (2007). Assessing functional equivalency of nekton habitat in enhanced habitats: comparison of terraced and unterraced marsh ponds. *Estuaries and Coasts*, 30(3): 526–536.

57. Addison, CD. (2006). *Oyster recruitment and yearly growth patterns in the Barataria estuary.* M.S. Thesis, Nicholls State Univ., Thibodeaux, LA. 119 pp.

58. Day, JW. & Hunter RG. (2013). *Restoration and Conservation of coastal forested wetlands in the gulf of Mexico.* U.S. Endowment for Forestry and Communities, Greenville, South Carolina.

59. Butler, P. A. (1985). Synoptic review of the literature on southern oyster drill Thais haemastoma floridana (No. 35) (pp. 69–77). NOAA.

60. Dennison, WC. and Thomas, JE. (2010). Environmental Leadership: achieving a sustainable future by fostering environmental champions. In: Longstaff, BJ., Carruthers, TJB., Dennison, WC., Lookingbill, TR., Hawkey, JM., Thomas, JE., Wicks, EC. and Woerner, JL. (eds). *Integrating and applying science: a practical handbook for effective coastal ecosystem assessment.* Chapter 2. 244 pp. IANPress.

61. Peters, DPC. (2010). Accessible ecology: synthesis of the long, deep, and broad. *Trends in Ecology and Evolution,* 25: 529–601.

62. Brown, G., Montag, JM., & Lyon, K. (2012). Public participation GIS: a method for identifying ecosystem services. *Society & Natural Resources*, 25(7): 633–651.

63. Clavel, L., Soudais, J., Baudet, D., & Leenhardt, D. (2011). Integrating expert knowledge and quantitative information for mapping cropping systems. *Land Use Policy*, 28(1): 57–65.

64. Day, JW., Britsch, LD., Hawes, SR., Shaffer, GP., Reed, DJ., & Cahoon, D. (2000). Pattern and process of land loss in the Mississippi Delta: A spatial and temporal analysis of wetland habitat change. *Estuaries* 23: 425.

65. Yuill, B., Lavoie, D., & Reed, DJ. (2009). Understanding subsidence processes in coastal Louisiana. *Journal of Coastal Research* 54: 23–36.

66. Newton, A., Carruthers, TJB., & Icely, J. (2012). The coastal syndromes and hotspots on the coast. *Estuarine, Coastal and Shelf Science,* 96: 39–47.

67. Couvillion, BR., Steyer, GD., Wang, H., Beck, HJ., & Rybczyk, JM. (2013). Forecasting the effects of coastal protection and restoration projects on wetland morphology in coastal Louisiana under multiple environmental uncertainty scenarios. *Journal of Coastal Research*, 67: 29–50.

68. Bailey, C., Gramling, R., & Laska, SB. (2014). Complexities of Resilience: Adaptation and Change within Human Communities of Coastal Louisiana. In *Perspectives on the Restoration of the Mississippi Delta*, ed. JW. Day, GP. Kemp, AM. Freeman, & DP. Muth, 125–140. Estuaries of the World. Springer Netherlands.

69. Couvillion, BR., Barras, JA., Steyer, GD., Sleavin, W., Fischer, M., Beck, H., Trahan, N., Griffin, B., & Heckman, D. (2011). *Land area change in coastal Louisiana from 1932 to 2010.* U.S. Geological Survey.

70. Batker, D., de la Torre, I., Costanza, R., Day, JW., Sweedeen, P., Boumans, R. and Bagstad, K. (2014). The threats to the value of ecosystem goods and services of the Mississippi Delta. In: Day, JW. et. al. (eds) *Perspectives on the restoration of the Mississippi Delta.* Springer pp155–173.

71. Visser, JM., Day, J., Battaglia, LL., Shaffer, GP., & Hester, MW. (2012). Mississippi River Delta Wetlands. In *Wetland Habitats of North America: Ecology and Conservation Concerns*, 63–74. California: University of California Press.

72. Beck, MW., Heck, KL., Able, KW., Childers, DL., Eggleston, DB., Gillanders, BM., Halpern, B. et al. (2001). The identification, conservation, and management of estuarine and marine nurseries for fishes and invertebrates. *Bioscience,* 51: 633–641.

