Using Louisiana's coastal history to innovate its coastal future

By

Natalie S. Peyronnin
Environmental Defense Fund, npeyronnin@edf.org

Richard Condrey
Louisiana State University (retired), coecnd@lsu.edu

Louisiana's Comprehensive Master Plan for a Sustainable Coast (Coastal Master Plan or CMP) is an evolving coastal planning process that began before 1998. The successive iterations of the Coastal Master Plan have never envisioned that its implemented projects would restore Louisiana's coast to historic levels (LCWCRTF and WCRA 1998 Table 5-1; Barras *et al.* 2003 Figure 19; Couvillion *et al.* 2011; CPRA 2012 Figures 5.11 and 5.12; Couvillion *et al.* 2013; CPRA 2017). Rather, until 2017, the plan predicted that its implemented projects would first slow then reverse Louisiana's current, catastrophic annual rates of land loss if, and only if, at least two events occurred: the observed rates of subsidence declined and the rate of sea level rise was "moderate" (CPRA 2012 Figure 3.3). The science behind the 2017 Coastal Master Plan suggests that neither of these events are likely. Rather the 2017 CMP concluded that the observed rates of subsidence had not declined (Reed and Yuill 2016) and concurred with the possibility that the rates of sea level rise would be "high" (CPRA 2017 Figure 3.6). As such, the 2017 CMP predicts an even less optimistic future for the Louisiana coast than its previous iterations, with the predicted loss of between 5,800 and 10,600 square kilometers of the coast, over the next 50 years, without further human intervention (CPRA 2017). The plan lays out $25 billion in projects over 50 years to restore the coastline (and another $25 billion in storm risk reduction features for communities). Even with this substantial investment, Louisiana is only predicted to stave off between 30%-40% of the potential loss. In keeping with the spirit of the CMP, we suggest that a bold, new approach will help to restore and rebuild coastal Louisiana and transition to a smaller, more sustainable delta — one that will embrace the delta-building properties of the Mississippi River and coastal-protection properties of vast offshore oyster reefs.

LOUISIANA'S COASTAL REEF HISTORY

To envision a more sustainable coastal future, it might help to look back at our coastal history, back to when the coast was functioning as a more natural system — one that was self-sustaining. Within 45 years of their "discovery of the New World," Spanish sailors had outlined the coast of the Americas from the northern Atlantic to the southern Pacific and documented the extensive reefs which lined the Gulf of Mexico's (GoM) shore (Chaves ca. 1537; Condrey *et al.* 2014).

At least three of the reefs throughout the GoM were apparently dominated by the oyster *Crassostrea virginica* and are hypothesized to have depended on submarine freshwater discharges of groundwater, as well as periodic surface water inputs during flood periods, from the Mississippi, Apalachicola, and Suwanee River basin aquifers to maintain viable offshore salinities (Chaves ca. 1537; Barroto 1667; Evia 1968; Dumain 1807; Charlevoix 1744; Condrey *et al.* 2014).

One of these offshore oyster reefs — as we here name it, the Great Barrier Reef of the Americas (GBRA) — was massive. It extended along the coast of central Louisiana for more than 160 km and out into the GoM for 8 to 16 km (Figure 1). Its surface was normally under ~1 m of water, but was visible to sailors during periods of low water (Chaves ca. 1537; Barroto 1667; Evia 1968; Dumain 1807; Condrey *et al.* 2014).

At its western end, the GBRA was the southern face of an important offshore harbor, apparently frequented in the 1500s by Spanish vessels catching favorable winds from Veracruz to Havana and Spain. Once in the harbor, the vessels were protected from southerly and easterly winds and seas by the GBRA and from northerly winds by the Cape of the Cross (now Chenier au Tigre, the most easterly oak ridge of Louisiana's Chenier Plain). This harbor provided an entrance into the River of the Holy Spirit (now Vermillion Bay's Southwest Pass), the westernmost outlet for the Mississippi River. During the annual flood, the River of the Holy Spirit sent plumes of fresh water out over the face of the reef for 16 km into the GoM (Chaves ca 1537; Evia 1968; Condrey *et al.* 2014), likely limiting the reef's height.

