Risks, Resiliency, and Restoration:
The Three Rs of Sustainable Development in a Coastal Barrier Resources System

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Testimony
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Subcommittee on Fisheries and Oceans
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There are fundamental policies that the subcommittee of Fisheries and Oceans should consider as they support the inventory of our coastal barrier resources system. Such principles are very important in policies that solve problems within coastal boundaries including: (1) habitat loss, (2) eutrophication, and (3) coastal hazards. With 80% of the coastal land loss of the entire US, the largest seasonal hypoxic zone (nearly the size of New Jersey), and now two devastating hurricanes in a single month, the Gulf Coast has the opportunity to promote sound policy associated with issues dealing with coastal barrier resources systems. The issues and policies (federal and state) associated with rebuilding the Gulf Coast are those of national importance, which will require strong leadership in integrating risks, resiliency and restoration.

Coastal Louisiana has long been a landscape of rich natural resources and extensive human settlements that have tried to manage the **risks** of occupying an extremely dynamic coastal environment – the eight largest river delta in the world. This process of adaptation by both ecological and social systems provides insights into how coastal communities in the US will face increased challenges to sustainable development. Now the stakes are higher as we in Louisiana struggle with not only rebuilding our natural resources, 'America's Wetlands' of the Mississippi River delta, but also the social systems that have been devastated by two hurricanes, Katrina and Rita. So we are dealing with the challenge of promoting the **resiliency** of both natural and social systems by providing necessary resources. If **restored** properly, the Gulf Region will develop new paradigms as to how coastal communities deal with risks and hazards of the coastal zone. But we are developing this rebuilding process in a political environment of great urgency, which I advocate requires even greater commitment to a few fundamental principles of how to integrate protection and restoration of the ecological-social landscape within the coastal barrier resources system.

The loss of wetland resources in Louisiana has been occurring for over one hundred years, estimated at 1.2 million acres of coastal wetlands since the 1900's, and prior to Katrina was projected to lose another 300,000 acres by 2050. In post-hurricane analysis, it is estimated that another 100 square miles of wetlands in Louisiana were damaged by

the two recent hurricanes (analysis by USGS). Although many of these apparent disturbances to coastal barrier system may recover, there are some regions that longer-term impacts may take several months to accumulate; while many regions are stressed to the point that natural recovery may not be possible.

These wetlands relied on the distribution of water and sediment from the Mississippi River to keep the geomorphic landscape upon which diverse natural resources, both plant and animal communities, thrived to support a state known as 'sportsman paradise'. The underlying causes of losing 'America's Wetlands' include public work projects in navigation and flood control that reduced risks to social systems by directing river resources, fertile sediments and freshwater, directly out to the Gulf of Mexico, bypassing the deltaic floodplain where human communities had developed. In addition, energy related industries built various canals and waterways through marsh landscape that not only promoted access for oil and gas rigs, but also provided conduits for saltwater intrusion and storm surges. These artificial changes to the landscape to reduce risks to social systems worked against the **coastal processes** of the river delta causing stress and risks to wetland vegetation. So over the last 50 years reducing the risks to human settlements and economic infrastructure has been done at increased risk to ecological systems that rely upon the coastal barrier system for survival.

The coastal wetland landscape has been degrading for nearly 100 years, while the entire social system and industrial infrastructure along the coast was devastated in a month by hurricanes Katrina and Rita. There is an urgency to promote the resiliency of economic infrastructure that will rebuild social systems and provide protection and jobs to communities along the coast. This has to be done while we validate models and their assumptions as to the proper combination of wetland resources and levee systems that are needed to secure and protect sustainable economic development. This validation process, with intense data collection and proper peer review, will be instrumental in planning for risks in the future. This planning needs a science and engineering program that integrates the theories and practices of natural and social sciences to establish guidelines with the engineering sciences in designing a sustainable and safe coastal barrier resources systems. This will require these three sciences (natural, social and engineering) to resolve the following three questions in a cooperative environment. **What is at stake? What processes are at work? What can be done to sustain economic and natural resources?** The continued isolation of these three issues by these three disciplines among existing institutions will amplify the continued increased risks of living in coastal communities of Louisiana and throughout the US. From now on, the public will demand accountability to the long-standing paradigm of projects with 'unintended consequences'.

