The Central Role of the Mississippi River and Delta in Restoration of the Northern Gulf of Mexico

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Executive Summary

The ecological and economic well-being of the five states of the Northern Gulf of Mexico are heavily dependent on a healthy and resilient Mississippi River and Delta (MRD), without which much of the biological resources, beaches, fisheries, shipping and other key economic interests of Alabama, Florida, Louisiana, Mississippi and Texas will be at risk. The ongoing loss and degradation of the MRD and its associated habitats threatens key populations of wildlife and seafood species, and has greatly reduced its value in protecting Gulf of Mexico (GOM) ecosystems and the communities that depend upon them. The Delta wetlands also play an important role in buffering storms, through reduced storm surge and wave height, which can help protect vitally important oil and gas infrastructure that is increasingly concentrated on and off shore of the MRD. Unless urgent attention is directed to restoration of the declining MRD, investments already made in these other states to developing those economic interests could be lost. This paper identifies the driving biophysical systems, indicators of threats to those systems, and the most pressing restoration opportunities.

The size of this watershed, the historical extent and vulnerability of the MRD's coastal wetlands, and the role of those wetlands in defending the condition of broader northern Gulf ecosystems make its protection an issue of national importance. The Mississippi River (MSR) drains 40% of the continental US, making it the fourth-largest watershed in the world at 1.2 million square miles. The MRD is home to 60 percent of all Gulf coastal wetlands. At the same time, it has lost almost 1900 square miles since the 1930s, more than 80 percent of US coastal wetland loss.

The MRD and its deltaic estuaries are the engine of productivity that drives complex, interdependent biophysical systems across the northern Gulf, and thus requires the most immediate attention in order to ensure recovery of the Gulf Ecosystem. The Mississippi Delta with the MSR mainstem and the Atchafalaya River outlets dominates ecosystem processes in the northern Gulf of Mexico. These ecosystem attributes include:

1. *Freshwater Inflow* – The Mississippi River provides 80-90% of freshwater entering the Gulf of Mexico from rivers, creating critically important freshwater and brackish wetland habitats.

2. *Sediment Balances and Delivery* – The Mississippi/Atchafalaya Rivers rank sixth in the world for sediment discharge and contribute 95% of all sediment entering the northern GOM. This huge sediment load created and maintained the massive historic wetlands and barrier islands with all their ecosystem functions of water filtration, pollution reduction and storm protection for coastal communities, industry and infrastructure.

3. *Nutrient Balances and Delivery* – The historic wetlands created by the Mississippi and Atchafalaya Rivers protected the Gulf from rising nutrient loads from the watershed. The deteriorating wetlands now allow huge delivery of fixed nitrogen and organic carbon that combine to form the dead zone that affects a significant portion of the entire GOM shelf each summer.

4. *Wildlife & Endangered Species* – Freshwater and brackish wetland habitats provide key habitats for a wide array of resident wildlife species which are intimately linked to cultural use patterns in the Gulf region, and for migratory songbirds, shorebirds, wading birds and raptorial birds moving through Central U.S. flyways. Freshwater wetlands and related waters also provide important opportunities for inshore recreational fishing and subsistence and commercial harvest of inshore fishes and crustaceans, including crawfish.

5. *Fish and Fisheries* – Brackish water and saltwater wetlands, including brackish marshes and salt marshes, provide key nursery habitats for many economically important seafood species that are harvested throughout the northern Gulf, including shrimps and crabs, oysters and clams, Gulf menhaden, and many other nearshore fish species, which also provide key prey for many other offshore species.

6. *Storm Surge Protection* – MRD wetlands and barrier islands provide important storm protection to coastal communities and economic infrastructure by reducing surge and lowering wave heights. Further erosion and loss of these protective buffers could have adverse impacts on oil and gas interests of regional and national importance.

The health of the Delta is vital to the economic health of the nation. Coastal Louisiana is home to the largest wetlands ecosystem in the United States, major energy, fishing, shipping and tourism industries, and unique people and cultures. All of these precious benefits are at stake if we do not reverse land loss, revitalize the system, and redesign the Delta. A healthy MRD ecosystem, along with its underlying biological and physical processes, is critically important to the sustainability of vital Gulf-wide economic interests, including:

1. *Navigation and Shipping* -— The MSR is essential to one of the world's most important economic transport corridors carrying 60% of all grain exported from the US and making the deepwater ports from Baton Rouge through New Orleans to the Gulf the most active in terms of tonnage shipped in the world.