73. Minello, TJ. & Rozas, LP. (2002). Nekton in Gulf coast wetlands: Fine-scale distributions, landscape patterns, and restoration implications. *Ecological Applications,* 2: 441–455.

74. Minello, TJ., Able, KW., Weinstein, MP., & Hays, CG. (2003). Salt marshes as nurseries for nekton: testing hypotheses on density, growth and survival through meta-analysis. *Marine Ecology Progress Series,* 246: 39–59.

75. De Groot, RS., Wilson, MA., & Boumans, RMJ. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics,* 41: 393–408.

76. Mitsch, WJ., & Gosselink, JG. (1986). *Wetlands*. Van Nostrand Reinhold Company.

77. Walbridge, MR. (1995). Functions and values of forested wetlands in the southern United States. *J. For*. 91: 15–19.

78. Keller, CE., Spendelow, JA., & Greer, RD. (1984). *Atlas of wading bird and seabird nesting colonies in coastal Louisiana, Mississippi, and Alabama: 1983*. U.S+E70. Fish Wildl. Serv. FWS/OBS-84/13. vi and 127 pp.

79. Brasher MG. (2016). *Review of the Benefits of Marsh Terraces in the Northern Gulf of Mexico*. Ducks Unlimited, Inc., Gulf Coast Joint Venture, 700 Cajundome Blvd, Lafayette, LA 70506.

80. U.S. Army Corps of Engineers. (2014). *Economic Guidance Memorandum*, 15–01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2015.

81. Ferrario, F., Beck, MW., Storlazzi, CD., Micheli, F., Shepard, CC., Airoldi, L. (2014). The effectiveness of coral reefs for coastal hazard risk reduction and adaptation. *Nature Communications*, 5(3794): 1–9.

82. Möller, I., Kudella, M., Rupprecht, F., Spencer, T., Paul, M., van Wesenbeeck, BK., Wolters, G., Jensen, K., Bouma, T.J., Miranda-Lange, M., Schimmels, S. (2014). Wave attenuation over coastal salt marshes under storm surge conditions. *Nature Geoscience*, 7: 727–731.

83. U.S. Army Corps of Engineers. (2013). *Coastal Risk Reduction and Resilience: USACE Civil Works Directorate.*

84. Lane, RR., Mack, SK., Day, JW., DeLaune, RD., Madison, MJ., & Precht, PR. (2016). Fate of Soil Organic Carbon During Wetland Loss. *Wetlands*, 36: 1167.

85. Mack, SK., Yankel, C., Lane, RR., Day, JW., Kempka, D., Mack, JS., Hardee, E., & LeBlanc, C. (2014). *Carbon market opportunities for Louisiana's coastal wetlands* (p. 70). Tierra Resources.

86. Chabreck, RH. (1972). *Vegetation, water, and soil characteristics of the Louisiana coastal region.* Louisiana State University Agricultural Experiment Station.

87. Odum, WE., Smith III, TJ., Hoover, JK., & McIcor, CC. (1984). *The ecology of tidal freshwater marshes of the United States east coast: a community profile* (No. FWS/OBS-83/17). Washington D.C.: U.S. Fish and Wildlife Service.

88. Cowardin, LM., Carter, V., Golet, FC., & LaRoe, ET. (1979). *Classification of wetlands and deepwater habitats of the United States*. Washington, D.C.: US Department of the Interior, Fish and Wildlife Service.

89. Visser, JM., Sasser, CE., Chabreck, RH., & Linscombe, RG. (1998). Marsh Vegetation Types of the Mississippi River Deltaic Plain. *Estuaries*, 21(4): 818–828.

90. Duarte, CM., Middelburg, J., Caraco, N. (2005). Major role of marine vegetation on the oceanic carbon cycle. *Biogeosciences,* 2: 1–8.

91. Heck, KL., Carruthers, TJB., Duarte, CM., Hughes, AR., Kendrick, G., Orth, RJ., & Williams, SW. (2008). Trophic transfers from seagrass meadows subsidize marine and terrestrial consumers. *Ecosystems,* 11: 1190–1210.