So **what is at stake** if we do not properly rebuild both the social and natural capital of coastal barrier resources systems. More than 30% of the nation's fisheries catch comes from America's Wetland, and it provides one of the largest habitats in the world for migratory waterfowl. More than 25% of all the oil and gas used in the United States either originates from or passes through this working wetland, the distribution point for energy supplies to the entire eastern U.S. Louisiana's port system, including New Orleans, Port Fourchon, Baton Rouge, and related smaller ports connected by the

Intracoastal Waterway, is the largest in the world, including greater tonnage that Rotterdam or Singapore, the next largest port systems. The coastal area currently provides a buffer from hurricane storm effects to approximately 2 million residents who live within the 19 coastal parishes (counties). Roughly half of the Louisiana coastal population resides outside of New Orleans and depends on the wetlands either directly or indirectly for employment in fisheries and the oil and gas industry.

So we cannot abandon either the economic or the natural resources of this region – this is a working coast that provides goods and services of tremendous national importance. At the same time, we have natural resources that also provide goods and services of equally national importance. The challenge is to find engineering solutions to risks and sustainability that consider the goods and services of both economic and natural resources of coastal regions.

So **what are the processes at work** in coastal barrier resource system along this region of the Gulf coast (Boesch et al. 1994). Understanding the fundamental processes of the delta cycle is prerequisite to any policy that deals with geomorphic and ecologic features of this coastal barrier resources system (Fig. 1). Transgressional sequences at the province and basin scales of coastal Louisiana govern smaller scale successional changes at the habitat scale of the marsh. The proximity of fluvial processes to marshes shift as distributaries of the Mississippi River migrate along the coast, changing the distribution of sediment, nutrients, and salt that control the type of habitat that colonizes the emergent zones of the basin. Thus there are continued changes not only from emergent to open water as part of the transgressional sequences, but the community composition of the emergent lands changes among fresh water, intermediate, brackish, and salt marsh vegetation (Fig. 2). As fluvial processes decrease, there is a lack of fresh water discharge to control sea water encroachment, causing salt and brackish marshes to migrate landward, either replacing fresh water marshes or converting marshes to open water (Fig. 2). During active delta formation, such as observed in the Atchafalaya River basin, there is a migration of fresh water and intermediate vegetation toward the coast as salinity regimes decrease in the coastal zone. Processes at all three spatial scales including province, basin and habitat levels are coupled to produce a spatial mosaic of changes in wetland cover and composition that form very complex and dynamic patterns of coastal barrier system. The result of these processes across the Mississippi River Deltaic Plain is 6,177,610 acres (2,500,000 ha) of marshes that account for 60% of the coastal wetlands in the lower 48 states. These patterns of coastal processes have to be incorporated in any perspective of coastal restoration and rehabilitation.

The fundamental **processes** that the natural, social and engineering sciences will have to consider include a very dynamic landscape – which requires policies that promote adaptation rather than a philosophy of control. New Orleans, Louisiana's port and many coastal communities exist within a changing mosaic of barrier islands, salt marshes and freshwater swamps. Rebuilding after Katrina and Rita must address the ongoing and dynamic changes in this landscape – just as coastal restoration efforts did before these storms inflicted their damage, as described in our November 2004 LCA (Louisiana Coastal Area) report . For the last several thousand years, the land building or deltaic

processes resulted in a net increase of more than 4 million acres of coastal wetlands, even with the occurrence of sea level rise, subsidence, and hurricanes. In addition, there was the creation of an extensive skeleton of higher natural levee ridges along the past and present Mississippi River channels, distributaries, and bayous in the river deltaic plain and beach ridges of the Chenier deltaic plain.

