ANSWERING 10 FUNDAMENTAL QUESTIONS ABOUT THE MISSISSIPPI RIVER DELTA

2012

A Report by the Mississippi River Delta Science and Engineering Special Team

The Science and Engineering Special Team is a network of eminent scientists and engineers convened by the National Audubon Society, the Environmental Defense Fund, and the National Wildlife Federation to provide objective and independent analysis pertaining to Mississippi River Delta restoration.

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INTRODUCTION

The Mississippi River Delta is one of the largest and most productive coastal ecosystems in North America. From energy, to fisheries, to navigation, the richness of this ecosystem has sustained the U.S. economy for 300 years. In particular, the coastal wetlands have protected communities and critical national assets from storm damage. However, this ecosystem is in grave danger. Unless we act soon, the delta and the benefits it provides our country will disappear.

The Mississippi River created the delta over the past 7,500 years, depositing sediment from upstream and changing its course periodically to find a shorter route to the Gulf of Mexico. But in the 19th and 20th centuries, levees and other artificial structures were built along the lower river for navigation and flood control. These levees isolated the river from its delta, even as dams, dikes, and other changes on the Mississippi River and its tributaries diminished sediment supply by 50 percent. When the life sustaining water and sediment of the river no longer flowed over the delta, wetlands loss rapidly accelerated. A quarter of the deltaic landscape, over 1,800 square miles, have been lost in the past 100 years. Oil and gas canals, dredged to provide energy to U.S. markets, allowed salt water from the Gulf of Mexico to intrude into freshwater areas, further stressing the ecosystem. A host of other factors—invasive species, subsidence, and sea level rise, to name a few—add to the problem. If we do not turn the tide now, much of the ecological and economic value of the delta will be lost by the end of this century.

There is widespread recognition of the need to restore the delta, but doing so will require innovative technology, billions of dollars, and a national commitment. In the face of these challenges, many have asked whether it is even possible to restore the delta. Others have wondered whether doing so should be a national priority. With so many other needs throughout our country, the thinking goes, we need compelling evidence of both feasibility and merit if we are to put the Mississippi River Delta at the top of the list.

This document presents that evidence, based on a thorough examination of the primary questions people have raised about the future of the Mississippi River Delta: What are the economic impacts of maintaining the status quo? How will restoration affect communities, fisheries, and navigation? Will sea level rise and subsidence negate our efforts? This paper systematically answers these and other questions. Our research reveals considerable consensus within and across scientific disciplines about how the Mississippi River Delta functions and what actions must be taken to ensure long term sustainability. It is clear that immediate action is warranted and is essential to the future stability of our nation's economy. Yes, saving the delta will require bold thinking and focused action. But the cost of doing nothing is far greater.

SAVING THE MISSISSIPPI RIVER DELTA

Summaries of our research are presented below.

1. Is There Enough Sediment to Restore the Delta?

The Mississippi River does not now, nor has it ever supplied enough sediment to continuously sustain the entire delta coastline. There have always been areas that were building and areas that were eroding. In recent decades, we have reduced river sediment supply by approximately half, which further constrains our ability to build land. Nevertheless, the available sediment supply is still huge and adequate to the challenge of sustaining targeted regions of coastal Louisiana, if we are able to use this valuable resource efficiently.

2. Are Diversions Useful Tools for Building Land?

If properly designed and operated, sediment diversions can build substantial land from river sediment. Historical patterns of land growth and loss also suggest that with continued subsidence and sea level rise, sediment supply must be maintained in order to sustain the land that is formed.

Photo By: Yuki Kokubo, www.yukikokubo.com

3. Will Diversions Introduce Nutrients That Harm Wetland Vegetation?

Diversions will have impacts on vegetation, particularly on the distribution of some plant species. However, without diversions and other methods for introducing sediment-rich fresh water into the ecosystems of coastal Louisiana, the wetlands will degrade to open water. Thus, the effect of nutrients is not large enough to offset the larger benefits of diversions for coastal Louisiana, particularly if diversions are pulsed to maximize sediment introduction.

4. Will Diversions Harm Fisheries?

Different species will react in varying ways to landscape changes. However, our analysis supports the claim that the large scale sediment diversions being considered for the Mississippi River Delta have a good chance of supporting the health of fisheries because they may allow the ecosystem to reset to a more sustainable baseline. In any case, the status quo will prove disastrous for the Gulf fisheries and the many human communities that depend on them.

5. How Will Restoration Affect Navigation?

Reconfiguring the river and revising the decades old Mississippi River and Tributaries Project is imperative. Doing so will secure the long term viability of Louisiana's navigation industry and its key role in the nation's economy. These needs dovetail with the state's plans to use sediment diversions to address coastal land loss.

6. Can Levees Alone Provide Enough Flood Protection?

By themselves, levees cannot provide the storm protection that will protect national assets and coastal residents. In fact, by damaging nearby wetlands or encouraging unwise development in protected areas that require pumps to stay dry, levees can actually increase exposure to flood risks. Levee systems should be only one of several lines of defense, including wetland buffers.

7. Will Restoration Measures Displace Communities?

Some communities will be affected by restoration measures that change water salinity and the locations of coastal resources. For most communities, however, lack of wetland restoration will make the coast more vulnerable to continued flooding as well as hazards such as the BP oil spill. Ultimately, these threats, and not restoration, will be what force people away from the coast. If restoration and mitigation projects are coordinated to create compatible outcomes, they will be positive activities for coastal communities.

Photo By: Yuki Kokubo, www.yukikokubo.com

8. What Does Louisiana Stand to Lose If We Do Not Restore the Delta?

Restoration of the Mississippi River Delta is required to maintain billions of dollars in state economic value. Without an aggressive restoration program, the economic activity of the coast, worth hundreds of billions of dollars, cannot be maintained.

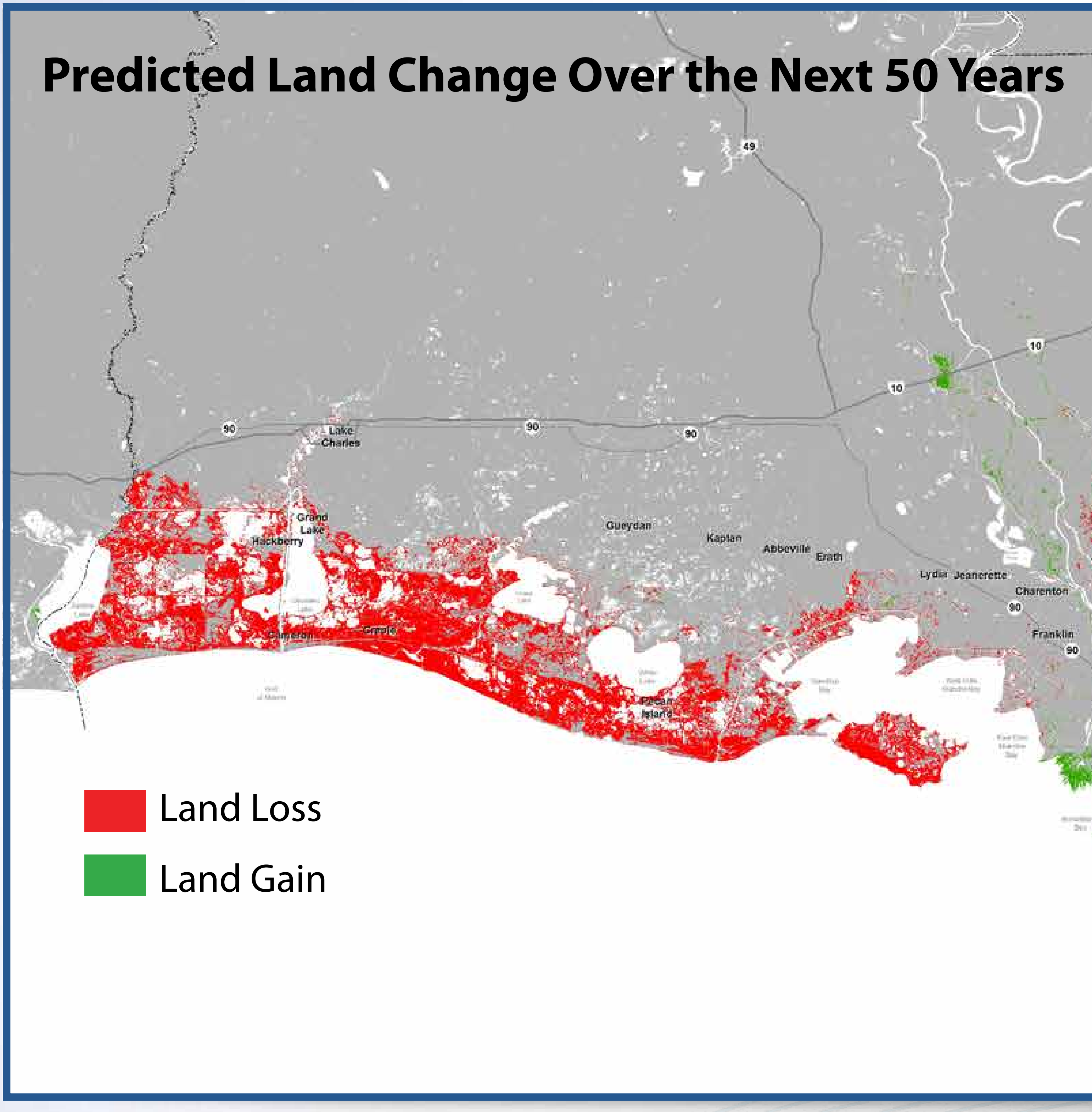
9. Why Should Restoring the Delta Be a National Priority?

An investment of up to $50 billion in initial costs to modernize the delta is justified, particularly if we substitute natural renewable energy for fossil energy to transport sediment from the river to coastal wetlands. Not only is the future of one of the world's most unique and important ecosystems at stake (along with all the economic and cultural benefits associated with that ecosystem), but the economic health of much of the United States depends on sustaining the navigation, flood control, energy production, and seafood production functions of this system. Each of those functions is currently at severe risk due to the degradation of the coastal wetlands.