From the 1500s through the early 1800s, the GBRA was a dangerous impediment to navigation. Spanish vessels sailed along its southern face in the open waters of the GoM even though this made the mainland hard to see, apparently using grounded drifttrees from the Mississippi River as markers (Barroto 1687). Narrow channels meant tedious passage of shallow draft vessels across the north-south axis of the reef (Evia 1968; Audubon 1837). An east-west channel separated the GRBA's northern face from Louisiana's mainland, and was used as an "inland passage" during the late 1700s and 1800s. Frequent shipwrecks involving the GBRA and its east-west channel prompted two government-financed surveys, while international rivalry prompted a third. The first was conducted under Spanish rule by Evia in 1785, the second under U.S. President Thomas Jefferson's orders to Dumain in 1807, and the third by Gauld in 1778 scouting the Spanish coast of Louisiana coast for Great Britain. Evia (1968) provides detailed measurements of the GBRA, the freshwater outflow of the Mississippi River's flood into the GoM, and vividly documents the reef's first-line-of-defense role in coastal protection. Dumain (1807) provides independent confirmation of Evia's measurements, discusses the necessity of a GBRA-related lighthouse, and describes how enemy vessels could attack New Orleans through GBRA-associated waterways. Gauld's observations (1778) independently support those of Evia, Dumain, and Barroto and explain how islands were forming from grounded drifttrees on the GBRA.

When Audubon sailed from the Mississippi's Southwest Pass to Galveston Bay, Louisiana's still sparsely settled coast was beginning to erode. Passage between Louisiana's islands was no longer limited to pirogues. The oysters on at least the northern face of the GBRA were dead, had been dead for some time, and their empty shells were accumulating on the Louisiana shore, bleaching in the sun. As Audubon writes to his "dear friend" William MacGuillivary while "snugly" anchored in Cote Blanche Bay (Audubon 1838):

> "After visiting 'Rabbit Island,'… we make our way between it and Friskey Point [possibly Point au Fer], by a narrow and somewhat difficult channel leading to the bay in which I now write. The shores around us are entirely formed of a bank, from twenty to thirty feet [6-9 m] high, and composed of concrete shells of various kinds, among which the Common Oyster, however, predominates. This bank, which at present looks as if bleached by the sunshine and rains of centuries, is so white that it might well form a guiding line to the vessels which navigate this bay even in the darkest nights…
>
> "The crossing of large bays, cumbered with shallow bars and banks of oyster-shells, is always to me extremely disagreeable, and more especially when all these bars and banks do not contain a single living specimen of that most delectable shell-fish. Nay, I am assured by our pilot, who is no youngster, that ever since he first visited this extensive waste, not an oyster has been procured in these parts."

In the year 1853, Lieutenant B. F. Sands surveyed the area between Ship Shoal and Last Island for the U.S. government which was considering the need for and location of a lighthouse. Despite a detailed survey which included 35,000 lead casts, Sands' report and accompanying map show no indication of this portion of the GBRA (Sands 1853; Gerdes 1853), suggesting that at least this portion of the reef which Audubon had found dead in 1837 had not recovered, but disintegrated, likely due to human-induced reductions in the amount of Mississippi River water flowing to the basins as a result of levees and distributary closure and resulting aquifer recharge.