Wetland loss is caused by soil accumulation insufficient to offset sinking of the land and rising sea levels. Human activities (canals, hydrologic modifications, failed reclamation, flood control measures) have caused wetland loss to accelerate; and prevented the natural processes to rebuild landscape features elsewhere along the coast. Without an aggressive ecosystem restoration effort, high rates of wetland loss will continue. The relative rise in sea level is an issue in coastal Louisiana; as it is in the Everglades, coastal Carolinas, Delmarva Peninsula, and New Jersey-New York coast. Given the high subsidence rates (land sinking) along with the seas rising, New Orleans is seeing now what many of these other coastal communities will see in about 4-5 decades. Given this condition, many proponents argue that we should give up on New Orleans. If that is the case, then we should also begin the systematic retreat of every coastal community in the U.S. Or we can reflect and think about a better partnership with nature; rather than viewing these situations as some sort of war with nature. This river delta experienced sea level rise three times it present level nearly 5000 years ago; and still was able to build wetland landscape given ample river resources.

As for nearly all river deltas in the world, to give up on the landscape and cultural heritage of an ecosystem that has such potential for 'ecosystem resilience' is a major statement in our political will to rehabilitate natural resources in this country. It is a statement of our stewardship of natural resources without a fight to overcome 'business as usual'. I have personally been involved in reconnecting sediment and freshwater resources from the Magdalena River in Colombia to a wetland floodplain consisting of one the largest mangrove areas in the Caribbean. Reconnecting these coastal processes, while maintaining several of the economic activities of the region, resulted in immediate and extensive response of wetland ecosystems. And in Louisiana, projects such as Caernarvon freshwater diversion, with the Caernarvon Interagency Advisory Committee, has effectively resolved conflict in ecosystem needs and stakeholder opportunities by developing ideas around the natural 'pulsing' of this landscape. Again, finding solutions by managing natural processes to sustain wetland resources while considering stakeholder use of coastal barrier resources systems. There are trade offs, and realities of consequences must be clearly stated. But business as usual can be corrected to include collaboration among natural, social and engineering sciences to build more sustainable systems in such dynamic coastal barrier resources systems.

So **what can be done** to provide proper guidelines that balance the risks to social and natural resources to promote a more integrated restoration and protection of coastal barrier resources systems along the Gulf coast (Fig. 3). The key is to understand how to deal with uncertainty in such a dynamic landscape – and how that is factored into risk management. First, effective ecosystem restoration that will sustain coastal wetlands is to manage and use the natural resources that created the coastal area. The present waste of

river resources each day is sufficient to mount a very aggressive, albeit energy intensive, campaign to artificially distribute sediments to recover some of the geomorphic features of this degrading landscape. This may take 5-10 years of aggressive use of long-distance conveyance of sediment slurries connected to present and proposed dredging activities. Then freshwater diversions, which are concrete structures in levees that allow river flow through gates to adjacent wetland floodplains, will sustain the landscape over longer several decades. These river resources are important to sustain wetland resources facing natural disturbances from relative rise in sea levels, storms, and subsidence. Along with rebuilding the deltaic floodplain, there must be an aggressive effort to restore shoreline protection and barrier islands. Many of these features will have to evaluate the negative effects of existing artificial features of the landscape, and think about reauthorizations and land-use practices that can provide opportunity of distributing water resources across the coast. Inventory of coastal barrier resources systems features, the coastal processes that sustain those features, and the free goods and services they provide are key elements of any restoration program.

The process of rebuilding coastal ecosystems as part of the social landscape will require new approaches to adaptive management strategies shared by natural, social and engineering sciences. These strategies will have to deal with uncertainties, and establish methodologies to evaluate how services from both natural and social resources reduce risks to communities along the coast. There has to be conflict resolution in securing resources to support rebuilding the infrastructure of both ecosystems, urban, and industrial sectors of the coast. As restoration alternatives are developed to change the ecosystem and rebuild human settlements, system response must be monitored to incorporate learning as part of the process. We have to accept that not all the answers are apparent in the initial investments in this joint enterprise of science and engineering, but there must be institutional commitment that financial resources will be held accountable to an adaptive management framework. It is the only way to deal with such uncertainties in a dynamic coastal setting. The only worst-case scenario is no action at all.