92. Heck, KL., Hays, C., & Orth, RJ. (2003). A critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series,* 253: 123–136.

93. Couvillion BR., Fischer, MR., Beck, HJ. & Sleavin, WJ. (2016). Spatial configuration trends in coastal Louisiana from 1985 to 2010. *Wetlands,* 36: 347–359.

94. Jerabek, AS., Darnell, KM., Pellerin, C., & Carruthers, TJB. Submitted. Use of marsh edge and submerged aquatic vegetation as habitat by fish and crustaceans in south Louisiana. Southeastern Geographer, submitted for publication.

95. McKee, KL., & Faulkner, PL. (2000). Restoration of Biogeochemical Function in Mangrove Forests. *Restoration Ecology*, 8(3), 247–259.

96. Beck, M.W. (2014). *Coasts at Risk: An Assessment of Coastal Risks and the Role of Environmental Solutions*. A joint publication of United Nations University – Institute for Environment and Human Security (UNU-EHS), The Nature Conservancy (TNC) and the Coastal Resources Center (CRC) at the University of Rhode Island Graduate School of Oceanography.

97. Massel, SR., Furukawa, K., & Brinkman, RM. (1999). Surface wave propagation in mangrove forests. *Fluid Dynamics Research,* 24: 219–249.

98. UNEP-WCMC (2006) I*n the Front Line: Shoreline Protection and other Ecosystem Services from Mangroves*. UNEP World Conservation Monitoring Centre, Cambridge, UK, 33 pp.

99. Ong, JE. (1993). Mangroves—a carbon source and sink. *Chemosphere,* 27: 1097–1107.

100. Osland, MJ., Enwright, N., Day RH., & Doyle, TW. (2013). Winter climate change and coastal wetland foundation species: salt marshes vs. mangrove forests in the southeastern United States. *Global Change Biology*, 19: 1482–1494.

101. Day, JW., Kemp, GP., Reed, DJ., Cahoon, DR., Boumans, RM., Suhayda, JM., & Gambrell, R. (2011). Vegetation death and rapid loss of surface elevation in two contrasting Mississippi delta salt marshes: The role of sedimentation, autocompaction and sea-level rise. *Ecological Engineering*, 37(2): 229–240.

102. Scavia, D., Field, J., Boesch, D., Buddemeier, R., Burkett, V., Cayan, D., Fogarty, M., Harwell, M., Howarth, R., Mason, C., Reed, D., Royer, T., Sallenger, A., & Titus, J. (2002). Climate change impacts on U.S. Coastal and Marine Ecosystems. *Estuaries,* 25(2): 149–164.

103. Peyronnin, N., Green, M., Richards, CP., Owens, A., Reed, D., Chamberlain, J., Groves, DG., Rhinehart, WK., & Belhadjali, K. (2013). Louisiana's 2012 coastal master plan: Overview of a science-based and publicly informed decision-making process. *Journal of Coastal Research*, *67*: 1–15.

104. Muth, DP. (2014). The once and future delta. In: Day, JW., Kemp, GP., Freeman, AM. and Muth, DP. (eds). *Perspectives on the restoration of the Mississippi Delta – The once and future delta.* Springer. 194 pp.

105. Coastal Protection and Restoration Authority of Louisiana. (2007). *Louisiana's 2007 Comprehensive Master Plan for a Sustainable Coast*. Baton Rouge, LA: Coastal Protection and Restoration Authority of Louisiana.

106. Coastal Protection and Restoration Authority of Louisiana. (2017). *Louisiana's 2017 Comprehensive Master Plan for a Sustainable Coast*. Baton Rouge, LA: Coastal Protection and Restoration Authority of Louisiana.

107. Byrnes, MR., Griffee, SF., & Osler, MS. (2010). *Channel dredging and geomorphic response at and adjacent to Mobile Pass, Alabama*. Technical Report ERDC/CHL TR-10-8, U.S. Army Engineer Research and Development Center, Vicksburg, MS, 309 pp.