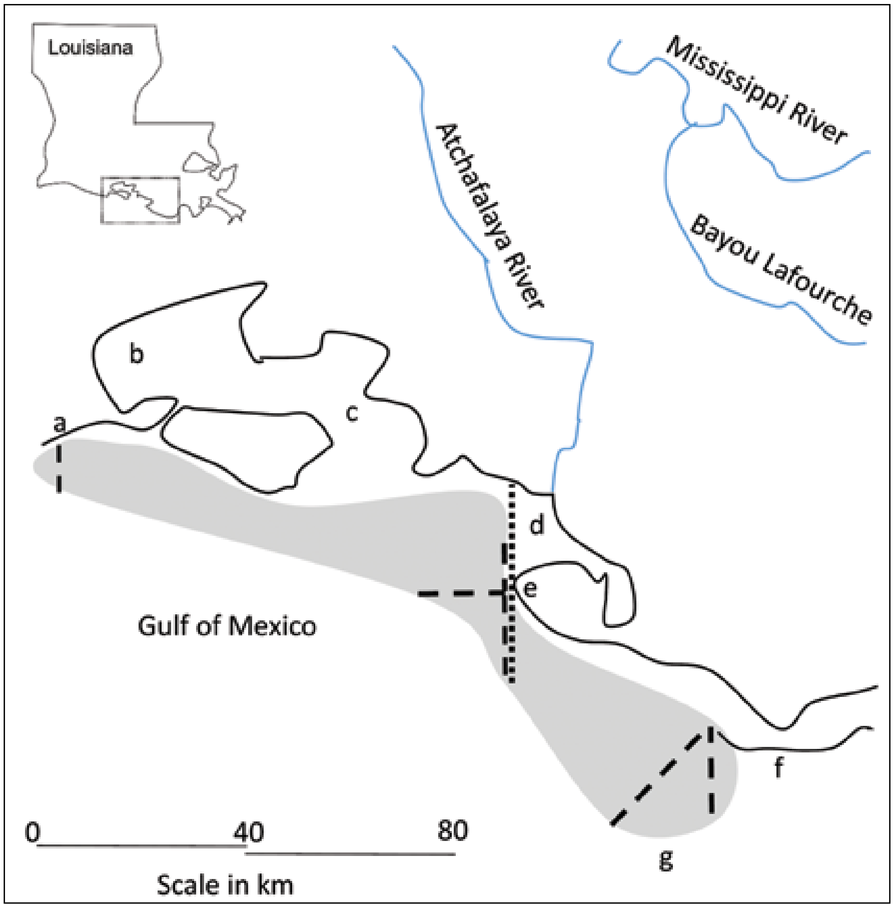


Figure 1. Estimated extent of the Great Barrier Reef of the Americas (GBRA, gray area) in 1785-1807 based on the surveys conducted by Evia (1968, dashed lines) and Dumain (1807, dotted line) and the consistency of their measurements with the observations reported in Chaves (ca. 1537), Barroto (1687), Gauld (1778), and Audubon (1838). Coastal points: a) Cheniere au Tigre; b) Vermilion Bay; c) Cote Blanche Bay; d) Atchafalaya Bay; e) Point au Fer; f) estimated extent of Last Island in 1800; g) Ship Shoal. The reef, while a major impediment to navigation, played a vital role in coastal protection and advance until its demise in first half of the 1800s, likely as the result of human alterations in ground- and surface-water discharges of the Mississippi River Basin. No pre-1840 surveys have been located which contradict this interpretation.

VAST OYSTER REEFS WERE OUR FIRST LINE OF DEFENSE

As Louisiana focuses on re-establishing the natural, land-building processes of the river in the current CMP, this recently discovered history of the GBRA suggests it had reached a size substantial enough to provide key ecosystem services to the coast. These vast oyster reefs, or "living shorelines," played an essential role in attenuating wave energies from storms or regular tidal cycles and stabilizing sediments, subsequently protecting sandy barrier islands and headlands, as well as interior wetlands from erosion (Evia 1968), allowing the wetlands in turn to provide additional storm protection benefits.

Remnants of these historic oyster reefs along Louisiana's coast were heavily mined from the 1940s through the 1990s for commercial purposes, including road bed material, until a moratorium and later law was passed in 1998 (USACE 2004). The shell mining operations of the 20th century decimated what was left of the GBRA. The mining of historic oyster reefs in the East Cote Blanche Bay (which Audubon had visited in 1837) has resulted in drastic changes to the hydrodynamics of the Atchafalaya and Vermilion Bay systems and a substantial increase in the freshwater influence on the western portion of this system. Modeling indicates that wave heights in Atchafalaya Bay have increased by nearly 2.5 feet in fair-weather conditions due to the loss of