Large-scale ecosystem restoration programs must begin immediately, in concert with the urgency to rebuild the urban and industrial infrastructure following major disturbances. Many coastal wetland landscapes, such as Louisiana, are reaching critical points and will become technically more challenging and certainly more costly to rebuild unless actions to stabilize them occur immediately. Following major disturbances, the rebuilding process has to look at opportunities that exist to improve protection of social systems – with stronger emphasis on how restoring natural resources can provide service, at no charge once restored, to coastal communities. Coastal barrier resources systems represent some of the most impacted and altered ecosystems worldwide and are sensitive to many hazards and risks, from floods to cyclones to disease epidemics (Adger et al. 2005, Science 309:1036-1039). Thus, management agencies need to explore 'linkages between ecosystems and human societies to help reduce vulnerability and enhance resiliency of these linked systems in coastal areas'.

Footnote:

“Every phenomenon and apparent eccentricity of the river …is controlled by law as immutable as the Creator, and the engineer need only to be insured that he does not ignore the existence of any of these laws, to feel positively certain of the results that he aims at. ”

“If the profession of an engineer were not based upon exact science, I might tremble for the result, in view of the immensity of the interest dependent on my success.”

From James B. Eads, USACE
taken from ‘The Control of Nature’ by John McPhee, 1989

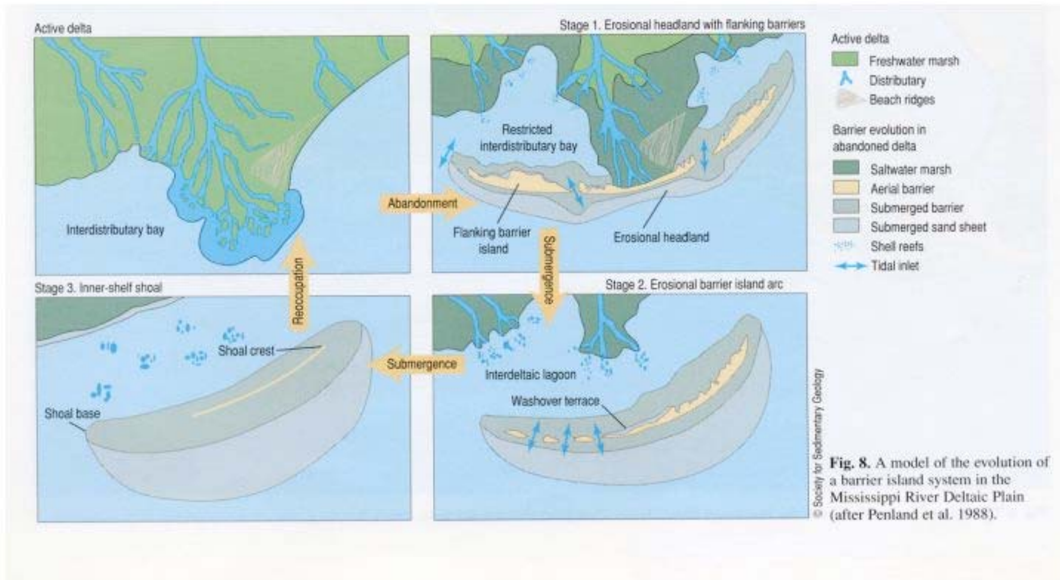

Figure 1. Model of the evolution of a barrier island system in the Mississippi River Deltaic Plain (Figure from Gosselink 1998; Original from Penland et al. 1988).

west by the natural levees of old distributaries and on the seaward edge by a barrier headland or island system. The interdistributary basin is