2. *Wildlife, Fisheries and Related Tourism* – Protecting and restoring MRD estuaries is vital to sustaining fisheries and endangered species Gulf-wide and can be done with the help of diverted MR sediments, off-shore sediments and beneficial use of sediments dredged from navigation channels.

3. *Oil and Gas Production* – Most existing and proposed US oil and gas infrastructure on the continental shelf and slope in the US GOM – particularly deep and ultra-deep development – is clustered offshore of the MRD. In restoring the Delta's capacity to build protective wetlands and barrier islands, this extensive oil and gas infrastructure can gain needed storm protection.

Any successful strategy to restore the northern Gulf of Mexico to a healthier and more resilient condition should go beyond correcting the immediate impacts of the oil blowout to leverage the healing potential of the Mississippi River and its deltaic estuaries and wetlands. This requires recognition of systemic problems that are the result of decades of environmental decline along with ongoing threats that came into stark focus last summer. Accordingly, the deltaic estuaries built and nourished by the Mississippi and Atchafalaya Rivers should be singled out for special attention by this Gulf Restoration Task Force. Protecting the MRD estuaries is vital to sustaining fisheries of the northern GOM and this can be done by restoring the land-building capacity of the Delta, e.g., through MSR sediments, off-shore sediment and beneficial use of sediments dredged from navigation channels.

The Size of the Watershed

The Mississippi River is one of the world's major river systems in size, habitat diversity and biological productivity. From its source at Lake Itasca, it is the third longest river in North America. If we use the Mississippi-Missouri River combination, however at 3,710 miles, it ranks fourth in the world (National Park Service).

The Mississippi River Watershed drains 40% of continental United States including parts of 31 states and 2 Canadian provinces. The total area drained by the watershed is some 1.2 million square miles, the fourth largest in the world and far larger than the watersheds of all other rivers discharging into US Gulf waters combined.

Figure 1. Watershed of the Mississippi River drains 40% of the continental US.
(*Source: Wikimedia Commons)*

The MSR and its many navigable tributaries constitute the most important natural and economic corridor in North America, providing both the ancient highway for great hemispheric migrations of birds and dispersion of fish and other aquatic organisms, as well as a more modern avenue connecting peoples and goods throughout the Nation to markets throughout the world.

Interdependent Gulf Ecosystem Processes

1. Freshwater Inflow

The Mississippi River system ranks seventh among rivers worldwide for water discharge (470 million acre-feet/yr). If we consider total inflow, rather than mean discharge from the US into the Gulf of Mexico, the Mississippi and Atchafalaya together account for between 80 and 90 percent of all freshwater delivered by rivers to the US GOM (Table 1) (Strauss et al. 2009).