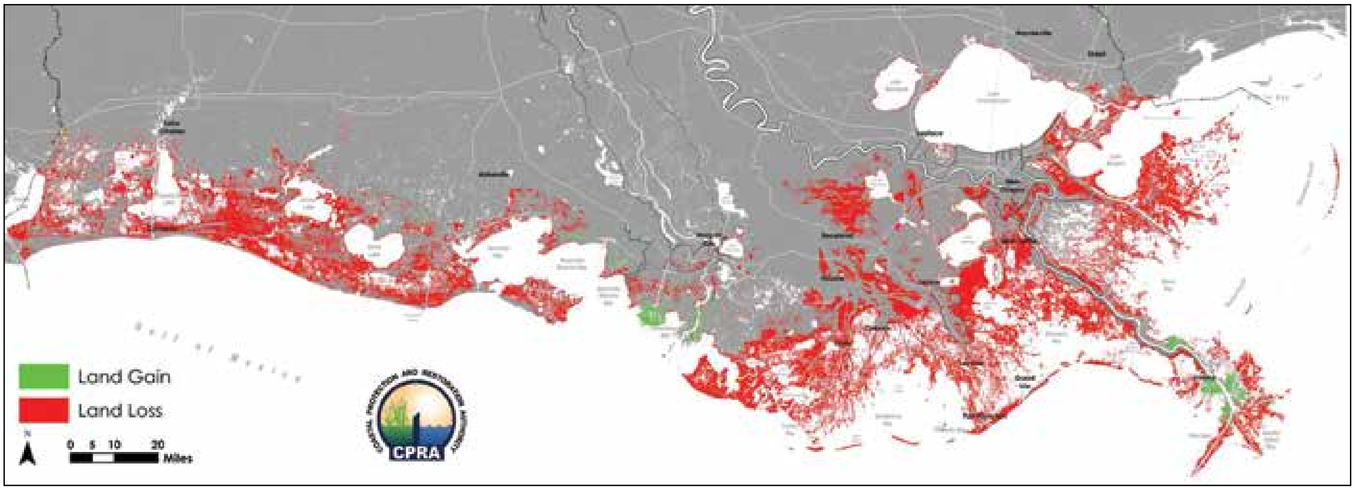


Figure 2. Coastal land change over 50 years without human intervention under the medium environmental scenario (CPRA 2017).

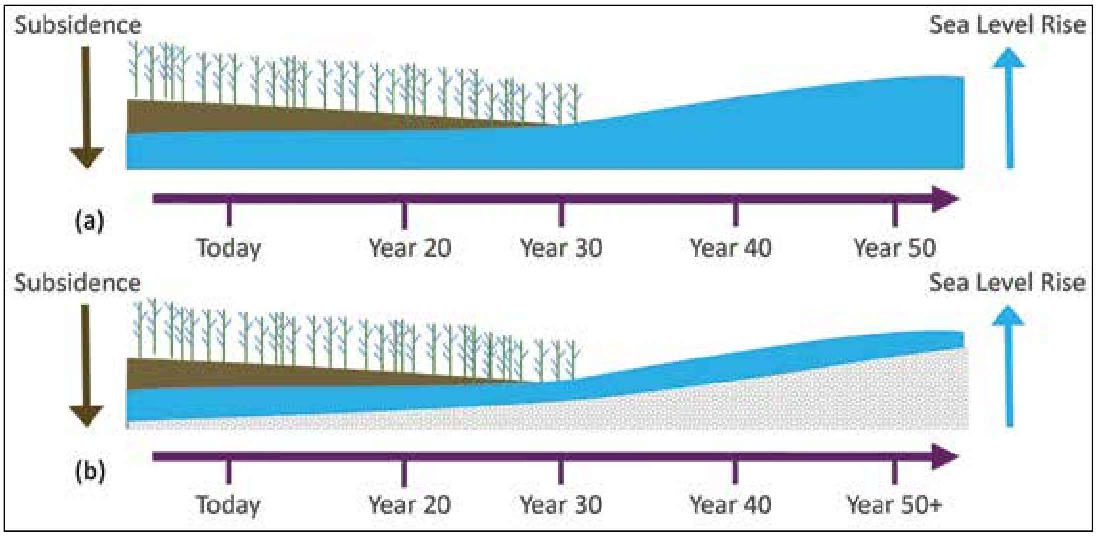
these reef structures (Stone *et al.* 2004). The increase in storm surge energy and waves during tropical events can also be attributed in part to the removal of the historic shoal reefs. The loss of this protective coastal feature resulted in much of the Louisiana coast being transformed from a low-energy, protected environment to an open, wave-dominated, high-energy marine environment (Stone and McBride 1998; Sheremet and Stone 2003; Stone *et al.* 2004). The loss of shoreline oyster reefs has also allowed increased water exchange between the gulf and the interior water bodies of the Chenier Plain (USACE 2004), allowing more saltwater intrusion into interior freshwater and intermediate marshes.