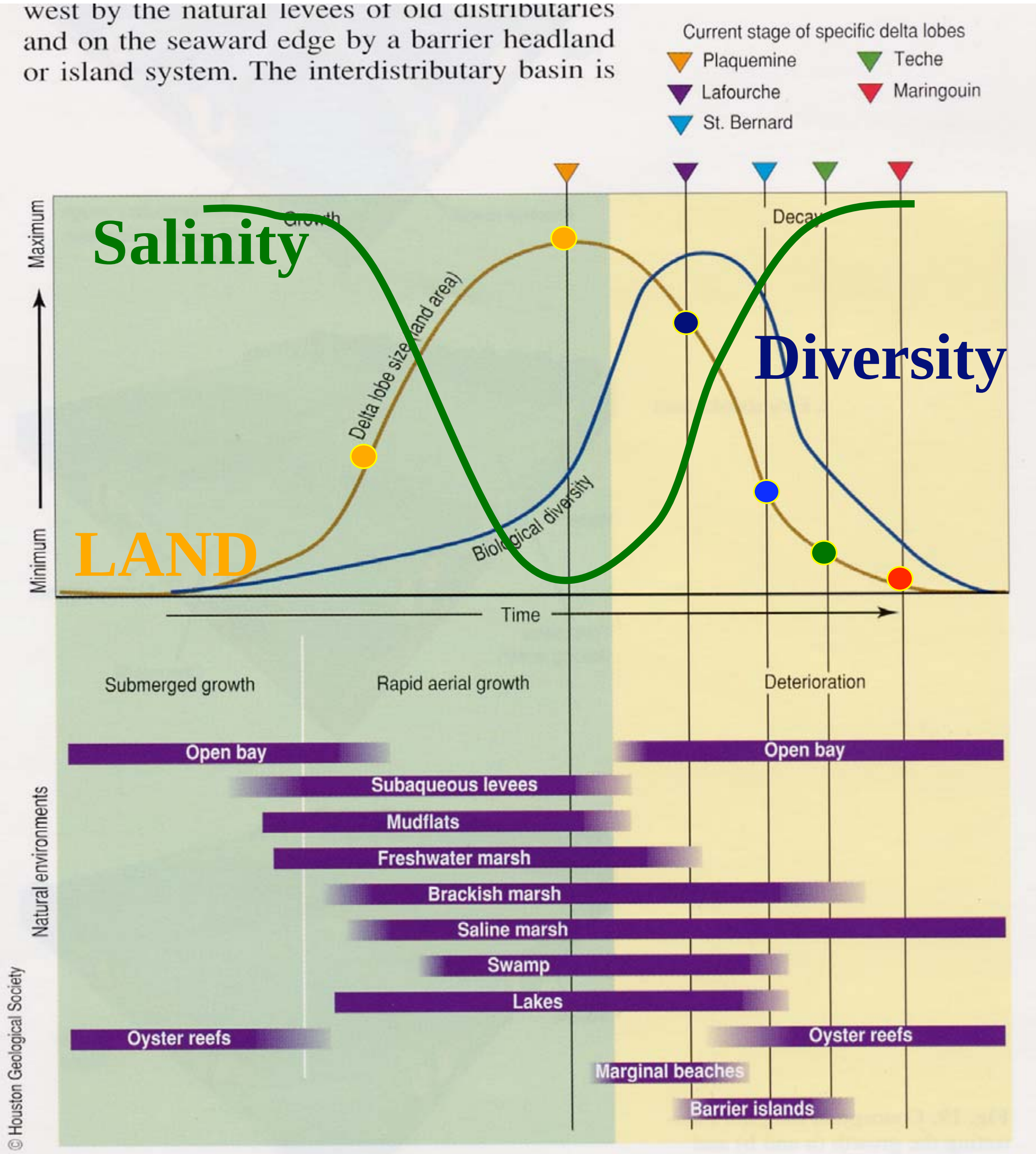

Fig. 18. Graphical depiction of the growth and decay of a delta lobe (adapted from Gagliano and Van Beek 1975; Neill and Deegan 1986). Habitat and biological diversity peak in the early to middle stage of the decay phase.

Figure 2. Conceptual model of the delta cycle depicting the growth and decay of a delta lobe (Figure from Gosselink 1998; modified from Gagliano and Van Beek 1975; Neill and Deegan 1986).