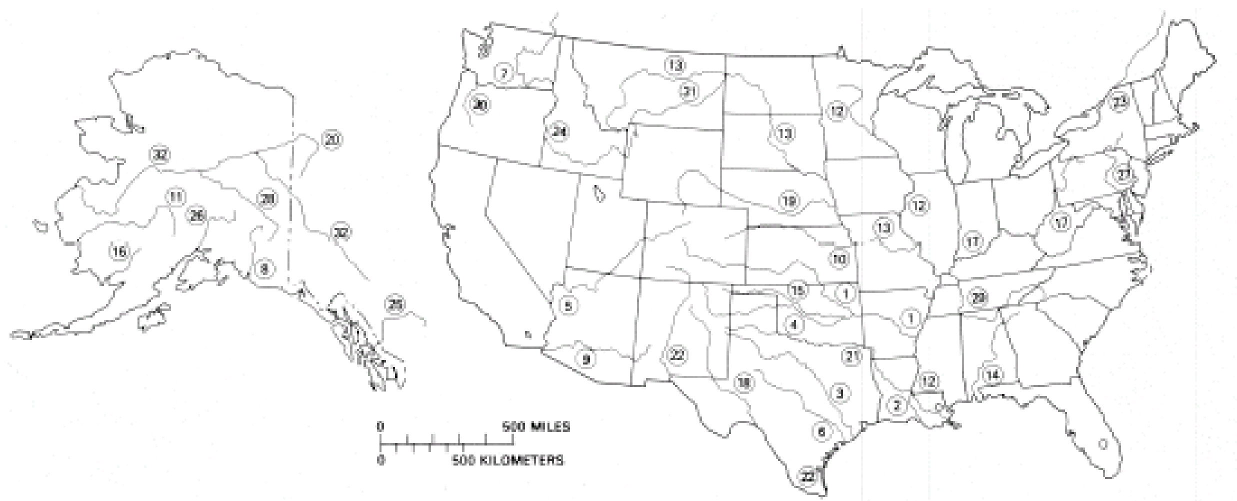

Figure 2. USGS showing the largest rivers in the United States either in length, drainage basin or discharge (*Source: Kammerer*)

Table 1. Major rivers discharging to the U.S. Gulf of Mexico Coast Ranked by Discharge

Map Number	River Name	Mouth Location	Mean Discharge (1,000 ft^3/s)	Drainage Area (1,000 mi^2)
12	Mississippi	Louisiana	426	1,150
2	Atchafalaya	Louisiana	225	95
14	Mobile	Alabama	67	45
	Pearl	Mississippi	30	8.0
	Apalachicola	Florida	20	2.6
	Pascagoula	Mississippi	5.5	9.6
3	Brazos	Texas	3.6	46
6	Colorado	Texas	3.0	42
22	Rio Grande	Texas/Mexico	1.5	336

(*Sources: Kammerer, USGS*)

Under natural conditions, the massive watershed of the Mississippi delivered huge amounts of fresh water and massive amounts of sediment to create the salinity mixing zones and re-nourish the deltaic structure which together support the wetlands that both cleanse waters entering the Gulf and providing habitats for a plethora of wildlife and fisheries species.

Furthermore, the Mississippi once delivered freshwater and sediments to the Gulf through multiple outlets, including a number that were significant only during large discharge events. Today that discharge is delivered through only two, with most flow directed into deep water off the continental shelf where it is stratified with lighter freshwater forming a layer over denser salt water. This is the artificially induced situation that gives rise to the dead zone. If this water were released through multiple outlets, particularly to the east, it would drive wetland creation and rehabilitation within the deteriorating wetlands just over the levees that are today being lost at higher rates than anywhere else on the planet. Finally, creating controllable lateral discharges through the levees would generate estuarine conditions farther east on the shallow shelf, giving rise to higher productivity in Chandeleur and Mississippi Sounds far beyond the Louisiana border.

Thus, the vast majority of river water entering the US GOM comes in at two points located about 150 miles apart, with most entering during the first six months of the year. The nature of these outlets has been heavily modified by man, with the largest input at the MSR bird's foot artificially pinned precariously to the edge of the continental shelf by a vast complex of rock structures built to allow deep-draft navigation into the MSR.

Maintaining this entrance requires nearly constant dredging as the MSR is no longer capable of efficiently transporting sand through these structures and is seeking other outlets. Upstream, the MSR is managed for a single deep channel to facilitate barge traffic during the lowest discharge periods, and is flanked by thousands of miles of flood control levees designed to confine the highest discharges and speed floods into the GOM.

Modifications in this century-old management scheme to provide more outlets for sediment and water within the MRD could greatly improve the sustainability and cost-effectiveness of both flood control and navigation, while allowing the MSR to better sustain not only MRD wetlands, but also those in other Gulf states as far east as Mobile Bay. The effectiveness of the small diversions operated at Caernarvon and Davis Pond in keeping oil out of MRD estuaries during the BP disaster provided much evidence that additional river outlets offer the best potential for limiting ecological damage to critical estuaries during future oil releases, whether caused by blowouts or tanker accidents.

2. Sediment Balances and Delivery

The Mississippi River carries an average of 436,000 tons of sediment each day and up to 550 million tons of sediment in a major flood year (NASA). The sediment load of the Mississippi River below the Old River Control Structure to the mouth has declined over the last several decades, primarily as a result of dam building on the Missouri River, but still conveys an average of 200 million tons per year to the GOM. Historically, most sediment transported by the Mississippi River has come from the arid drainage of the Missouri (Figure 2).