These reefs can provide a wide array of other ecosystem services. Their three-dimensional structure can reduce water velocities, increase sedimentation rates, and enhance propagule settlement and retention, creating a more suitable environment for many species (Scyphers *et al.* 2011). The more quiescent environment created behind the reef increases sediment deposition and trapping from river flood events, sustaining and building interior marshes. Older, established reefs can also contribute shell bits to the marsh surface that help maintain marsh surface elevation, which is particularly important in areas of high subsidence and low sediment input, such as Terrebonne Bay and the Chenier Plain.

Oyster reefs provide a diversity of microhabitats that support complex ecological communities including fish and invertebrate species. The oyster reef ecosystem function is linked to the reef's unique shell structure, as the reefs are created by the constant adhesion of new larva to existing shells. As new oysters grow, available space accretes above the substrate, which forms a matrix of interstitial spaces that are critical to habitation by oysters and other organisms (NOAA n.d.). Similar to coral, oysters are referred to as "ecosystem engineers" because they change the physical environment and provide spatial habitat for a multitude of other marine organisms (Stokes *et al.* 2012). Recent studies of natural, restored, and artificial reefs indicate that oyster reef communities in many areas are highly diverse and include many species not found in adjacent soft-bottom habitats. Plunket and La Peyre (2005) found that the oyster structures provide important habitat for benthic fish and decapod crustaceans and provided valuable foraging sites for transient species.

Oysters greatly influence nutrient cycling in estuarine systems and help to maintain ecosystem stability. Oysters filter large amounts of phytoplankton and detritus in the water column, as well as metabolize nutrients and cycling carbon which benefits the entire ecosystem. In this cycling process, oysters consume suspended particles and utilize the or-

Figure 3. Conceptual diagram depicting the future of coastal marshes affected by sea level rise and subsidence both (a) without human intervention and (b) with the potential growth of oyster reefs over decades and centuries to replace ill-fated marshes and provide a coastal buffer.



ganic matter for growth, and the excess inorganic nutrients (dissolved carbon, nitrogen, phosphorous) are excreted by the bivalves for use to support the trophic system (NOAA n.d.). Encrusting organisms on oyster reefs, such as tunicates and barnacles, can contribute to the overall filter capacity of a reef, and thrive where the structure of reefs is three-dimensional (e.g. pyramid-shaped) rather than shallow (NOAA n.d.). In addition to nutrient cycling, the denitrification of coastal waters and filtering of suspended sediment facilitates the growth of marine grasses which helps to hold wetlands in place (Stokes *et al.* 2012).

Since these oyster reefs provide concentrated and abundant food sources for gamefish, they also enhance the value of recreational fisheries and help support other trophic levels of the estuarine ecosystem. Their potential to increase marine fisheries production supports over 200,000 jobs in a $2.4 billion fishing industry (Stokes *et al.* 2012).

LOUISIANA'S COASTAL REEF FUTURE

The 2017 Coastal Master Plan clearly suggests that a loss of marsh habitat will occur across the coast over the next 50 years (Figure 2), even with planned wetland restoration efforts. Instead of considering success in terms of restoring the "status quo," we may be better served to start envisioning a smaller, more sustainable coastline of the future that could be restored and maintained with the limited natural resources, such as sediment and fresh water, and limited societal resources, such as time and funding. We propose that we should explore innovative approaches to transforming the current landscape instead of maintaining the landscape that exists today.

We cannot rebuild the GBRA or other massive offshore oyster reefs, due to the lack of appropriate salinities and human alterations to the hydrology, as well as the immense cost of such an endeavor. But the coastline of today will become the offshore environment of the future. Within 50 years, and in some areas as soon as 30 years, water depths within the current marsh platform will increase, especially as sea level rises exponentially, and large swaths of marsh will be lost. Land loss and increasing water depths will challenge the cost-effectiveness of putting off establishing large-scale oyster reefs until the marsh is already gone. Instead, we propose to utilize the natural growing features of an oyster reef over the next few decades to transform areas of brackish or intermediate marsh today into extensive oyster reefs in the future. By constructing shallow subtidal oyster reefs in small, open-water bodies within areas of degraded marsh, the oyster reefs can establish and grow over the coming decades and centuries, provide diversity, and provide protection to delay the demise of the adjacent wetlands (Figure 3). Over time, the marsh slowly subsides or floods while oyster reefs grow and expand in their place (Figure 4). In the near-term, the oyster reef restoration will increase habitat diversity and provide other key ecosystem services. In the long-term, habitats could transition from a marsh complex to an oyster reef complex, thereby maintaining the coastline, protecting interior wetlands from further erosion and providing storm surge protection to valuable infrastructure and communities.