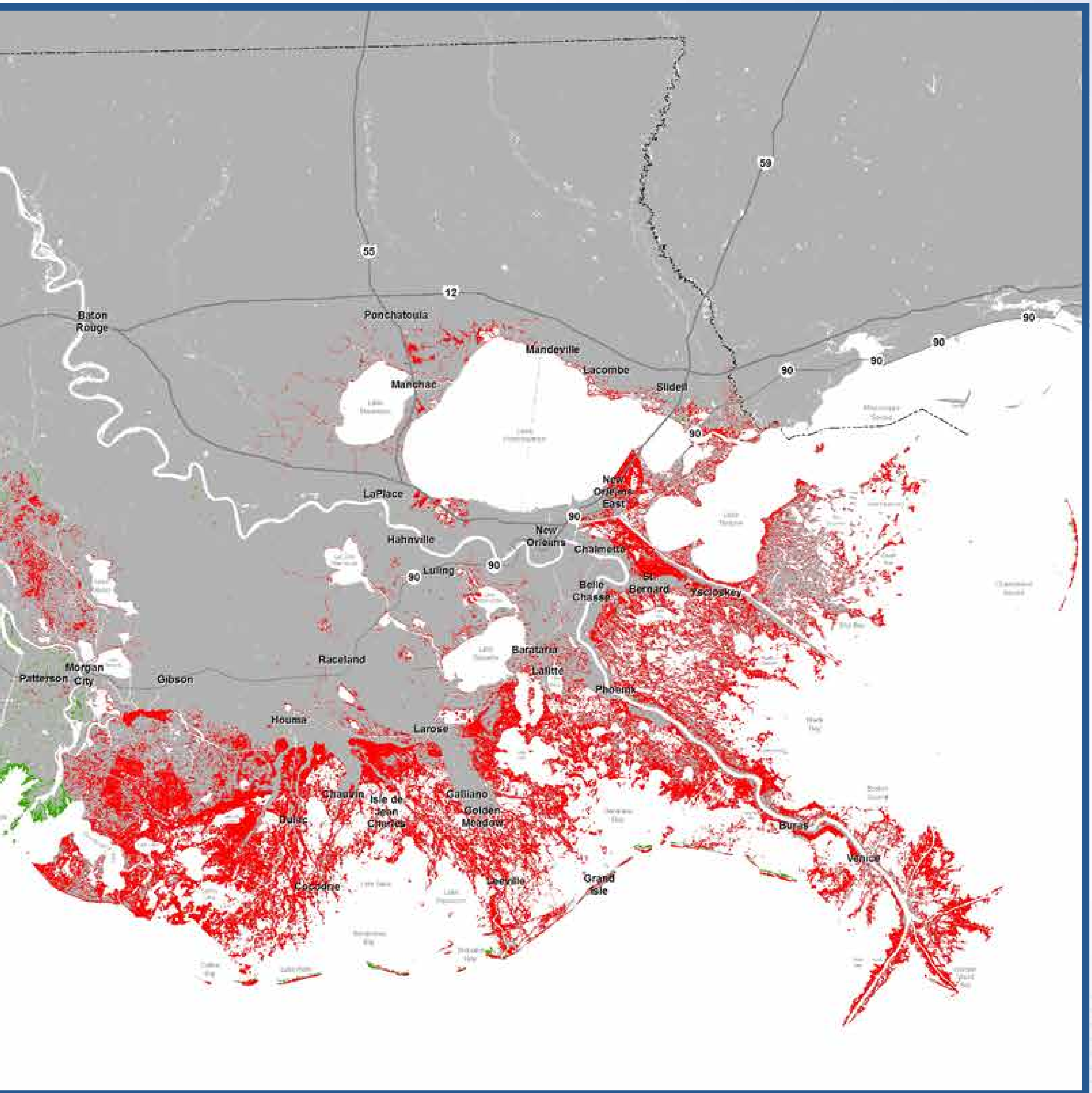
10. Is Restoration Feasible Given Climate Change and Rising Energy Costs?

Climate trends and energy costs indicate that current management of the Mississippi River and its delta will lead to cascading failures in navigation, flood protection, and wetland restoration. If the risk is recognized and effectively addressed, however, a sustainable trajectory can be achieved. This trajectory will lead to a less ecologically destructive scheme for managing the Mississippi River, one that improves the long term economic viability of deep draft navigation, storm protection, and the economy of south Louisiana. This new approach will have the additional benefit of building more coastal land to offset projected land losses.

Predicted Land Change Over the Next 50 Years



Predicted land change along the Louisiana coast over the next 50 years if we do nothing more than we have done to date. Red indicates areas likely to be lost, and green indicates areas of new land. This map is based on assumptions about increases in sea level rise, subsidence, and other factors. (Estimate based on less optimistic scenario of future coastal conditions.) Map provided courtesy of the Louisiana's Coastal Protection and Restoration Authority.



Baton Rouge
Ponchatoula
Mandeville
Lacombe
Slidell
Manchac
LaPlace
New Orleans East
New Orleans
Chalmette
Hahnville
Luling
Belle Chasse
St. Bernard
Ycloskey
Barataria
Lafitte
Phoenix
Raceland
Morgan City
Patterson
Gibson
Houma
Larose
Chauvin
Isle de Jean Charles
Galliano
Golden Meadow
Dulac
Cocodrie
Leeville
Grand Isle
Buras
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SEDIMENT AVAILABILITY

Samuel Bentley, Clinton S. Willson, Angelina Freeman

QUESTION 1

IS THERE ENOUGH SEDIMENT REMAINING IN THE MISSISSIPPI RIVER TO PROVIDE WHAT IS NEEDED FOR RESTORATION?

Sediment diversions have been identified as important tools for restoring Louisiana's coast. However, upriver management practices have reduced the amount of Mississippi River sediment carried to coastal Louisiana. As a result, some have questioned whether there is enough sediment in the river to make large scale diversions a workable strategy.

OUR ANALYSIS

We wanted to provide accurate figures about the amount of sediment in the river. To put these figures in context, we looked at the natural cycles of the Mississippi River Delta over the last 7,500 years. Doing so gave us a long term view of the levels of sediment that the river has historically provided the coastal region. We assumed that the land building capacity of the river was proportional to the sediment supply.

WHAT THE SCIENCE SAYS

For the last 7,500 years or so, the delta has undergone cyclical changes of land building. Land would build in one small part of the delta, while the majority of the coastline was retreating. Thus, the coastal extent of land retreating has always been greater than the extent of land building. The locations of land retreat and building have shifted every 1,000 to 2,000 years with the river's changing course.

The sediment supply from the Mississippi River was approximately 400 million tons per year, before the river basin was modified by dams, levees, and other structures that capture and control sediment. Of that total natural sediment supply, about 30 to 70 percent of the sediment was incorporated into the delta's landscape, while the remaining 70 to 30 percent was transported into the ocean. The present sediment supply carried by the river is approximately 200 million tons per year, making the modern land building capacity of the river about half of historic levels. Given the current amount of available sediment and understanding how the Louisiana coast was formed, today there is enough sediment to maintain about 20 percent of the Mississippi River lower delta plain, extending from the Chandeleur Islands in the east to Vermilion Bay and Marsh Island in the west.

Hurricanes and other tropical storms are another source of sediment for Louisiana's wetland ecosystems. Such storms stir up sediment from water bottoms and deposit it on the marsh surface. These fine sediments are particularly effective at maintaining existing marsh. In order to retain and consolidate this sediment, however, marshes must be healthy. For example, two different salt marshes—one at Old Oyster Bayou and one at Bayou Chitigue near lower Fourleague Bay—each received a great deal of storm driven sediment from Hurricane Andrew in 1992. Before the storm, the Old Oyster Bayou marshes were about 10 centimeters higher, had much higher soil strength in the root zone, and had been stable for over 50 years compared to Bayou Chitigue's salt marshes. Bayou Chitigue received twice as much sediment from the storm, but it retained less than half of this sediment. The healthier Old Oyster Bayou marshes retained almost all the storm driven sediment they received. This example demonstrates that for healthy marshes high enough to have adequate drainage, a little sediment can go a long way.

IMPLICATIONS FOR POLICY MAKERS

The Mississippi River does not now, nor has it ever supplied enough sediment to continuously sustain the entire delta coastline. There have always been areas that were building and areas that were eroding. In recent decades, we have reduced river sediment supply by approximately half, which constrains our ability to build land. Nevertheless, the available sediment supply is still huge and adequate to the challenge of sustaining targeted regions of coastal Louisiana, if we are able to use this valuable resource efficiently.

- As an upriver river management goal for the future, we should increase sediment flux by bypassing clogged dams, particularly on the Missouri River.
- Building diversions near upstream edges of basins with low rates of subsidence will take advantage of higher river stages and will produce the greatest and longest lasting land building effects. We recommend that these projects be constructed as quickly as possible to keep costs down.
- Some increase in river sediment is likely if high volume flood events become more common as a result of climate change.
- We should design river diversions to carry large sediment loads and deposit this sediment in relatively enclosed basins. This will ensure that the sediment is deposited in areas where it will not erode and be washed out to sea.
- Adding sediment to healthy marshes using pipelines can also be a good way to maintain existing wetlands, especially in areas distant from the river. For these projects to be successful, the marshes must be high enough to retain what is piped in.

USEFULNESS OF DIVERSIONS

Samuel Bentley, Angelina Freeman, Liviu Giosan, Clinton S. Willson, Jaye Cable

QUESTION 2

ARE DIVERSIONS OF WATER AND SEDIMENT FROM THE MISSISSIPPI RIVER USEFUL TOOLS FOR BUILDING LAND IN THE MISSISSIPPI RIVER DELTA?

Sediment diversions are man made channels for delivering sediment laden river water to the coastal ecosystem. Diversions have been proposed for land building in the Mississippi River's lower delta plain. However, some have questioned the suitability of diversions, given projected sea level rise and subsidence rates as well as the catastrophic rate of land loss that Louisiana's coast is experiencing. Our analysis examined the question: can diversions build enough land to make a difference?

OUR ANALYSIS

We considered the land building capacity of a diversion to be the ability of deposited sediment to increase the elevation of a land or seabed surface. More specifically, we viewed the change of elevation in relation to what we called "sink" factors. These include factors such as rises in global sea level and local subsidence as well as sediment compaction. Sink factors can interact in many different ways, but their combined effect is always negative for land building. If this negative effect exceeds the supply of sediment, then land will not build. If the supply of sediment exceeds the negative effect of the sink factors, then land will build in varying degrees, depending on conditions on the ground. We considered several case studies as part of our analysis, including three kinds of diversions: flood control, land building, and freshwater.

KEY TERMS

- ***Global Sea Level Rise****, also known as eustatic sea level rise, is the expansion of the ocean's volume worldwide.*
- ***Subsidence*** *is the sinking of land. Louisiana's wetlands are subsiding at varying rates.*
- ***Relative Sea Level Rise*** *is a term that encompasses the effect of both global sea level rise and local subsidence rates.*

Case Study: Wax Lake Delta

The Wax Lake Outlet of the Atchafalaya River was completed by the U.S. Army Corps of Engineers in 1942 to relieve flood pressure downstream in Morgan City, Louisiana. A small delta at the outlet mouth emerged following the 1973 flood and has since grown rapidly at rates of 2 to 3 square kilometers per year to approximately 100 square kilometers in 2005. Measurements and model simulations show that this delta growth developed while local subsidence was occurring at rates of 5 millimeters per year and sea level rise was 2 millimeters per year. Model simulations indicated that this delta growth could continue to develop at combined rates of subsidence and sea level rise of up to 14 millimeters per year. This range of net subsidence plus sea level rise is characteristic of present and projected conditions for much of the delta region.

Case Study: Cubits Gap Subdelta

The Cubits Gap Subdelta, upstream from the Head of Passes, developed from a man made cut in the Mississippi River bank made in 1862. By 1868, the gap had widened to over 200 meters, and over the next two decades an extensive delta developed that had remarkable similarities to the Wax Lake Delta at the same age. The delta reached a maximum size of approximately 200 square kilometers by the 1940s, growing at rates of 2 to 3 square kilometers per year. Following the natural delta growth and decline cycle and impacted by high subsidence rates, the Cubits Gap Subdelta then began to decline and is now in an advanced state of deterioration.

Case Study: Caernarvon Diversion

The Caernarvon and David Pond Diversions are the two largest constructed freshwater diversions in Louisiana and are subject to strict flow regulation. The Caernarvon Diversion was designed to supply fresh water and optimize salinities for oyster cultivation; it was not designed to supply sediment and build land. The diversion began operation in 1992 and has discharged, on average, considerably less water than its maximum rated flow capacity of about 220 cubic meters per second. Land building in streamside marshes at Caernarvon has been able to keep up with local relative water level rise. Sediment capture is rapidly filling Big Mar, a lake that receives flow from Caernarvon, in which about 4 square kilometers of new land have emerged in the past five years.

There has been vigorous debate as to whether the introduction of fresh water by Caernarvon made the nearby marsh more susceptible to marsh tearing during Hurricane Katrina. Some scientists claim that the fresh water weakened the marsh soils and made them more vulnerable to storm related effects. Other scientists disagree. Excessive nutrients, lack of sediments, and low salinity due to freshwater conditions may have all contributed to Katrina induced marsh tearing. Most scientists who have studied the diversion believe, however, that to improve land building, Caernarvon should introduce more sediment per unit of water diverted. This could be done by diverting water during periods when sediment concentrations in the river are high or by enhancing the concentration of sediments in diverted water. Pumping dredged sediment into the diversion stream would increase this concentration, as would constructing a berm in the river bottom to direct more of the bedload into diverted water.

Case Study: West Bay Diversion

The West Bay Diversion near Head of Passes was designed to build land. New land appeared in 2011 following a historic flood, nearly a decade after the project's construction, although extensive underwater deposits had been forming since the diversion was opened in 2004. However, the combined effects of local subsidence and rising sea level are particularly significant in this portion of the Bird's Foot Delta and may impair the long term stability of the new land built. Despite the success of new land formation at West Bay, it is currently slated for closure.