108. Horstman, EM., Dohmen-Janssen, CM., Narra, PMF., van den Berg, NJF., Siemerink, M. & Hulscher, SJMH. (2014). Wave attenuation in mangroves: A quantitative approach to field observations. *Coastal Engineering*, 94: 47–62.

ACKNOWLEDGEMENTS

Thank you to the many people who provided input and assistance during this project.

In particular, we would like to thank Matt Bethel (Louisiana Sea Grant), Rex Caffey (Louisiana Sea Grant), Megan LePeyre (U.S. Geological Survey and Louisiana State University AgCenter), Corey Miller (Coalition to Restore Coastal Louisiana), Mike Osland (U.S. Geological Survey), Amy Smith-Kyle (The Nature Conservancy), Greg Steyer (U.S. Geological Survey), and Jenneke Visser (University of Louisiana Lafayette) for your help preparing for and facilitating the social and ecosystem science workshop, as well as providing input to the habitat summary pages, and reviewing drafts of the report. We thank Laura Hundy, and Eric Yando for assistance with note taking during breakout sessions.

We would also like to thank participants who are members of academic, state, federal, and not-for-profit organizations working on various aspects of coastal restoration. Participants included: Melissa Baustian, Traci Birch, Hillary Collis, Craig Colten, Kelly Darnell, Richard Day, Jim Flocks, Mark Ford, Sean Graham, Raynie Harlan, James Harris, Theryn Henkel, Mark Hester, Richard Keim, Tara Lambeth, Nicole Love, Earl Melancon, Leland Moss, Tyler Otego, Mike Pasquier, Melanie Saucier, Gary Shaffer, Michael Seymour, Jason Shakelford, Courtney Schupp, Camille Stagg, John Tirpak, and Julie Whitbeck.

Organizing community workshops and events in Delcambre would not have been possible without the help of Tom Hymel from Louisiana Sea Grant and Wendell Verret from Delcambre Direct and the Port of Delcambre. We would like to extend our gratitude to Jim Wiggins for the use of his beautiful camp, Ken 'Mushy' Fremin for his culinary skills, and the Delcambre Seafood and Farmer's Market for inviting us to participate in their monthly event. Special thanks to the women at CWPPRA's outreach and media team, Victoria Sagrera and Nikki Cavalier, for joining us in Delcambre. Of course, much thanks must be extended to folks from Delcambre who participated in our first session for the valuable input and good company they provided: Jacob Bourque, Julie DuBois, Ken 'Mushy' Fremin, Tom Hymel, Jennifer Mestayer-Kidd, Danelle Rednard, Victoria Sagrera, Donald Segrera, Mary Segrera, Barry Toupes, Wendell Verret, Jim Wiggins, and GloriaWiggins.

In St. Bernard, Rhonda Rodriguez, president of the Isleño Heritage and Culture Society, graciously allowed us the use of the Isleño Center and helped reach out to residents from east St. Bernard Parish. She also fed us with a delicious shrimp stew! We would also like to thank councilwoman Kerri Callais for allowing us to set up at the Sippin' on the Bayou events. The participants from our small group meeting gave us valuable details about the changes they have seen in their backyards, the frustrations they face, and the advice of where and how to address their community's pressing environmental crisis. Our gratitude goes out to these participants who took the time to walk us through their stories and concerns: Carrie Bernal, Robert Campo, Jerry Estopinal, Freddy Everhart, Rusty Gaude, Rhonda Hannan, Bill Hylan, Glen Menesses, Blaise Pezold, Louis Pomes, Charlie Robin, Ricky Robin, Susan Robin, Henry Rodriguez, Jr., Doris Serigne, Lloyd 'Wimpy' Serigne, and Monique Verdin.

Finally, thanks to Harris Bienn, Ryan Clark, Shila Daswani, Andrea Jerabek, Philip Lafargue, Chincie Mouton, Maddie Munch, and Sequoia Riley at the Water Institute of the Gulf for assistance with workshops.

"This community has deep roots. A few broken branches won't kill us."

St. Bernard workshop participant, May 2016

THE WATER INSTITUTE
OF THE GULF®

301 NORTH MAIN STREET, SUITE 2000
BATON ROUGE, LA 70825

(225) 448-2813
WWW.THEWATERINSTITUTE.ORG