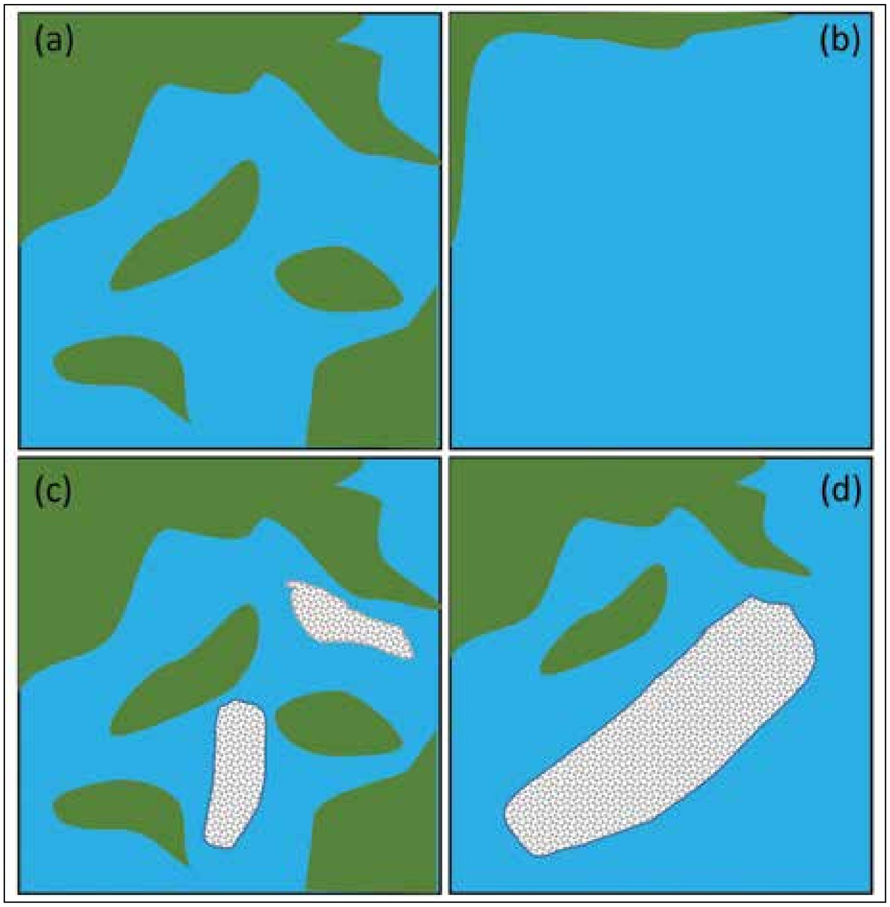


Figure 4. Conceptual diagram depicting the: a) current degraded state of coastal wetlands; b) predicted future wetland loss without human intervention; c) implementation of shallow oyster reefs among degraded marsh today; and d) the growth of oyster reefs over decades and centuries to provide a coastal buffer, prevent future wetland loss, and protect remnant coastal marshes.

The predicted future without human intervention (Figure 2) can be used to define areas where oyster reefs could be established to provide protection to coastal communities and remnant marshes that would otherwise be lost. Proper siting would be necessary to ensure that the oyster reefs could be established and prosper. However, the location does not need to be constrained by the narrower range of the harvestable oyster, as growth will occur over many decades. Sediment diversions, hydrologic restoration and the maintenance of existing freshwater flows would be essential to the establishment and long-term viability of these oyster reefs. Under the right salinity conditions, oyster reefs can adapt to other environmental shifts, such as sea level rise, growing fast enough to outpace even the most extreme predictions of future sea level rise (Rodriguez *et al.* 2014).