WHAT THE SCIENCE SAYS

Sediment diversions can build extensive land in open bays and other areas throughout the coast, taking into account present and projected levels of sea level rise and local subsidence. In order to achieve this outcome, however, sufficient water and sediment must be provided to allow wetland elevation to keep up with sea level rise. If the wetlands can achieve and maintain this elevation, it is possible to envision a long term future for Louisiana's coast.

Photo By: Yuki Kokubo, www.yukikokubo.com

It takes between 50 and 75 years to develop small deltas, which peak in size at about 200 square kilometers. Crevasse splay deposits, which were historically important for forming and maintaining the natural levee of the Mississippi River Delta, developed over shorter timescales of 20 to 30 years, creating deposits on the order of 15 to 20 square kilometers. The speed with which these landforms grow depends on how the system retains sediment. In Wax Lake, West Bay, and probably Cubits Gap, sediment retention rates are/were on the order of 25 to 50 percent. These rates could be increased by sending the sediment where it is most likely to build land, such as wetlands and enclosed basins that are not exposed to open water. For example, a recent study indicates that sediment retention in Lake Pontchartrain, which has fewer open boundaries to the ocean than Wax Lake or Cubits Gap, was near 100 percent following the 2011 flood and operation of the Bonnet Carré Spillway. The retention rates influencing crevasse splay deposits are not known with any confidence but are likely to be of similar order, or higher, if the flow is directed to enclosed swamps or basins.

IMPLICATIONS FOR POLICY MAKERS

If properly designed and operated, sediment diversions are capable of building substantial land from river sediment. Historical patterns of land growth and loss also suggest that with continued subsidence and sea level rise, sediment supply must be maintained in order to sustain the land that is formed. To be effective, diversions must be much larger than Caernarvon and Davis Pond, and they must deliver more sediment, both fine and coarse, than these two freshwater diversions. Future diversions should approximate the size of the many natural diversions that occurred along the Mississippi River's distributary channels as well as the Bonnet Carré Spillway, which regularly flowed at rates of 5,000 to 10,000 cubic meters per second.

Optimizing diversions' design, location, and operation for sediment capture will increase land building capacity. Data collected in specific reaches of the Mississippi River have shown a 50-fold increase above average in coarser grained sediment when the river's flow is two to three times above average. If sediment retention rates can be increased by careful selection and engineering of the basins into which diversions flow, the time required for building land can be decreased.

- Large diversions need not function every year to be effective land builders. The Bonnet Carré Spillway has been opened about once a decade, and elevations in the spillway between U.S. 61 and Lake Pontchartrain have risen as high as 2 meters, far outstripping subsidence and sea level rise.

- A pulsed diversion is one option for maximizing sediment capture. Using this approach, the diversion is operated at low to no discharge most of the year, reserving its additional pulsing capacity for those weeks of the year when river levels are high and the water contains significantly more sediment.

- Climate projections indicate that if no aggressive restoration action is taken, most coastal wetlands will disappear. A program of very large diversions will be necessary to offset this projected wetland loss.

- Large diversions should be located as far inland within deltaic basins as possible. This would take advantage of higher upstream river stages that have power to deliver sediment, and lead to a greater capture of sediment and restoration of coastal forested wetlands that are rapidly degrading.

- Building a series of very large diversions in the next decade would be a defense against rising energy costs because diversions like the Bonnet Carré Spillway can operate for more than a century with few energy subsidies following construction.

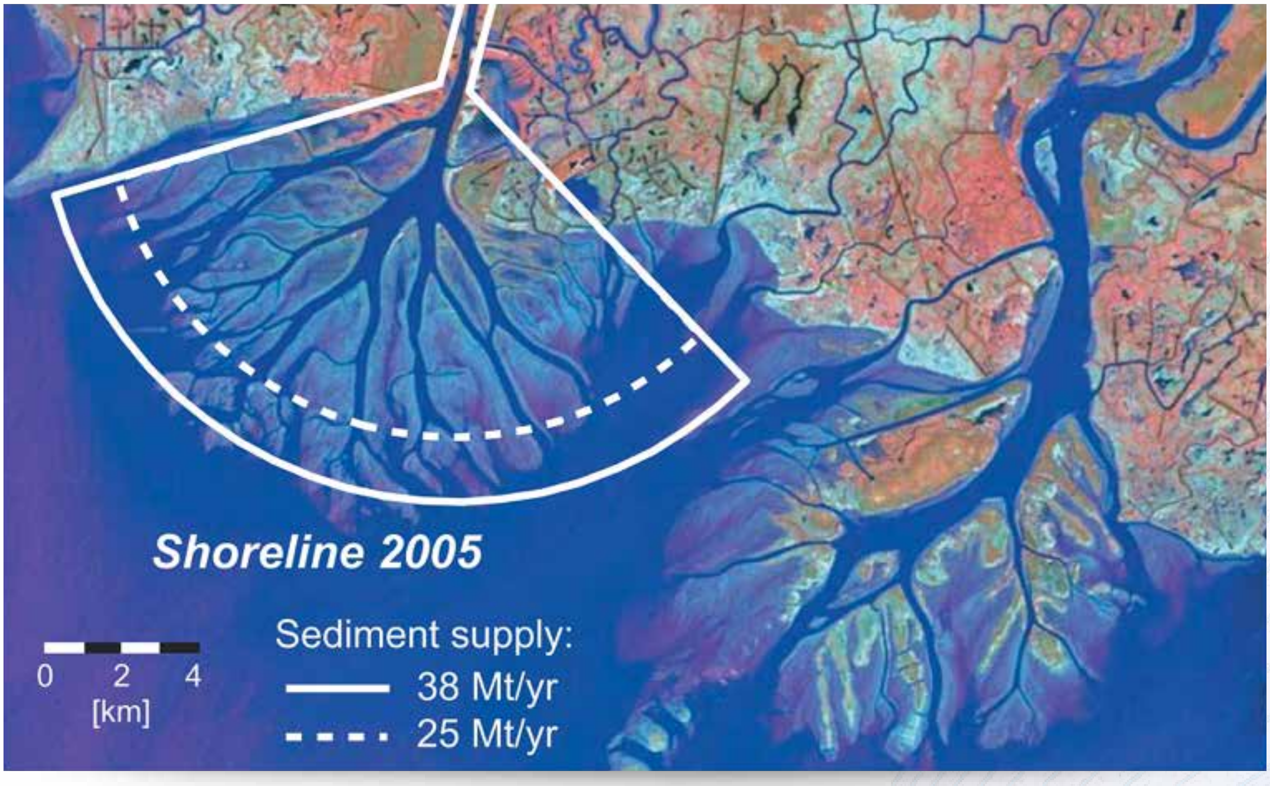

Figure 1: Wax Lake and Atchafalaya River Deltas from Kim et. al 2009 (Landsat Image). Reproduced/modified by permission of American Geophysical Union.

THE EFFECT OF NUTRIENTS ON WETLAND VEGETATION

QUESTION 3

James Morris, Andy Nyman, Gary Shaffer

DO THE EFFECTS OF NUTRIENTS OUTWEIGH THE BENEFITS OF SEDIMENT DIVERSIONS?

Most scientists would agree that, in theory, diversions can help build wetlands. However, the water brought into the system by diversions contains pollutants from upstream sources, such as nutrients. Some researchers have questioned whether the harmful effects of nutrients carried into the system by river water could cancel out the benefits of diversions.

OUR ANALYSIS

We reviewed a number of documented effects of nutrients on wetlands. In so doing, we examined several theories about how excess nutrients could harm vegetation. For example, some researchers have proposed that adding nutrients speeds up root system decay in wetland plants, which would make Louisiana's wetlands more susceptible to sea level rise. While much research on this subject remains to be done, we were able to draw some conclusions.

WHAT THE SCIENCE SAYS

Coastal wetland systems are affected by an array of stressors, including flooding, salinity changes, and nutrients. All of these stressors act on the system in combination, and the effects of nutrients should be evaluated in combination with these factors rather than in isolation.

Plants are affected by excess nutrients in a variety of ways. Many studies have shown that increased nutrient loadings decrease the ratio of belowground tissues (roots plus rhizomes) to above ground shoots. However, the absolute production of roots and rhizomes increases as nutrient loading increases. Contradictory results have been found when evaluating how nutrients affect plant responses to flooding. Adding nutrients appears to increase select species' resistance to flooding while decreasing other species' resistance. Given the range of plant responses, it is difficult to draw simple cause and effect conclusions about nutrient effects. We do know that plant species do not benefit equally from nutrient enrichment, and that river diversions will change the competitive interactions among plant species as well as the composition and locations of plant communities. Moreover, river diversions will reduce salinity, and this too will shift plant species. In certain areas, species typical of salt or brackish water habitats will lessen in favor of freshwater species.

Photo By: Yuki Kokubo, www.yukikokubo.com

One of the key factors to keep in mind about marsh health is elevation, or how high the marshes are situated above water. In general, high marshes are healthy because they are better able to resist flooding and they have stronger root systems. The fresh water and nutrients put into the system by diversions have the potential to increase the productivity of plants and reduce salinity. These factors, in turn, could help wetlands trap sediment, thereby raising surface elevation. There is ample empirical evidence that vegetation typical of coastal wetlands can thrive when sedimentation rates are experimentally raised. This line of reasoning supports the utility of diversions.

Some studies have shown that added nutrients accelerate the decomposition of plant root systems in certain kinds of soil, but we found conflicting views in the literature about this claim. Another question about nutrients, particularly nitrates, concerns their effects on the sustainability of peat marshes. In our view, mineral sediment and nutrients will likely change plant community composition in peat dominated wetlands, resulting in a marsh community that can build elevation more quickly and thus be more resilient to storms and high tides. The creation of lower salinity wetlands by diversions can result in weaker soils because lower salinity marsh soils have fewer live roots than higher salinity marsh soils. However, lower salinity marshes can recover from disturbances with relative speed because the vegetation in these marshes includes perennial plants that reproduce quickly and convert open water to emergent marsh.

The focus on the sustainability of a single landform—peat marshes—can also be misleading. Peat marshes, like other deltaic landforms such as bay bottoms, active deltas, and barrier islands, are not sustainable by themselves. Instead, all of these landforms are built by and degrade within the larger deltaic cycle. By seeking to replicate a version of this natural cycle, diversions offer the best long term option for nourishing marshes and other landforms. In order to create the varied salinities that most coastal plants and animals prefer, diversions could be operated in pulses; the flow of water could be increased from late summer through late fall, and the flow would be halted or reduced in other seasons. This approach would mimic the natural flooding cycle and allow periodic salt intrusion.

IMPLICATIONS FOR POLICY MAKERS

Diversions will have impacts on vegetation, particularly on the locations of some plant species. However, without diversions and other methods for introducing sediment-rich fresh water into the ecosystems of coastal Louisiana, the wetlands will degrade to open water. Thus, the effect of nutrients is not significant enough to offset the larger benefits of diversions for coastal Louisiana, particularly if diversions are pulsed to maximize sediment introduction.

- Climate change will make the restoration and maintenance of coastal wetlands more difficult. Rising sea level will lead to both more flooding and salinity increases. The risk of losing large wetland ecosystems to these stressors outweighs the potential harm posed by nutrients.

- Marshes receiving high levels of both sediments and nutrients are more stable. Diversions should be designed to convey as much sediment and freshwater and as many nutrients as possible, so that marshes with stronger soils will be formed.

- In areas without access to river water, energy intensive restoration techniques, such as building marshes by piping in sediments, will become more costly in future years. These areas can receive increased nutrient rich fresh water through other sources (e.g., pump stations, streams, assimilation wetlands).

- The effectiveness of sediment diversions will depend on the concentration of sediments in the diverted water, the volume of discharge, how the sediments are distributed, and how rapidly the receiving area is subsiding.