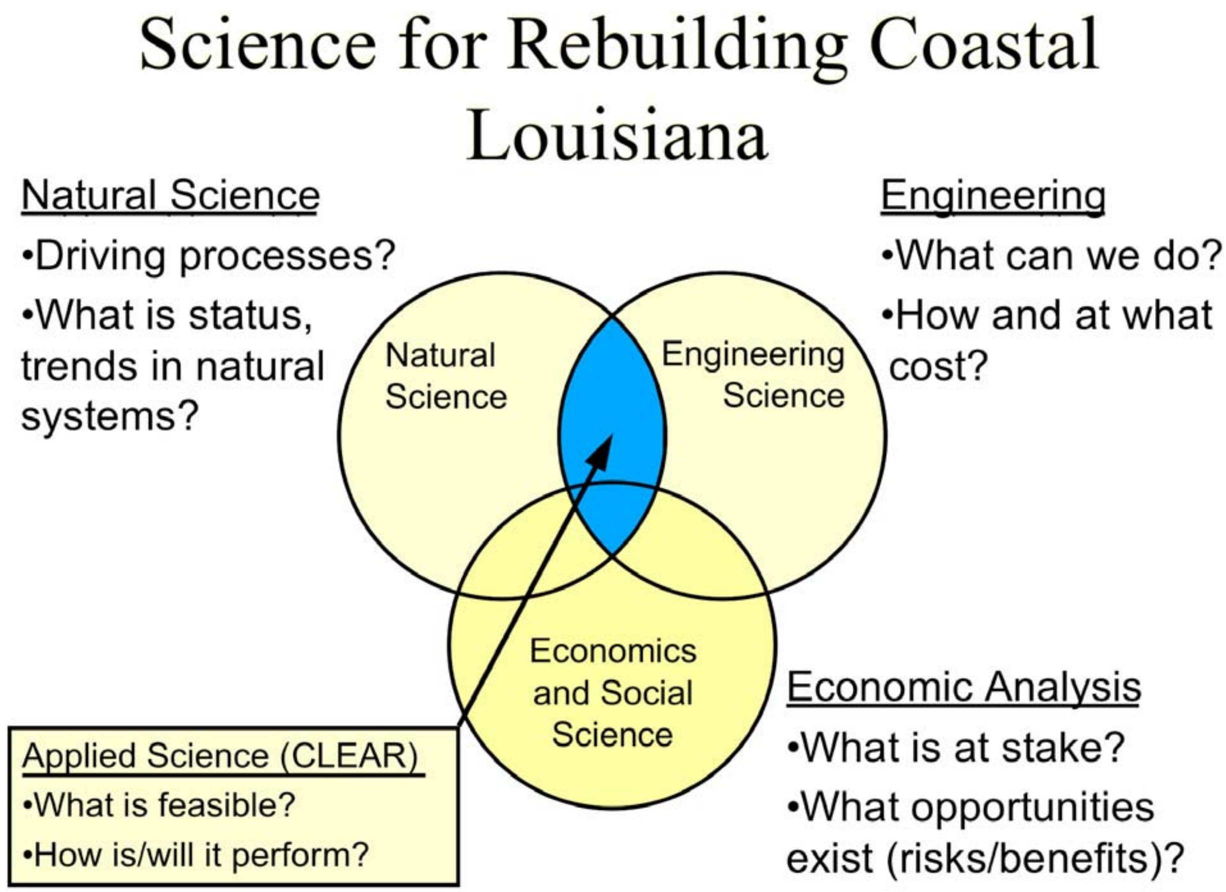

Fig. 3. Integration of the natural, social and engineering sciences to guide public work projects in coastal barrier resources systems such as coastal Louisiana. The Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) program (www.clear.lsu.edu) has developed some of the modules to accomplish this integrated framework.

References

Boesch, D.F., Josselyn M.N., Mehta A.J., Morris J.T., Nuttle W.K., Simenstad C.A., and D.J.P.Swift. 1994. Scientific assessment of coastal wetland loss, restoration and management in Louisiana. Journal of Coastal Research 20.

Gagliano, S. and J. L. Van Beek. 1975. An approach to multiuse managent in the Mississippi delta system, pp. 223-238. In, M. S. Broussard, (ed.), Deltas, models for exploration. Houston Geological Society, Texas. 555 pp.

Gosselink, J. G. 1998. Coastal Louisiana. In, Mac, M.J. P. A. Opler, C.E. Puckett Haecker, and P. D. Doran. Status and trends of the nation's biological resources. 2 vols. U. S. Department of the interior, U. S. Geological Survey, Reston, Va. 964 pp.

Neill, C. and L. A. Deegan. 1986. The effect of Mississippi River delta lobe development on the habitat composition and diversity of Louisiana coastal wetlands. American Midland Naturalist 116:296-303.