One example of where this could be implemented in is the Chenier Plain of the Texas and Louisiana coast. The gulfside marshes, such as in McFadden National Wildlife Refuge or the Rockefeller Wildlife Refuge, are predicted to be lost in the future, thereby exposing hundreds of thousands of acres of marsh, important infrastructure, such as Highway 82, and coastal communities, such as Cameron and Port Arthur to the high-energy Gulf environment. As the marsh either sinks due to subsidence or is flooded by rising seas, these oyster reef complexes can provide a hardened shoreline that offers protection to the vast remaining wetland complex of the Chenier Plain. We aren't suggesting that in 50 years you can rebuild what nature built over centuries, but we can build small portions of the GBRA, in new locations, that over the next centuries and generations of Louisianans, with on-going management of the freshwater resources, can provide substantial benefit to the nearby marshes and communities.

CONCLUSION

Louisiana's Coastal Master Plan consistently looks toward the past, when the Mississippi River flowed naturally, for ideas on how to restore the delta. Reconnecting the river through sediment diversions, keystone restoration projects of the plan, will provide some benefits today, but also have long-term benefits that will be seen in future generations. Oyster reef restoration can be carried out with the same long-term vision. Louisiana's coastal waters have historically been the site of vast offshore oyster reefs which played a vital role in the overall health and sustainability of Louisiana's coastline, but, planning efforts have consistently undervalued the benefits of oyster reef restoration. Shell mining, altered freshwater flows, and changes in hydrodynamics are largely responsible for the historic degradation of this resource, resulting in increased wave energy, erosion, and loss of interior wetlands during fair weather events and tropical storms, as well as a loss of biodiversity. We call on planners, scientists, and engineers in Louisiana — and beyond — to explore and research how investing in oyster reef restoration today can be a return on investment for future generations and help to establish a sustainable coast.

REFERENCES

Audubon, J.J., 1838. "On Board the Crusader, Cote Blanche, 18th April 1837." *The Edinburgh Journal of Natural History and of the Physical Sciences* 1:171.

Barras, J., S. Beville, D. Britsch, S. Hartley, S. Hawes, J. Johnston, P. Kemp, Q. Kinler, A. Martucci, J. Porthouse, D. Reed, K. Roy, S. Sapkota, and J. Suhayda, 2003. "Historical and projected coastal Louisiana land changes: 1978-2050." USGS Open File Report 03-334, 39 p. (Revised January 2004).

Barroto, J.E., 1667. *Diario del viaxe y navegazión que por orden del exmo. señor Conde de la Monclova virrey governador y capitán general de la Nueva Spaña, se executó en dos piraguas.* Real Biblioteca, Patrimonio Real, Madrid. 50 p.

Charlevoix, P.F.X. de, 1744. *Histoire et description generale de la Nouvelle France: avec le journal historique d'un voyage fait par ordre du roi dans l'Amérique septentrionnale.* 3v.

Chaves, A. de, ca. 1537. *Cosmografía práctica y moderna llamado Espejo de Navegantes.* Real Academia de la Historia, Madrid, MS 9/2791.

Condrey, R., P. Hoffman, and D.E. Evers, 2014. "The last naturally active delta complexes of the Mississippi River (LNDM): Discovery and implications." pp. 33-50 in *Perspectives on the restoration of the Mississippi Delta: The Once and Future Delta.* J. Day, G.P. Kemp, A. Freeman, and D.P. Muth (Editors). Elsevier. Estuaries of the World 20: 194 p.

CPRA, 2012. "Louisiana's comprehensive master plan for a sustainable coast: committed to our coast," draft Jan 2012. Coastal protection and restoration authority of Louisiana. Baton Rouge, LA. 170 p. and appendices.

CPRA, 2017. "Louisiana's Comprehensive Master Plan for a Sustainable Coast. Coastal Protection and Restoration Authority of Louisiana." Baton Rouge, LA. 171 p. and appendices.

Couvillion, B.R., J.A. Barras, G.D. Steyer, W. Sleavin, M. Fischer, H. Beck, N. Trahan, B. Griffin, and D. Heckman, 2011. "Land area change in coastal Louisiana from 1932 to 2010: pamphlet to accompany Scientific Investigations Map 3164." U.S. Geological Survey, Reston Virginia. 12 p.