Photo By: Yuki Kokubo, www.yukikokubo.com

THE RELATIONSHIP BETWEEN FISHERIES AND COASTAL RESTORATION

QUESTION 4

James Cowan, Linda Deegan

WHAT WILL BE THE FATE OF GULF FISHERIES WITHOUT RESTORATION IN LOUISIANA?

Gulf of Mexico fisheries, worth hundreds of millions of dollars, largely depend on Louisiana's wetlands as nursery grounds. We considered whether large scale restoration efforts would benefit gulf fisheries or whether, as some suggest, it is already too late to save this resource.

OUR ANALYSIS

We may be shooting at a moving target as we seek to understand a complex ecosystem that is experiencing large scale and rapid changes in fish habitat (much of which is human induced) against the backdrop of longer time scale changes caused by climate change and natural delta cycles. That said, a few thorough reviews on the subject allowed us to speculate about how the loss of habitat in Louisiana may impact fisheries production. We believe, as do the authors of reviews we considered, that it is not useful to consider the impacts of coastal wetland loss independently from other habitats in the estuarine ecosystem. Instead, it is important to view impacts on fisheries through the lens of the estuary as a whole.

WHAT THE SCIENCE SAYS

Perhaps the most perplexing aspect of the Mississippi River Delta ecosystem, given environmental insults that the system continues to endure, is the apparently robust state of the region's fisheries. One potential hypothesis proposes that marsh edge is critical habitat for many species, and that fisheries will not decline until the quantity of marsh edge declines. During marsh loss, the amount of marsh edge initially increases and then declines as healthy marsh is converted to open water. The temporary increase in marsh edge, which occurs as the marsh breaks up, may mask the immediate impacts of habitat loss on fisheries landings. Another related hypothesis considers that marsh edge is not the critical habitat per se, but serves as the essential conduit for essential fisheries food sources. Under either hypothesis, it is possible that marsh loss is actually having a positive impact, at least for now.

It is difficult to predict how fisheries productivity in Louisiana and the northern Gulf will change in response to environmental conditions. However, examples from Europe and our own research experience suggest that failure to stop wetland loss will have big impacts not just on wetlands but on the overall estuary. Today, the estuary provides a complex mixture of habitats. More than 75 percent of the species that support fisheries in Louisiana are estuarine resident or dependent, meaning that these species need the combinations of habitats found in the estuary to support their life cycles. Continued wetland loss is likely to convert this web of diverse estuarine habitats into a system dominated by a few marine species. These species would use the estuary as a feeding ground but would not depend on it to complete their life cycles. If loss is not addressed, therefore, it is likely to end badly for the fisheries of the Sportman's Paradise.

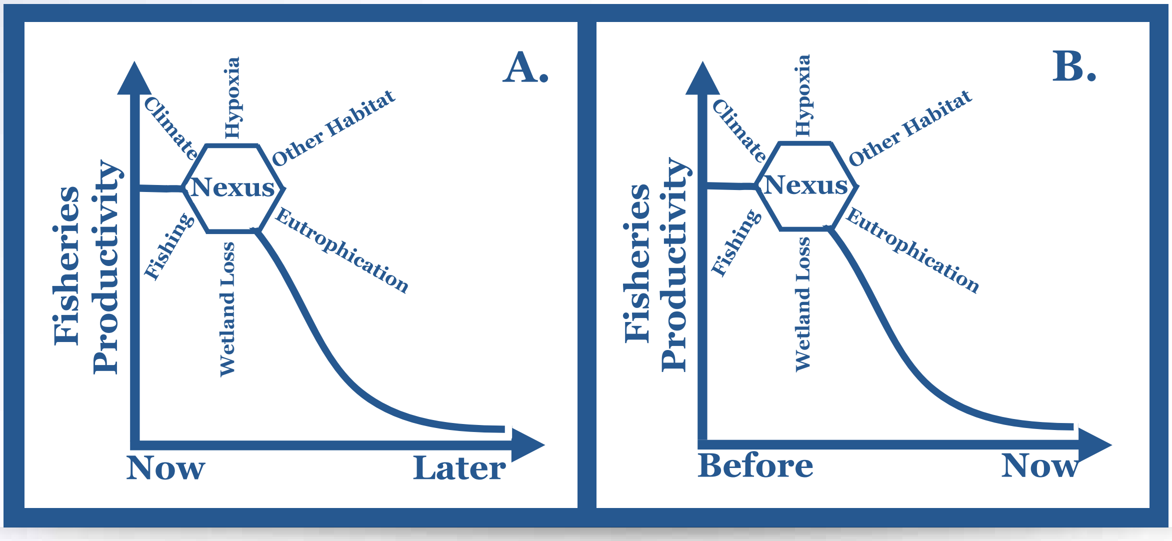

Figure 1: The history or, perhaps, future of fisheries productivity in Louisiana, and presumed causes for change. Panel A assumes that the fisheries remain intact and near historical highs, but that we may be headed toward a steep decline if cumulative impacts reach a tipping point. Panel B assumes that Louisiana fisheries have already declined below historically higher levels because of overfishing. Author drawn graphs (Scenario A and B), Cowan et al., 2008.

We may have reached, or are approaching, an important nexus in the history and/or future of fisheries productivity in the northern Gulf of Mexico (Figure 1).

If Panel B is true, the path forward may simply be more conservative fishing regulations. If Panel A is correct and future declines in fisheries productivity are inexorably linked to further declines in the Mississippi River ecosystem's ability to provide a complex web of habitats, the path forward will much more complicated. It is the latter possibility (Panel A) that we believe is most likely if restoration does not take place and if fisheries reach a tipping point of habitat loss and water quality decline.

Given the importance to fisheries of stopping wetland loss, the basic question remains: can we steer a degraded ecosystem towards some alternate steady state that resembles an historical baseline? It is possible, we believe, that restoration activities that are being proposed in Louisiana, including large scale sediment diversions, may be able to do just that. We base this assertion on the ability of large scale reintroduction of Mississippi River sediments to significantly shift the ecological baseline back toward more robust conditions in the short term, and toward less degraded baseline conditions in the longer term.

As we consider how Louisiana's coast/delta will react to restoration, two futures are possible. We could consider that Louisiana's delta is experiencing bottom up changes. Bottom up refers to those attributes of the ecosystem that affect fisheries productivity, such as loss of habitat and changes in food availability. When these bottom up changes occur, the ecosystem experiences a regime shift that affects a wide variety of species. One future could be that the Louisiana coastal ecosystem experienced a bottom up regime shift when large scale levees were built on the Mississippi River, and when oil and gas exploration began in earnest.

Perhaps the most well studied example of this type of regime shift is the eastern Pacific Ocean's response to changes in climate. These changes affect Pacific coastal ecosystems such that during cold regimes anchovies are favored, and during warmer periods sardines are favored. After each shift, the ecosystem reverts to an alternate steady state, followed by the system's recovery to nearly the state it had prior to the climate change. If the Louisiana coastal ecosystem responds to restoration as has the north Pacific to climate variability, restoration efforts may be able to restore ecosystem goods and services, including fisheries productivity.

A second future would be more difficult to manage. This future is one in which Louisiana continues to experience top down changes brought about by humans, such as fishing, habitat modifications, and pollution. In such cases, the altered ecosystems do not always return to their pre-disturbance condition, even when restoration actions are undertaken. In effect, these top down disturbances change the very baseline of the ecosystem. If this is the path Louisiana's coastal ecosystem takes, it does not bode well for fisheries.

Georges Bank in the North Atlantic represents the most notable example of a shift in the ecological baseline of a fisheries ecosystem. Long term overfishing of ground fish stocks spurred a reorganization of the Georges Bank food web, and more desirable species were replaced. Despite a concerted, ten year reduction in fishing pressure, the Georges Bank fishery has failed to recover overall, although the level of recovery is highly species specific.

In degraded systems, like Louisiana's delta, species often react differently to restoration actions. Some species, or even groups of species do not respond as expected. Will the Louisiana coastal ecosystem and its related fisheries respond to restoration efforts as if the region has experienced a bottom up regime shift? Or will the ecosystem respond as if it had experienced a top down shift in the ecological baseline?

We have reason to be optimistic even though we expect some components of the ecosystem to recover more slowly then others as wetlands are restored. Our optimism is based upon the premise that the current degraded condition of Louisiana's coastal wetlands, although driven by human activities from the top down, reflects changes that mimic a natural and short (less than 100 year) interruption in a cycle of delta creation and decay that normally takes hundreds to thousands of years to complete. As such, large scale restoration efforts to divert Mississippi River sediments back into degraded areas should begin the delta cycle anew and help the system reset to prior conditions. Delaying restoration efforts could reduce the likelihood and expected rates of ecosystem recovery.

IMPLICATIONS FOR POLICY MAKERS

There is much uncertainty about how the various factors affecting fisheries, including restoration actions, will interact. We do know that different species will react in different ways to landscape changes. However, our analysis supports the claim that the large scale sediment diversions being considered for Louisiana's coast have a good chance of supporting a future of fisheries productivity because they may allow the ecosystem to reset to a more sustainable baseline. The status quo, on the other hand, will likely lead to a reduction in gulf fisheries productivity and the many human communities that depend on them.

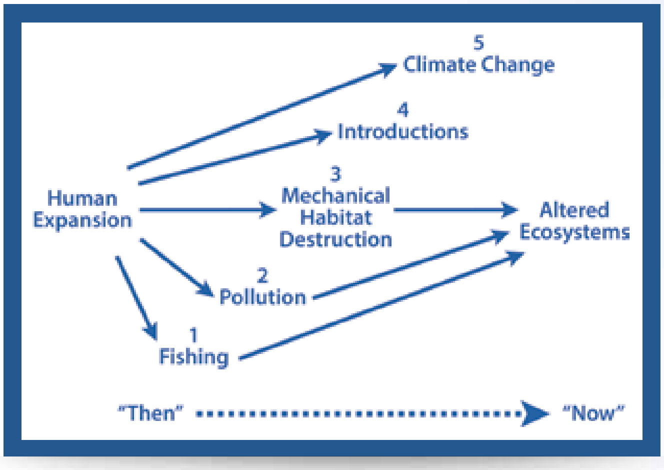

Figure 2: Examples of top down controls induced by human expansion resulting in altered ecological baselines. From Jackson et al. 2001; reprinted with permission from AAAS.

- Because it could eliminate most coastal wetlands, climate change poses a severe threat to fisheries. Practically all intertidal habitat used by fishery species will likely be gone by the end of the 21st century without an aggressive restoration program. Large scale restoration will cause shifts in the locations of the major fisheries, but it may be the only hope for maintaining sustainable fisheries.

- Rising fuel costs are already affecting fishing, and continued increases may make fishing as presently carried out unsustainable. It is unclear how the fishing industry can adapt to these challenges. It may be that fisheries will have to change to more energy efficient methods such as butterfly nets versus trawling. Increased energy costs may increase the price of imports compared to local fisheries. For example, when oil prices reached nearly $150 a barrel, the U.S. steel industry became competitive with Chinese imports because of increased shipping costs.

NAVIGATION ISSUES

QUESTION 5

David Rogers, Paul Kemp

IS LOUISIANA'S NAVIGATION INDUSTRY SUSTAINABLE WITHOUT LARGE SCALE COASTAL RESTORATION?

When it comes to managing the Mississippi River, business as usual is proving problematic on a number of different fronts. Lower Mississippi River flood levels are on the rise from Natchez to Belle Chasse, and Louisiana's ongoing wetland loss crisis continues—situations that are both directly affected by the way the river's water is distributed. In addition, with a new, larger lane of the Panama Canal scheduled to open in 2014, ships carrying much of the cargo in and out of Asia will require a greater draft than the 45 foot deep navigation channel currently maintained by the U.S. Army Corps of Engineers (Corps). We considered whether these challenges have a common solution: reengineering the Lower Mississippi River to support coastal restoration as well as the future competitiveness of the New Orleans port industry and the inland barge operators that depend on connections to deep draft shipping.