Penland, S., R. Boyd, and J. R. Suter. 1988. Transgressive depoisitional systems of the Mississippi Delta Plain: a model for barrier shoreline and shelf sand development. Journal of Sedimentary Petrology 58:932-949.

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c. Publications

(i) Related to project

1. Twilley, R. R. et al. 2003/2004. Louisiana Coastal Area Ecosystem Model. Louisiana Department of Natural Resources File Report, Volumes I/II, 578 pp.
2. Bianchi, T., J. Pennock, and R.R. Twilley (eds). **1999.** Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons, New York. 428 pp.
3. Twilley, R.R., E. Barron, H.L. Gholz, M.A. Harwell, R.L. Miller, D.J. Reed, J.B. Rose, E. Siemann, R.G. Welzel and R.J. Zimmerman. 2001. Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America**,** Washington, DC. October 2001.
4. Twilley, R. R., J. Cowan, T. Miller-Way, and P. Montagna, and B. Mortazavi. **1999**. Benthic fluxes of selected estuaries in the Gulf of Mexico, pp. 163-209. IN, T. Bianchi, J. Pennock and R. Twilley (eds). Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons.
5. Twilley, R.R, Rivera-Monroy, V.H., Chen, R., Botero, L. **1999**. Adapting an ecological mangrove model to simulate trajectories in restoration ecology. *Marine Pollution Bulletin 37:404-419.*
6. Twilley, R. R. and V.H. Rivera-Monroy. **2005**. Developing Performance Measures of Mangrove Wetlands Using Simulation Models of Hydrology, Nutrient Biogeochemistry and Community Dynamics. Journal of Coastal Research 40:79-93.
7. Perez, Brian C., John W. Day, Jr., Dubravko Justic, Robert R. Twilley. 2003. Nitrogen and Phosphorus Transport Between Fourleague Bay, Louisiana and the Gulf of Mexico: The Role of Winter Cold Fronts and Atchafalaya River Discharge. Estuarine, Coastal and Shelf Science Vol 57/56: 1065-1078. .

(ii) Other related to the project

1. Rivera-Monroy, V.H., R.R. Twilley, D. Bone, D. Childers, C. Coronodo-Molina, I.C. Feller; J. Herrera-Silveira, R. Jaffe, E. Mancera, E. Rejmankaova, J. Salisbury. **2004.** Conceptual Framework to Develop Long Term Ecological Research and Management Objectives in the Wider Caribbean Region. BIOSCIENCE 54:843-856.
2. Twilley, R.R. and R. Chen. **1998** A water budget and hydrology model of a basin mangrove forest in Rookery Bay, Florida. *Australian Journal of Freshwater and Marine Research*. 49:309-323.
3. Twilley, R.R., R.H. Chen, and T. Hargis. **1992**. Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. *Water, Air and Soil Pollution* 64: 265-288.
4. Chen, R. And R.R. Twilley. **1999**. Patterns of mangrove forest structure associated with soil nutrient dynamics along the Shark River estuary. *Estuaries* 22:1027-1042.
5. Chen, R. and R. R. Twilley. **1999**. A simulation model of organic matter and nutrient accumulation

in mangrove wetland soils. *Biogeochemistry* 44:93-118.

6. Rivera-Monroy, V., R. R. Twilley, E. Medina. **2004**. Spatial variability of soil nutrients in riverine mangrove forests at different stages of regeneration in the San Juan River estuary, Venezuela. Estuaries 27:44-57
7. Twilley, R.R., Cárdenas, W., Rivera-Monroy, V.H., Espinoza, J., Suescum, R., Armijos, M.M.' and Solórzano, L. **2000**. Ecology of the Gulf of Guayaquil and the Guayas River Estuary, pp. 245-263. IN: U. Seeliger, B.J. Kjerve (eds), Coastal Marine Ecosystems of Latin America. Springer-Verlag. New York. 360 pp.

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Climate Change Outreach/Public Service: Chair, Governor's Technical Committee on Brown Marsh Syndrome, 2000; Technical advisor, Governor's Water Commission;

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