As reservoirs fill along this important tributary and it is increasingly necessary to bypass sediment around the dams, it is anticipated that sediment flux from the Missouri to the Mississippi will be restored sooner or later to a more natural volume. But even in its current sediment-starved condition, the Mississippi River system still ranks sixth in the world for suspended-sediment discharge (Swarzenski 2003), and dwarfs all other sources of sediment to the US GOM (Figure 2). The key point is that the *sediment* loads sustained the active development of shifting deltaic lobes that in turn sustained the various types of wetland ecosystems, keeping ahead of rising seas. Interdiction/alteration of these sediment balance is the major threat to the long-term integrity of the system.

Table 2. Discharge of suspended sediment to the coastal zone by 10 major rivers of the United States, about 1980 (tons/yr = tons per year) (Meade and Parker, 1984)

Rivers		Average annual sediment discharge (million tons/yr)
Rivers that discharge the largest sediment loads:		
	Mississippi (includes the Atchafalaya River)	230
	Copper	80
	Yukon	65
	Susitna	25
	Eel	15
	Brazos	11
	Columbia	
	Before Mount St. Helens eruption	10
	Since Mount St. Helens eruption	40
Rivers with large drainage areas:		
	St. Lawrence	1.5
	Rio Grande	0.8
	Colorado	0.1

(*Source: USGS*)

Ten US rivers play a significant role in transporting sediment to the ocean by virtue of their large sediment discharges or drainage areas, but, of these, only the Mississippi/Atchafalaya discharge to the US GOM (Table 2). Other Gulf rivers draining arid parts of Texas like the Rio Grande, Brazos and Colorado River have experienced significant decreases in both freshwater and sediment discharges caused by dams and reservoirs.

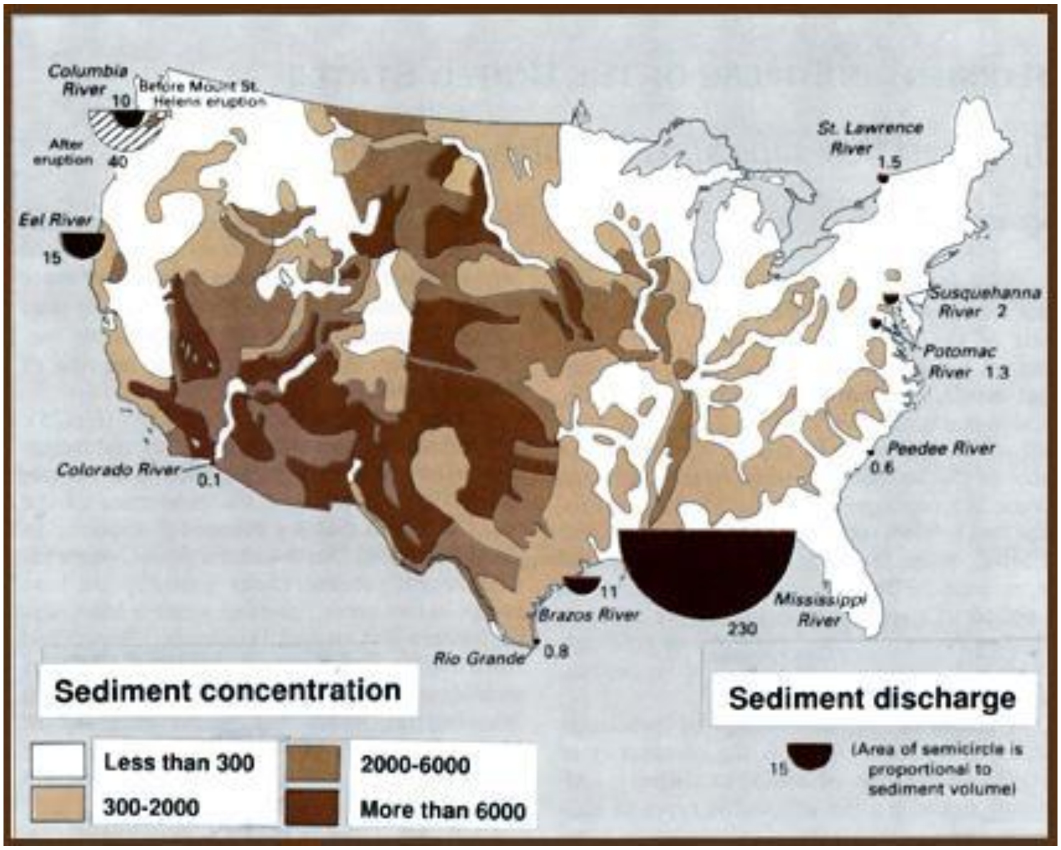

Figure 3. Average concentration of suspended sediment in rivers and average discharge of suspended sediment at the mouths of selected rivers of the conterminous United States. Map was simplified from Rainwater, 1962. (*Source: USGS*)