OUR ANALYSIS

Current Mississippi River management, enshrined in the 80-year-old Mississippi River and Tributaries Project (MR&T), is increasingly at odds with the way the river works today. We present the scientific and engineering consensus about these trends, a consensus that acknowledges the problems inherent in the current approach while pointing the way toward a new management paradigm. This paradigm can improve regional flood protection and navigation access while also unleashing the power of the river to save the Mississippi River Delta for future generations. Our analysis took the long term view asking whether both the coast and Louisiana's navigation industry could be sustained. In so doing, we considered the effects of climate change, rising energy costs, and trends in global shipping.

We also considered the history of flood control in the Mississippi River Delta. The 1928 Flood Control Act was passed after the disastrous 1927 Mississippi River flood. The act established the federal Mississippi River and Tributaries (MR&T) Project to provide a multi-pronged approach to flood protection, including earthen levees, flood relief outlets, and cut offs. The act also provided for the maintenance of a dredged channel for deep draft navigation access as far as Baton Rouge (now 45 feet), and for shallow draft barge traffic (12 feet) throughout the Mississippi River and its principal tributaries.

In the 1950s, the Mississippi River Commission, which was assigned responsibility for operating the MR&T Project, determined that a gated control structure was required to keep the Mississippi River from changing course. The river's established path to the Gulf of Mexico past New Orleans was much longer than the more direct route offered by the Atchafalaya River, one of the Mississippi's western tributaries. The Mississippi would normally have changed its course to take advantage of the shorter route down the Atchafalaya. To prevent this, three gated dams were built 75 miles upriver from Baton Rouge. Called the Old River Control Structure, these dams allow only 30 percent of the river's flow down the Atchafalaya and keep the remaining 70 percent moving down the channel that ends with the Bird's Foot Delta.

The 1928 Flood Control Act had two goals: keep property dry during high river flows and keep navigation routes functional during normal river flows. Those writing the law did not consider environmental impacts or how hurricanes could affect the deltaic landscape. This narrow focus has remained in force for the last 80 years; the 1928 Flood Control Act has not been changed since it was written. The original law still determines how the Corps manages the river for navigation and flood protection even though the Mississippi River Delta is disappearing and threats posed by flooding and hurricanes worsen each year.

WHAT THE SCIENCE SAYS

The artificial separation of the Mississippi River from its delta, both by closure of side channels and by levee construction, has been a major contributor to the loss of over 1,800 square miles of deltaic wetlands since the 1930s. This landscape level ecological collapse has had many effects, not the least of which is increased flooding. Wetlands can slow or spread storm surge, reducing threats to developed areas. The loss of so many wetlands, coupled with increased development, means that today flood risks for the two million residents of coastal Louisiana are higher than anything imagined when the Flood Control Act was passed. The delta region has experienced more than $150 billion in hurricane property losses and recovery costs in the last decade alone.

The lower Mississippi River and Missouri River floods of 2011 shed further light on the problem. It is true that the Mississippi River flood protection system prevented widespread flooding in Louisiana. No levees were breached unintentionally. However, despite use of all the MR&T emergency spillways, flood stages from Natchez through New Orleans reached levels two to five feet higher than the previous flood of record in 1973. The Corps estimates that just repairing damage to the MR&T flood control infrastructure will cost between $1 and $2 billion.

It is important to note that because of the ways that sediment has filled in areas of the riverbed, the river now runs higher than it did when the MR&T Project began. A flow of 1.75 million cubic feet per second flowing by Vicksburg, Mississippi is now flowing about six feet higher than that same flow 66 years ago. This does not bode well for the system's resilience in the face of future flooding.

If the MR&T Project no longer provides the most effective way to prevent flooding in the lower Mississippi's deltaic communities, it is also undermining the navigation industry. The Bird's Foot Delta at the river's mouth is used by 6,000 deep draft vessels a year and is one of the world's busiest shipping channels. The Bird's Foot also experiences the nation's highest rates of subsidence, about 0.5 feet per decade. When sea level rise is factored in, the Bird's Foot could see an increase in sea level of one foot per decade.

The combined effects of sea level rise and subsidence are leading to an upstream retreat of the river mouth. This geological shift is pushing more and more of the Mississippi River's flow out of the main channel between New Orleans and Head of Passes at the mouth of the river. With less river water coming through the Bird's Foot, the navigation channel has become increasingly prone to shoaling upstream. The Corps is not equipped to rapidly mitigate this deposition and has forced pilots to limit draft on ships to less than the river's authorized 45 foot channel depth. The Corps has also been obliged to reduce the effective channel width to less than what is authorized, which could impact safety. Emergency appropriations are required almost every year to dredge the channel, even as federal dredging budgets grow more constrained. As the shipping channel becomes less reliable, vessels will have to decrease their payloads to conserve draft and bypass New Orleans in the long term. If the narrowing channel increases the risk of groundings, or, far worse, collisions, traffic in both directions may be suspended for weeks or months.

We believe that the MR&T mandated river flows passing New Orleans are no longer capable of scouring the navigation channel's entrance at Head of Passes. This presents challenges and opportunities. For example, there is the potential to accelerate removal of sediment from the main channel by upstream diversions and arrange for sediment deposition in shallow wetland building sites beyond the flood control levees. Doing so would address the root causes of wetland loss in Louisiana and help restore the coastal ecosystem. Perhaps as importantly, this approach could be compatible with a redesigned river navigation entrance, one that could be reliably maintained with less dredging at between -50 and -55 feet at extreme low tide and at the full authorized width.

This reconfiguration will become a critical economic issue when the new lane of the Panama Canal is complete and a new generation of container ships and bulk carriers arrive in the Gulf in 2014. These "Post Panamax" ships have approximately three times the cargo capacity of current vessels, but require far less energy per ton to move than any other type of transport. Ports along the eastern seaboard are deepening channels and upgrading their facilities to handle these new ships. Unless significant changes are made at the mouth of the Mississippi River for a deeper entrance, fully loaded Post Panamax ships will not be able to reach ports along the lower river in Louisiana. This, in turn, will affect the terminal operators and shallow draft shippers that use the inland waterway system radiating from New Orleans.

IMPLICATIONS FOR POLICY MAKERS

Reconfiguring the river and revising the decades old MR&T project is imperative if we are to secure the long term viability of Louisiana's navigation industry. These needs dovetail with the state's plans to build sediment diversions to address coastal land loss.

- As this new approach to river management is refined, possible options to consider include: expanding the controlled use of diversions designed to extract sediment upstream of Head of Passes, separating the current Southwest Pass navigation channel at the mouth of the river, or creating a new outlet that is separate from the channel carrying river discharge. The latter option has been done in the Netherlands for the lower Rhine River.

- Even the most modest climate change projections suggest that larger river floods, such as the record 2011 discharge, will occur more frequently on the Mississippi River and its tributaries. Higher peak river flows may bring larger volumes of sandy sediment to the coast, particularly when bypassing of sediment around the major dams on the Missouri River begins. Rather than simply adding to the dredging burden already borne by the U.S. taxpayer, river diversions could extract sediment from the river during floods to rebuild wetlands while also lowering flood flowlines.

- Energy scarcity will complicate the current approach to operating the MR&T system for navigation on the river. Dredging costs will increase with energy prices. It makes sense to reconfigure the lower river to take advantage of the river's power to move sediments, while also upgrading the navigation system and lowering our reliance on costly fossil fuels.

LEVEES AND FLOOD PROTECTION

David Rogers, Jaye Cable, William Nuttle

QUESTION 6

HOW EFFECTIVE IS LEVEE-ONLY FLOOD PROTECTION?

Much of the population of southern Louisiana is threatened by flooding, from both hurricanes and the river. Many residents want that protection to be provided by levees or flood walls. Given recent trends, we examined whether such structures alone, as opposed to levees operating in conjunction with wetland buffers, could offer the kind of protection Louisiana residents need.

OUR ANALYSIS

We considered an array of flood protection needs in south Louisiana. In terms of areas needing protection from river and hurricane flooding, we considered the heavily populated river corridor south of Baton Rouge and areas south of the Atchafalaya Basin. We also examined communities inside the Atchafalaya Basin that must deal with river flooding. Our analysis assumed that almost the entire area south of I-10 and I-12 is subject to potentially catastrophic hurricane flooding.

When defining the terms of our analysis, it was important to clarify what protection means. In our view, no system of flood control can provide a guarantee of safety. This reality is reflected in the State of Louisiana's 2012 Coastal Master Plan, which explicitly states that its flood protection measures only cover risk to property and do not address the need to protect human life. In addition, the U.S. Army Corps of Engineers now uses the term "risk reduction" to describe the aim of its levee building efforts. Given the scope of what can be achieved, we use the term "protection" to mean introducing a lower flood risk level without eliminating the chance of flooding altogether.

WHAT THE SCIENCE SAYS

Our analysis endorses the multiple lines of defense approach to flood management. This approach assumes that many different landscape and structural features can work together to provide as much or more protection than a single structure. The first lines of defense are barrier islands, marshes, forested wetlands, and natural and constructed ridges. The next lines of defense are man made, such as levees or elevated and floodproofed buildings. This approach creates a more redundant system of protection, each component of which reinforces the whole.

The multiple lines of defense approach is particularly important given what we have learned from the last decade of storms in south Louisiana. The failures of the levees and floodwalls around New Orleans in the aftermath of Hurricane Katrina demonstrate how vulnerable structural flood protection measures can be, particularly when they are improperly constructed and there are no wetland buffers to help reduce storm surge. Some levees in St. Bernard Parish survived intact despite being overtopped, while others were completely washed away. These levees were built of materials with a high clay content, which made the structures stronger. The levees also had extensive wetlands in front of them. By contrast, levees adjacent to the expanded Mississippi River Gulf Outlet were poorly constructed, not properly maintained, and did not have wetland buffers. These levees were destroyed by waves before they were overtopped.

Some may suggest that we simply build higher, stronger levees and then pay every decade or so to lift them as they sink. But doing so is extremely expensive, and federal funding for this course of action may not be available in the future. Engineering limits on levee and floodwall reliability also come into play as we seek to build these structures ever higher. The soft soils found in much of Louisiana's coast make it impossible to build levees past a certain height without using wall structures buttressed by very expensive, deep pile-supported foundations.

Linear flood control structures can also impound wetlands, which the plants cannot survive. At a minimum, these structures reduce the sustainability of wetlands by changing water flow and preventing storms from depositing sediments where the wetlands can use them. Even relatively low levees can have this effect, as is the case for the LaBranche wetlands. A railroad embankment six feet high has significantly reduced sediment input and helped further impound a deteriorating marsh area. This has occurred even though channels under the railroad allow water and sediment to flow into the wetlands. This railroad embankment could be viewed as an example of a "leaky levee" that does not provide flood protection but still causes wetland deterioration. Other leaky levee concepts could provide more resilient flood protection, and this concept merits further exploration. However, achieving beneficial outcomes will require ongoing and in-depth management practices using the participation of both life scientists and engineers.

IMPLICATIONS FOR POLICY MAKERS

It will not be possible to provide levee protection to all outlying coastal communities. By themselves, even well constructed levees cannot provide the protection that Louisiana residents seek. In addition, by damaging nearby wetlands or encouraging unwise development in enclosed areas that require pumps to remain dry, levees can actually increase exposure to flood risks. As a result, levees should be one of several lines of defense and should not be operated as solitary structures.

- Levees put areas at risk from more extreme events in exchange for protection from more frequent and moderate events.
- By helping to degrade adjacent wetlands, levees themselves may become increasingly exposed to damage by waves, increasing the flood risk in areas they are intended to protect.
- Arguments for levee expansion can be persuasive in the short term, but the long term effects of unsafe development can be devastating, as we have seen throughout the coast in the last decade.
- Levees do not remove flood risk. Even with the $14 billion system currently being completed around the New Orleans area, the risk of catastrophic flooding is greater than zero in any year and approaches 100 percent at time scales of 50 years or more. The U.S. Army Corps of Engineers has stated that the improved levees should not be overtopped by a storm with a 1 percent chance of occurring in any given year. This is the minimum protection criterion for the sale of federal flood insurance. However, even this level of protection translates into a 26 percent likelihood that the property will flood during a standard 30 year mortgage.
- Climate change will make building and maintaining levees more difficult. For example, structural measures will sink and deteriorate over time, while sea level rise will require more frequent use of floodgates and other structures. All of these factors will drive up maintenance costs.
- Some restoration measures, such as river diversions, have large upfront construction costs but become increasingly effective over time, relying on gravity to transport fresh water and sediment rather than fossil energy. Building land in this way could lead to higher levels of protection for the coastal communities of the future.