Couvillion, B.R., G.D. Steyer, H. Wang, H.J. Beck, and J. M. Rybczyk, 2013. "Forecasting the effects of coastal protection and restoration projects on wetland morphology in coastal Louisiana under multiple environmental uncertainty scenarios." *J. Coastal Res.,* 67 (sp1), 29-50.

Dumain, L., 1807. Letter of July 20, 1807, to A. Gallatin. American State Papers. Documents, legislative and executive, of the Congress of the United States, from the first session of the first to the third session of the 13th Congress, inclusive: Commencing 3 March 1799 and ending 3 March 1815. W. Lowrie and M St. C. Claire eds. Gales and Seaton, Washington. American State Papers 1832. vol VII. Class IV. Commerce and Navigation. p 841.

Evia, J. de, 1968." Jose de Evia y sus reconocimientos del Golfo de México, 1783-1796." *Ediones J. Porrua Turanzas*, Madrid. 264 pp.

Gauld, G., 1778. "A Plan of the coast of part of west Florida & Louisiana: including the River Yazous." https://www.loc.gov/resource/g4012c.ct000670/.

Gerdes, F.N., 1853. "Preliminary Chart of Ship Island Shoal Louisiana." Sketch H No. 6, U.S. Coast Survey.

Kilgen, R.H., and R.J. Dugas. 1989. "The ecology of oyster reefs of the northern Gulf of Mexico: an open file report." NWRC-open file rep. 89-02

LCWCRTF and WCRA, 1998. *Coast 2050: Toward a sustainable coastal Louisiana. Louisiana coastal wetlands conservation and restoration task force and the wetlands conservation and restoration authority.* Louisiana Department of Natural Resources, Baton Rouge, LA, 161 p.

National Oceanic and Atmospheric Administration (NOAA), n.d. "Value of Oysters." Retrieved 20 June 2017, from http://www.habitat.noaa.gov/pdf/value_of_oysters.pdf.

Plunket, J., and M.K. La Peyre, 2005. "Oyster beds as fish and macroinvertebrate habitat in Barataria Bay, Louisiana." *Bulletin of Marine Science* 77(1): 155-164.

Reed, D., and B. Yuill, 2016. 2017 *Coastal Master Plan: Attachment C2-2: Subsidence.* Version I. (p. 15). Baton Rouge, Louisiana: Coastal Protection and Restoration Authority. 8 p.

Rodriguez, A.B., F.J. Fodrie, J.T. Ridge, N.L. Lindquist, E.J. Theuerkauf, S.E. Coleman, J.H. Grabowski, M.C. Brodeur, R.K. Gittman, D.A. Keller, and M.D. Kenworthy, 2014. "Oyster reefs can outpace sea-level rise". *Nature Climate Change* 4: 493-497.

Sands, B.F., 1853. [Report to Professor A.D. Bauche, Superintendent U.S. Coast Survey] page 69 in Report of the Superintendent of the Coast Survey, showing the progress of the Survey during the year 1853. Washington. 184 p.

Scyphers, S., S. Powers, K. Heck, and D. Byron, 2011. "Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries." *PubMed Central (PMC)*,6(8).

Sheremet, A., and G. Stone, 2003. "Observations of nearshore wave dissipation over muddy sea beds." *J. Geophysical Res.* 108 (C11): 3357.

Stokes, S., S. Wunderink, M. Lowe, and G. Gereffi, 2012. "Restoring Gulf Oyster Reefs." Retrieved 20 June 2017, from http://www.mississippiriverdelta.org/files/2012/07/CGGC_Oyster-Reef-Restoration.pdf.

Stone, G., and R. McBride, 1998. "Louisiana barrier islands and their importance in wetland protection: forecasting shoreline change and subsequent response of wave climate." J. *of Coastal Research* 14: 900-915.

Stone, G., A. Sheremet, X. Zhang, and D. Braud, 2004. "Wave and storm protection provided by Louisiana's Gulf Shoreline: Barrier islands and shell reefs." In: *Louisiana Gulf Shoreline Restoration Report.* University of New Orleans, Pontchartrain Institute for Environmental Sciences. Technical Series 04-003.

U.S. Army Corps of Engineers (USACE), 2004. "Louisiana Coastal Area (LCA), Louisiana Ecosystem Restoration Study." New Orleans, Louisiana. www.lca.gov.