RESTORATION AND COMMUNITIES

QUESTION 7

Conner Bailey, Shirley Laska, Robert Gramling

WILL RESTORATION OF LOUISIANA'S COAST REQUIRE COASTAL RESIDENTS TO LEAVE THEIR COMMUNITIES?

Coastal restoration in Louisiana is widely supported, but it is important to consider the effect these restoration activities will have on coastal communities. We considered patterns of change in coastal communities as well as future options for managing transitions.

OUR ANALYSIS

In order to better understand this complex subject, we evaluated a cross section of communities as well as coastal demographic changes over the last 30 years. As we evaluated these data, we used the following assumptions:

- humans are by nature a highly adaptive species
- people living in dynamic ecosystems such as coastal Louisiana are culturally disposed to adaptive behaviors that create personal, community, and social resilience
- science as well as local residents' traditional ecological knowledge should both be used to identify options for the future.

WHAT THE SCIENCE SAYS

With some exceptions, coastal restoration efforts will not force people from their communities. Residents of coastal parishes in Louisiana are heavily invested in and have a great attachment to their communities. Many coastal communities are centered around the harvest of renewable resources—such as shrimp, oysters, and crabs—as well as the local knowledge and skills that makes this harvest possible. In addition, social networks in coastal Louisiana are fundamental not only to people's ways of life, but to their very survival. These networks extend beyond economic transactions to mutual forms of support that subsidize more visible economic activities.

Photo By: Yuki Kokubo, www.yukikokubo.com

Despite these important ties to existing community structures, residents of coastal Louisiana are adapting to changing conditions and making difficult decisions about their lives and livelihoods. The census data show patterns of steady population loss in census tracts that are most vulnerable to storms due to subsidence, sea level rise, and coastal erosion. The combined effect of these factors has been a gradual retreat of residents from Louisiana's coast. We considered the pros and cons of four different approaches for helping communities continue to cope with these changes.

Relocation

After the upper Mississippi River floods of 1993, individual households were relocated out of the flood plain and onto nearby bluffs. Individually relocating residents of coastal Louisiana would require moves of a greater distance. This would scatter residents, rendering their former exchange networks unworkable and making it more difficult for them to continue their harvesting occupations.

One solution would be to move entire communities to the same location. However, as a nation we have little experience in relocating entire communities to more protected locations. In addition, these relocations require a commitment from residents and government agencies that would be difficult to secure, as we have seen with efforts to relocate the Isle de Jean Charles community. In a recent survey of coastal officials regarding adaptation methods, both voluntary and assisted relocation were by far the least desired options overall. These factors would seem to indicate that if relocation is undertaken, much of the support derived from tightly knit communities would be lost.

Staying in Place, Protected by Levees

The creation of reconfigured communities surrounded by storm barriers is one way to retain the current location of threatened communities. For example, the U.S. Army Corps of Engineers has proposed creating a ring levee around one of the most densely inhabited areas of Barataria Basin. However, the associated technical challenges are considerable. Because population density varies in most communities, pursuing this option would require reconfiguring community footprints to allow encirclement by levees.

As with community wide relocation, building levee systems requires broad based agreement, and some land/home owners may have to exchange their properties for new locations. Given that many coastal properties have been handed down within families for five or more generations, this could be a difficult challenge. While it might be possible to accomplish such protection for very small fishing communities, the negotiations would be time consuming at best. In addition, certain threatened communities—Isle de Jean Charles, Pointe au Chien, Des Allemands, and the beach front communities of Cameron and Grand Isle, for example—could not adopt this strategy. These communities are built along the natural levees of waterways or coastal cheniers. Such communities are too long to be surrounded by levees, and it is not feasible to enclose the neighboring waterways.

Seasonal Use of the Coast and Long Commutes for Harvesters

This option does not take into account the close relationships that residents have with the landscape as well as the web of personal connections that many coastal Louisiana residents hold. From an economic angle, a fisher who today parks his boat on the bayou next to his backyard would find it difficult to adapt to a scenario in which he has to commute and pay for extra fuel as well as mooring fees. Many fishing vessels are too large to fit on a trailer. They may also be worth more than the house they are moored by, and thus cannot be left behind in times of danger. We know of one small community that prepared for Hurricane Katrina by evacuating vulnerable residents by car while other men and women took their boats to a sheltered location to ride out the storm. Given all of these factors, it may be very difficult to relocate harvesters inland without impairing the viability of their traditional occupations.

COMMUNITY IMPACTS: DEFINING TERMS

To the U.S. Army Corps of Engineers "structural" mitigation means large structures that block water (e.g., levees or floodwalls). For the Corps, any other form of mitigation (e.g., elevating buildings, floodproofing) is called a nonstructural measure. The terms "nonstructural," "mitigation," (often used by FEMA) and "adaptation" (often used by climate specialists) are interchangeable.

Adapting to and/or Mitigating the Effects of Flood Risks and Land Loss

Understandably, most coastal Louisiana residents want to be protected where they are because this maintains the social networks that are key to their community and cultural survival. If levees are not feasible, a next step is to use nonstructural measures to help residents adapt to and prepare for increased flooding. Nonstructural measures may include floodproofing and elevation of homes and businesses, as well as land use planning, building codes, and zoning ordinances that seek to minimize a community's risk. One possible obstacle to nonstructural measures is the reluctance of some residents and local leaders to agree to regulations that would take away their control over use of privately owned land. At the same time, when residents have fully understood the magnitude of the flooding risks facing them, they have been quick to embrace nonstructural measures.

One successful case of voluntary home elevation has been studied in Delcambre Louisiana. Following Hurricane Rita in 2005 there initially was little support for elevating homes. However, after Hurricane Ike in 2008, residents began to realize that a 1-in-100 year storm like Rita had a 1 percent chance of occurring each year. Previously, many residents had thought such a storm would occur once in 100 years. A June 2009 survey of houses in Delcambre found that over 40 percent of the 850 houses in the sample were elevated above Hurricane Rita's surge. We estimate that this trend has continued to the point where over 50 percent of the area's homes are now elevated. As this example illustrates, helping local communities commit to appropriate levels of nonstructural adaptation requires that affected residents understand the full range of challenges, including climate and energy scenarios, which they are facing.

IMPLICATIONS FOR POLICY MAKERS

Some communities will be affected by restoration measures such as diversions that change water salinity and the locations of coastal resources. For most communities, however, lack of wetland restoration will make the coast more vulnerable to continued flooding as well as hazards such as the BP oil spill. Ultimately, these threats will be what force people away from the coast. If restoration and mitigation are coordinated to create compatible outcomes, they will be positive activities for coastal communities.

The populations of these communities are changing today, and some communities will be lost. However, there are ways for most communities to adapt to the changing landscape, using both science and their own ecological knowledge. Residents need full information about the risks and options they face so they can make informed choices.

Photo By: Yuki Kokubo, www.yukikokubo.com

WHAT LOUISIANA STANDS TO LOSE

David Batker, Sarah Mack, Fred Sklar, Mary Kelly, Angelina Freeman, William Nuttle, Robert Costanza

QUESTION 8

WHAT ARE THE COSTS TO LOUISIANA IF WE DON'T RESTORE THE COAST?

We examined what is at stake economically for Louisiana if we maintain the status quo and do not undertake large scale action to restore the coast.

OUR ANALYSIS

Our analysis considers the Mississippi River Delta to include the area from southeast Louisiana streching west to the wetlands of the Chenier Plain. Our review used two different metrics: standard indices of economic activity (e.g., GDP, jobs) and the value of ecosystem goods and services. Our key assumption was that all of this value was at risk from storm damage and coastal deterioration if we do not recreate a strong wetland buffer through large scale restoration activities. We further assumed that the feasibility of restoring the delta was not in question, and that options exist for saving this ecosystem.

WHAT THE SCIENCE SAYS

From oil and gas, to tourism, to fisheries, the delta provides a wealth of economic activity. Between 80 and 90 percent of the state's economy, seafood production, and quality of life is linked to coastal ecosystem goods and services. Over 2 million residents live in the coastal parishes (47 percent of total state population), and the bulk of Louisiana's economic activity is generated in the southern part of the state. The following indices explain these economic effects in more detail.

Standard Indices of Economic Activity

Five of the top 15 largest ports in the United States are located in Louisiana. The Port of South Louisiana ships more than 200 million tons of cargo annually and is the largest port in the U.S. in terms of tons shipped. Altogether south Louisiana ports carry over 457 million tons of waterborne commerce annually, accounting for 18 percent of all waterborne commerce in the United States. This port activity is linked to a trucking network that serves the entire contiguous United States (see Figure 1). Further loss of Louisiana's coastal wetlands will degrade segments of the Gulf Intracoastal Waterway (GIWW), which is a prime transportation route for goods, services, and commodities.

Ecosystem Services

Mississippi River Delta ecosystems provide economically valuable services including hurricane storm protection, fresh water supply, climate stability, food, furs, habitat, waste treatment, and other benefits worth at least \$12 to \$47 billion per year. These annual benefits provide a vast amount of value to people across time. Estimates of the present value of the benefits from 11 coastal ecosystem goods and services are between \$330 billion and \$1.3 trillion (3.5 percent discount rate). Wetlands include fresh water, salt water, estuaries, tidal bays, and cypress swamps. These habitats account for more than 90 percent of the estimated total value of ecosystem services provided in the Mississippi River Delta.

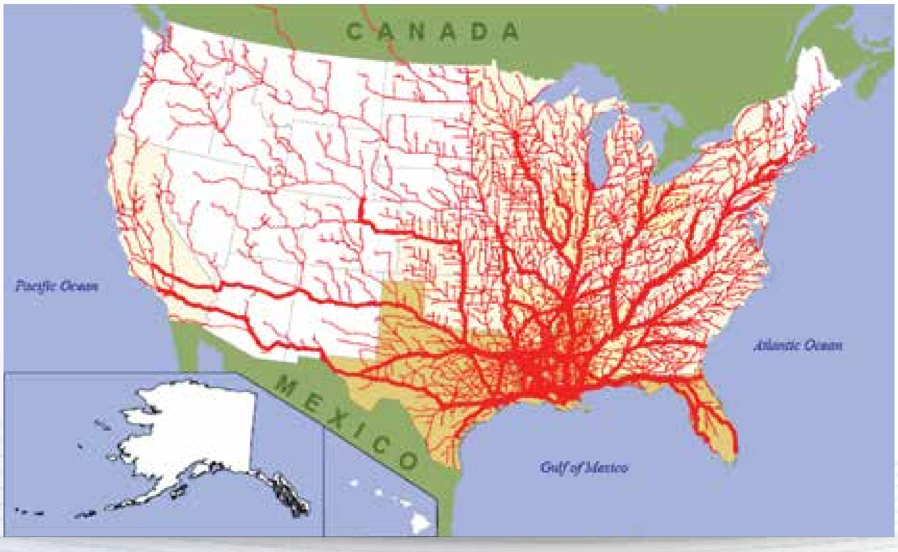

Figure 1: Louisiana's Mississippi River ports: Inland movement of maritime cargo by truck. Louisiana Coastal Protection and Restoration Authority, 2006, (courtesy FHWA).

Recent Losses from Storm Damages and Coastal Deterioration

Over the last century, hurricanes have caused approximately $2.7 trillion (2010 dollars) of significant asset damage across Texas, Louisiana, Mississippi, and Alabama. The continued loss of protective wetlands will greatly exacerbate these economic impacts. The Gulf Coast is vulnerable to growing environmental risks today and could expect over $350 billion in cumulative expected losses by 2030. In 20 years, storms with Hurricane Katrina/Rita levels of economic impact may become once a generation events instead of the once a century events they are today. A healthy wetland buffer will help protect communities and assets from the storm surge and waves associated with these hurricanes.

The table below lists a sampling of the economic value that is at risk without large scale coastal restoration in Louisiana.

THE ECONOMIC CONTRIBUTIONS OF LOUISIANA'S COAST

CATEGORY	INDEX & SOURCE	DOLLAR IMPACT	STATE OR GULF JOBS
Commercial Fisheries	Yearly impact 2003 (WaterMarks 2007)	$2.85 billion	40,000
Recreational Fisheries	Yearly impact 2003 (NOAA, 2011)	$1.7 billion	20,000
Wildlife	Hunting related expenditures (LDWF, 2011)	$975 million annually	
	Wildlife watching (LDWF, 2006)	$517 million annually	
	Fur harvest 2007-2008 (LDWF, 2008)	$1.27 million	
	Alligator and egg harvest (LDWF, 2006)	$109.2 million	
Tourism	Lodging and food services in coastal Louisiana (Louisiana Workforce Commission, 2006)		110,000
	Statewide value of tourism before Hurricane Katrina, most in south Louisiana (Louisiana Workforce Commission, 2006)	$10 billion	
Oil and Gas	Economic impact (Secure Gulf Project, 2010)	$1.1 billion to state and local taxes	Direct employment of 131,500
	Job related benefits	$2.7 billion to state and local taxes from payroll	More than 42,000 Louisiana residents
Sugar Industry	Economic value	$1.7 billion	
Shipping	Direct economic impact of south LA ports (Ryan, 2001)	In 1999, $10.3 billion	250,000
Transportation and Material Moving	Economic impact (Secure Gulf Project, 2010)	$3.7 billion to state and local taxes from payroll	1.1 million

Photo By: Yuki Kokubo, www.yukikokubo.com

IMPLICATIONS FOR POLICY MAKERS

Restoration of Louisiana's coast is required to maintain billions in state economic value. Without an aggressive restoration program, the economic activity of the coast, worth hundreds of billions of dollars, cannot be maintained.

- Solving this problem requires accounting for and investing in the economic assets of nature – natural capital – as an integral component of hurricane damage prevention and as a critical foundation for healthy communities and economies.

- Large scale restoration activities represent a sound investment in natural capital. Restoration will provide economically critical natural capital in the form of improved fresh water supplies, flood control, hunting, fishing, ranching, farming, and other nature based uses of the coast.

- All aspects of our economy are linked to climate change. Climate change, particularly increases in sea level, will severely impact coastal areas around the world. This is especially true for the coastal communities at elevations near or in some cases below sea level.

- Many studies link coastal conditions to home values. Given the housing stocks that are at risk to flooding due to coastal erosion in Louisiana, the economic impacts of restored wetlands are several times larger than other locations in the nation.

- Wetland restoration can create twice as many jobs as the oil/gas and road construction industries combined.

- Habitat restoration projects not only create direct local jobs, but they also stimulate indirect jobs in industries that supply project materials such as lumber, concrete, and plant material. Restoration projects can spur job creation in businesses that provide local goods and services to restoration workers.

- Restoration projects provide strong returns on investment to local and regional economies in the form of new jobs, increased tourism and tourist dollars, hunting and fishing revenues, tax revenues, and property values.

URGENCY OF RESTORING LOUISIANA'S COAST

David Batker, Sarah Mack, Fred Sklar, Mary Kelly, Angelina Freeman, William Nuttle, Robert Costanza

QUESTION 9

IS RESTORATION OF LOUISIANA'S COAST SOMETHING THAT THE FEDERAL GOVERNMENT NEEDS TO DO NOW?

Louisiana is indeed facing a coastal crisis, but some have wondered whether this crisis justifies a substantial federal investment given other national priorities.

OUR ANALYSIS

We considered the Mississippi River Delta to include the area from southeast Louisiana streching west to the wetlands of the Chenier Plain. We examined a range of sectors using standard indices of economic impact. As in Question #8, our key assumption was that the delta's economic value was at risk from storm damage if we do not recreate a strong wetland buffer through large scale restoration activities. We further assumed that the feasibility of restoring the delta was not in question, and that options exist for saving this ecosystem.

WHAT THE SCIENCE SAYS

Our analysis fully supports the utility of a federal investment in coastal Louisiana's restoration based on the ability of wetlands to reduce storm surge and stabilize river levees. Specific economic sectors that would benefit from the wetlands' protective function are discussed in more detail below.

Navigation and Mississippi River Commerce

The nation as a whole benefits from the navigation system of the Mississippi River. The Mississippi River is one of the world's most important economic transport corridors, carrying 60 percent of all grain exported from the U.S., along with coal and other products. U.S. waterborne foreign trade along the Mississippi River in 2003, adjusted to 2005 dollars, had an import value of $103.8 billion, an export value of $53.5 billion and a total economic value of $157.3 billion.

All of this commerce depends on a functioning entry to the river from the Gulf of Mexico. The deepwater ports along the Lower Mississippi River from Baton Rouge through New Orleans to the gulf collectively constitute the largest tonnage port in the Western Hemisphere. Waterborne commerce along this corridor amounts to some $35 billion annually and provides approximately 300,000 jobs. The 2004 Nelson Study found that a seven day closure of the lower Mississippi River would raise shipping costs by $50 million. A 14 day closure would raise costs by $200 million and cost the nation $88.6 million in lost earnings as well as over $323 million in lost sales.

Energy Production

Louisiana is the U.S. number one in crude oil production, number two in total energy production, number two in petrochemical production, number two in natural gas production, and number two in refining capacity. In addition, the Louisiana Offshore Oil Port facility provides critical infrastructure for bringing imported oil to the nation. There are two major refineries in Louisiana's coastal area, seven major petrochemical facilities, and three gas processing facilities. Thousands of miles of pipelines move a major share of natural gas produced in the Gulf of Mexico to markets in the northeast, including New York, Philadelphia, and Washington, D.C.

The nation's Strategic Petroleum Reserve is located in four, 2000 feet deep salt caverns in Louisiana and Texas that contain approximately 755 million barrels of crude oil. While the salt caverns are virtually invulnerable to meteorological hazards and are relatively immune from earthquakes, their distribution network shares the hazards of the other energy infrastructure: damage from encroaching salt water and storm surge. Should these risks intensify, the national costs will be enormous. The combined economic impact of a three week oil production and natural gas outage is over $4.5 billion in sales and 45,000 jobs.

Figure 1: Pipelines located in the Outer Continental Shelf, offshore of Louisiana's coast (BSEE, 2012).

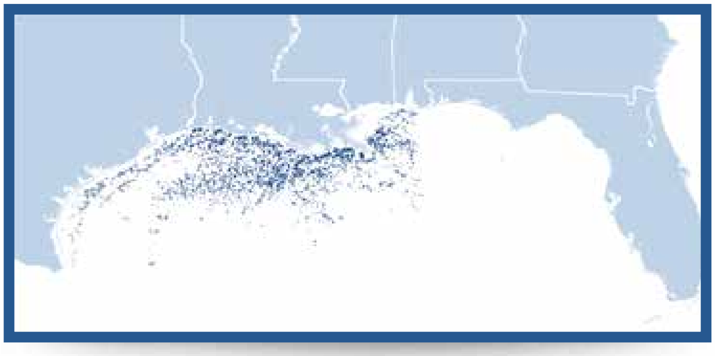

Figure 2: Outer Continental Shelf oil and gas production platforms, offshore of Louisiana's coast (BSEE, 2010).

Fisheries and Wildlife

Protecting and restoring the estuaries of the Mississippi River Delta is vital to sustaining fisheries and endangered species in the Gulf of Mexico. Louisiana fisheries contributed 13 percent of total U.S. commercial landings between 1995 and 2004, and this figure does not include the fish and shellfish reared in the Mississippi River Delta but caught elsewhere in the Gulf of Mexico. One-third of the nation's oysters come from the Mississippi River Delta, and this fishery constitutes a $300 million industry in Louisiana. In addition to fisheries, the Mississippi River Delta ecosystem supports 100 million migratory, nesting, and wintering birds.

Summary

Louisiana's coastal ecosystems provide at least $12 to 47 billion in benefits to people every year. If this natural capital were treated as an economic asset, the coast's minimum natural capital asset value would be $330 billion to $1.3 trillion (using a 3.5 percent discount rate). These values come from a study by Batker et al. (2010) that calculated the most comprehensive measure of the economic value of Louisiana's coastal systems to date.

As shown in the table below, the estimated costs of protecting and restoring the coast range from $15 billion to $150 billion. Is this national investment worthwhile during a period of financial crisis? Our analysis results say "yes." If business as usual continues, we estimate economic losses of $41 billion annually, excluding damages from future hurricanes, caused by a disorderly retreat inland that damages people and businesses at great cost to the nation. By comparison, if a large scale restoration program is implemented that maintains and expands the Mississippi River Delta, an additional annual net benefit of at least $62 billion in ecosystem services would be realized. This value does not include other benefits that the nation would gain, such as increased protection for levees, or avoided catastrophic impacts such as levee breaching. It does not include the benefit of reduced displacement of residents, reduced FEMA relief and recovery costs, lower insurance rates, lower national oil and gas prices, less litigation, or the benefits of an expanding coastal economy, greater employment, and stability gained for existing communities and residents.

PROTECTING AND RESTORING THE COAST: A RANGE OF BUDGET ESTIMATES

SOURCE	PROJECTED COST
Coast 2050	$15 billion over 30 years
Louisiana Coastal Area Study	$2 billion for near-term, priority projects.
2007 State Master Plan	Over $50 billion
LACPR	$100 to $150 billion
2012 State Master Plan	$50 billion over 50 years
Entergy Report	$44 billion for key infrastructure projects over 20 years

IMPLICATIONS FOR POLICY MAKERS

Restoration of the Mississippi River Delta should be a national priority. An investment of up to $50 billion in initial costs to modernize the coast in ways that allow it to gain ground and sustain critical transportation infrastructure far into the future is justified, particularly if we substitute natural renewable energy for fossil energy to transport sediment from the river to coastal wetlands. The future of one of the world's most unique and important ecosystems is at stake, along with all the economic and cultural benefits associated with that ecosystem. In addition, the economic health of much of the United States depends on sustaining the navigation, flood control, energy production, and seafood production functions in this region. Each of those functions is currently at severe risk due to the degradation of coastal wetlands.

- Consumers throughout the nation will pay the price should we fail to act. Because the national implications are so far reaching, protecting these assets should not fall on one state or region.

- Unless the delta is restored and maintained, the entry to the Lower Mississippi navigation system, the lynchpin of the entire Mississippi navigation system, is likely to collapse. Even if the system could be temporarily repaired, which is doubtful, interim losses and damage to the U.S. economy would be staggering.

- Wetlands' ability to reduce storm surge makes their restoration a wise federal investment. The ability of wetlands to reduce storm surge should be of particular interest given that massive amounts of federal disaster aid are often required to address the aftermath of severe storms. Beyond effects on the federal budget, the economic impacts of disasters include unemployment, loss of investor confidence, increased foreign indebtedness, and depletion of capital reserves.

- Any threat to the energy sector in Louisiana is a direct threat to the U.S. economy. By restoring protective wetlands and barrier islands in Louisiana, this extensive energy infrastructure will gain needed storm protection, security, socioeconomic support, flood protection, and cultural stability.

- Wetland restoration not only enhances current carbon sequestration but also prevents the release of previously stored carbon. This will have huge climate and economic implications as carbon cap and trade systems come on line in coming years.

COASTAL RESTORATION, CLIMATE CHANGE, AND ENERGY

QUESTION 10

John Day, Matthew Moerschbaecher

CAN RESTORATION OF LOUISIANA'S MISSISSIPPI RIVER DELTA SUCCEED IN THE FACE OF SEVERE CLIMATE IMPACTS AND INCREASINGLY EXPENSIVE ENERGY?

Global climate change coupled with increasing energy costs pose significant threats to the ecological and social systems of Louisiana's coastal zone. In this section we review climate and energy issues and discuss their significance for Louisiana's coast.

OUR ANALYSIS

We performed an extensive survey of the latest research on climate change and energy trends. Like the vast majority of scientists, we accept that climate change is a reality and that mitigating its effects requires a swift and effective response. Similarly with energy costs and scarcity, we follow the mainstream view on peak oil and discuss its implications for coastal Louisiana.

WHAT THE SCIENCE SAYS

The mean global temperature increase in the 21st century is predicted to be as high as 6 degrees Celsius or about 10 degrees Fahrenheit. There is a strong scientific consensus that the rate of global sea level rise will accelerate as land based ice masses melt and the oceans expand due to heating. In 2007, the Intergovernmental Panel on Climate Change predicted that sea level rise will be about 40 centimeters by the end of the 21st century, with a range of uncertainty from 10 to 54 centimeters. More recent work suggests that this prediction may be too low and that sea level rise may be one meter or more by 2100. Sea level rise is especially worrisome in the Mississippi and other deltas, because it is augmented by high rates of subsidence, which can exceed 1 centimeter per year. Thus, if recent projections hold true, the effect of sea level rise plus subsidence may be as high as two meters by 2100 in much of the Mississippi River Delta.

It is now increasingly certain that the frequency of strong hurricanes will increase in the 21st century. Recent studies show that sea surface temperatures in the tropics increased by about 1 degree Celsius over the past half century. During the same period, total hurricane intensity increased by about 80 percent. Other studies have found an increase in the number of category 4 and 5 storms over the past several decades and have linked those increases to higher sea surface temperatures. Some have argued that these increases are not linked to climate change but to decadal cycles in tropical storm activity. Regardless of the reason, it appears likely that the future will bring stronger hurricanes, which will complicate Louisiana's coastal restoration and flood protection efforts.

Although no single weather event or flood can be attributed solely to climate change, the flood of 2011 is consistent with climate projections. The intense storms that delivered so much precipitation up river were created when warm air masses off a warming Gulf hit colder continental air masses. Precipitation is generally expected to increase in higher latitudes due to a wetter atmosphere, making floods like those in 2011 more common.

Climate change is not the only global trend with implications for Louisiana. Energy costs increased by a factor of five in the last decade, and similar increases are likely in the future. Considerable amounts of information have been published in the scientific literature on this subject, primarily by petroleum geologists with long experience in oil exploration and production. These scientists predict a peaking of total world oil production soon, perhaps within a decade. This is expected to usher in an era in which demand will consistently exceed supply. The price of energy can therefore be expected to increase significantly, under even the most optimistic scenarios.

The combined forces of climate change and energy cost increases will pose serious challenges to Louisiana's flood control and navigation systems. Higher water and increasing storms will make these systems more vulnerable to flood damage. At the same time, a flood control system based on levees is extremely energy intensive; costs for levee operation and maintenance will likely become progressively more expensive in coming decades as energy costs increase.

Given all of these factors, it may be impossible to protect some of Louisiana's coastal residents where they currently live. The loss of wetlands due to climate change may also make employment based on wetland estuaries less sustainable. This information should be clearly and honestly presented to coastal residents and others so that fully informed decisions can be made.

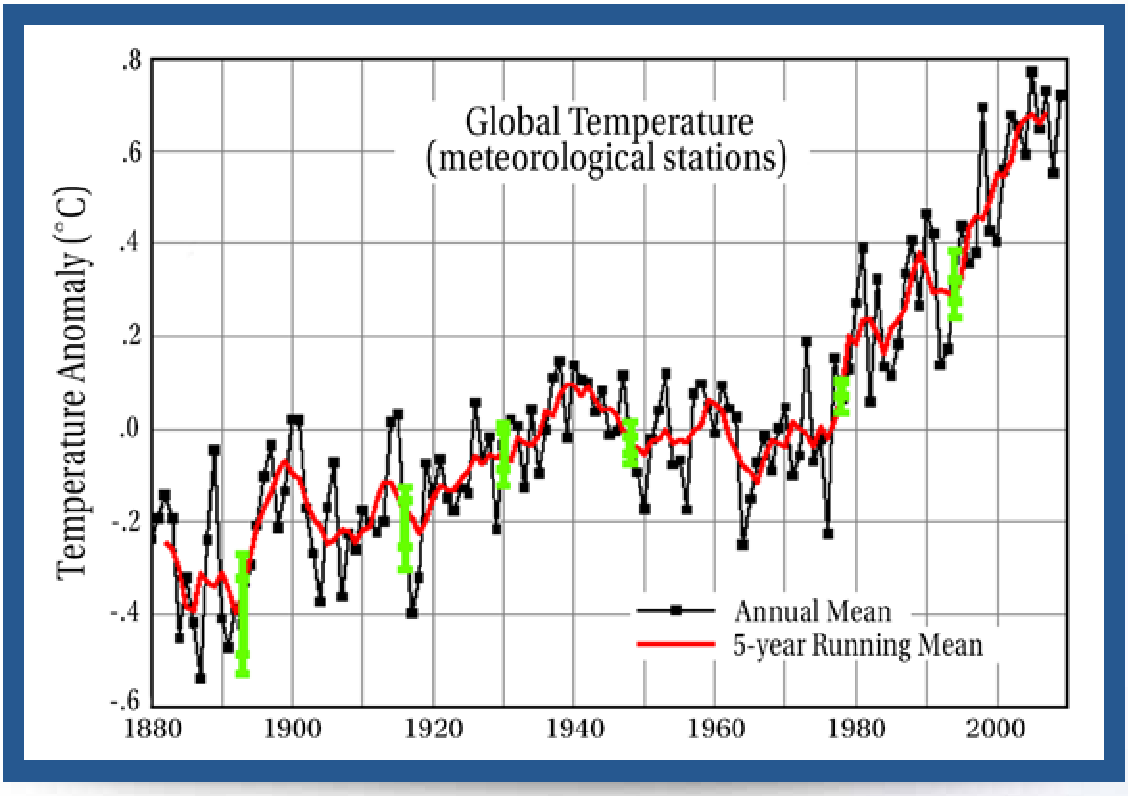

Figure 1: History of global mean surface air temperature, from the NASA Goddard Institute for Space Studies. The scale shows how much warmer or cooler the world was than the average temperature from 1951 to 1980. Recent warming is clear but with high year to year variability. The green vertical lines show data variability for the indicated time periods. Other research groups have produced similar plots. The figure is modified from Figure 1a in Hansen, J., Mki. Sato, R. Ruedy, K. Lo, D.W. Lea, and M. Medina-Elizade, 2006: Global Temperature Change. Proc. Natl. Acad. Sci., 103, 14288-14293, doi:10.1073/pnas.0606291103.).

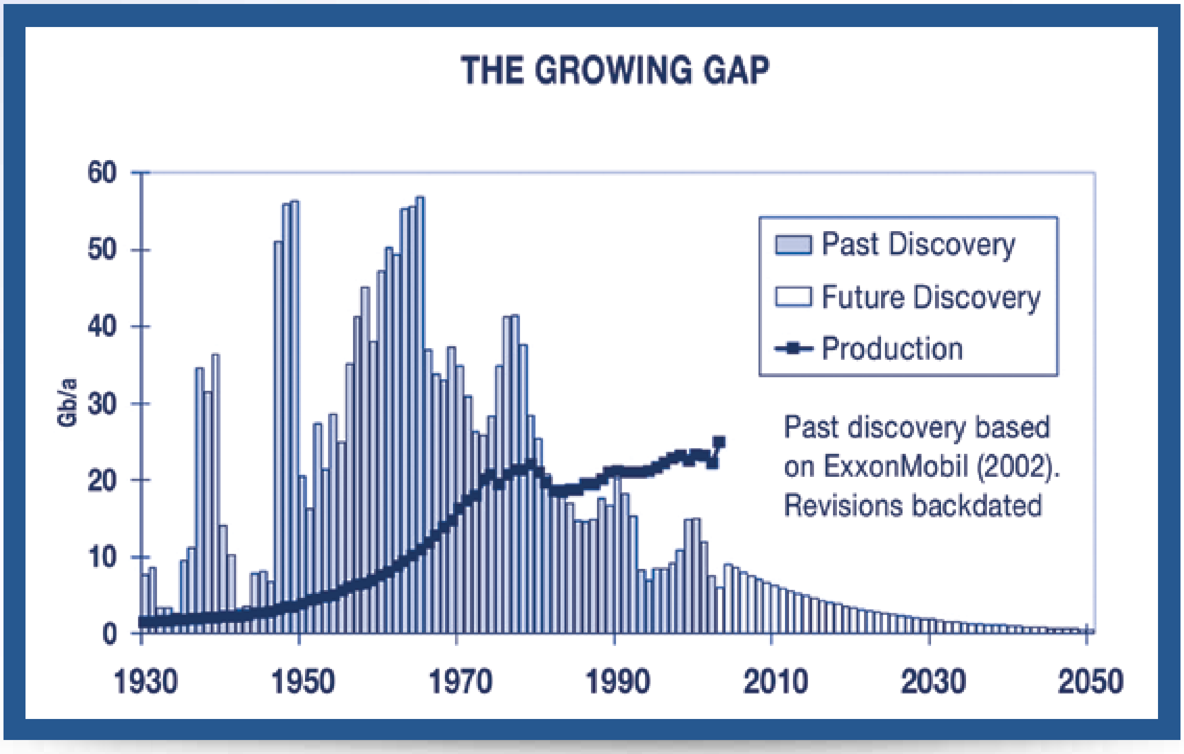

Figure 2: The rate at which oil is discovered globally has been dropping for decades and is projected to drop off even more precipitously in future years. The rate of oil supply and demand can be expected to widen. Data courtesy of Colin Campbell.

These trends are sobering, but the past need not be a prologue to the future. Deltaic systems are extremely sensitive to sediment supply, which is largely under human control in the Mississippi River Valley. We can use new and reengineered river diversions with the Atchafalaya/Wax Lake Deltas, and the Bonnet Carré Spillway as prototypes for a new generation of improved sediment diversions. Using the increased amount of sediment brought into coastal Louisiana by the projected uptick in river floods, these diversions offer the possibility of offsetting some of Louisiana's land loss.

IMPLICATIONS FOR POLICY MAKERS

Climate trends and energy costs indicate that current management of the Mississippi River and its delta will lead to cascading failures in navigation, flood protection, and wetland restoration. If this risk is quickly recognized and addressed, however, a sustainable trajectory can be achieved that will lead to a less ecologically destructive scheme for river management. This new approach will improve the long term economic viability of deep draft navigation, storm protection, and the economy of south Louisiana. Using the river in this way will have the additional benefit of building more coastal land to offset projected land losses.

- Accelerated sea level rise and stronger hurricanes will increase threats to jetties and other exposed channel infrastructure at the river mouth. Flood protection levees throughout the Mississippi River Delta will also face greater risk from storm damage.
- Projected climate change argues for an aggressive restoration program. This approach requires a commitment to a series of very large diversions that would need to be constructed soon. It will be critical to design these diversions to convey as much sediment as possible. This will allow marshes with strong soils to be formed before sea level rise and storms further damage the coastal ecosystem.
- Design of these diversions should factor in other already observed climate change effects in the Mississippi River watershed, including alternating severe floods and droughts.
- Projects should be devised that require as little fossil energy for operation and maintenance as possible so that performance is not hampered by energy scarcity or cost in the future.
- Planning horizons dictate that these large diversion projects begin implementation soon. The rationale for doing so should take into account that structural protection measures will continue to depreciate with time, requiring more operation and maintenance costs, particularly given rising sea levels. River diversions, on the other hand, have the potential to appreciate with time, having larger up front costs but reduced long term operation and maintenance.

Photo By: Yuki Kokubo, www.yukikokubo.com