3. Nutrient Balances and Delivery

The sources of nutrients in the Mississippi River waters can be broadly divided into *natural* and *anthropogenic* (Antweiler, 1995). The contribution of natural sources is usually low because natural systems maintain a balance between the production and consumption of nutrients that tends to reduce downstream export. For the Gulf Coast, the critical need is to reduce and manage excess nutrients so that they do not cause massive algal blooms and disrupt the shelf ecosystem.

Anthropogenic sources arise from excessive application of agricultural chemical fertilizers, animal wastes, and as by-products of manufacturing processes. Municipal wastewater, though treated, still contains the nutrients derived from human sewage, lawn fertilizers and household cleaners and detergents. The most significant nutrients that commonly limit the productivity of plants are nitrogen and phosphorus in their inorganic forms. Because of the turbidity of the Mississippi River, the major response of plants to these nutrients is delayed until the water reaches the Gulf of Mexico, where velocities decrease and sediment settles out of the water, allowing light to penetrate and algae to bloom.

Because nutrient inputs to the Gulf are more strongly correlated with river discharge than with concentration, the Mississippi and Atchafalaya Rivers are the major sources. A hypoxic zone in which water at the bottom drops below 2 ppm in dissolved oxygen forms annually off the Louisiana coast, and can extend west offshore of Texas (Figure 3) when river discharge is high and conditions are calm offshore so that this fresh water flows above and does not mix with salt water. But excessive nutrient inputs are problems in 38 of 55 Gulf Coast estuaries (Committee on Environment and Natural Resources 2010).

The dead zone has the effect of killing or lowering productivity of animals that live in or close to the sea bed that are an important source of food for fish offshore. Because the area involved is so large, in some years the size of the state of Delaware, it is thought to have an impact on the whole western U.S. GOM, though the scale of this impact on fisheries remains largely unquantified.

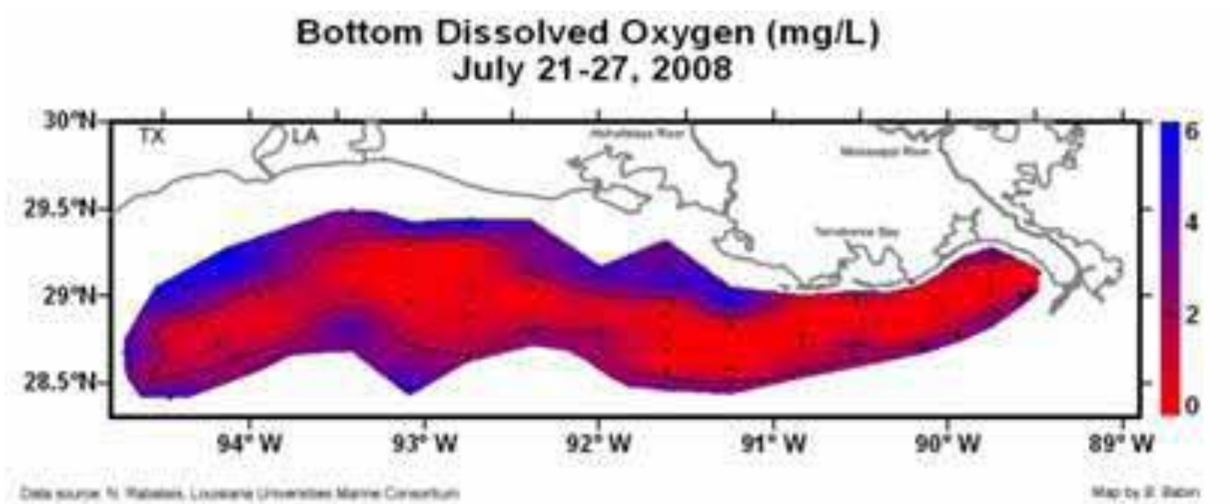

Figure 4. The 2008 extent of the “dead zone” off the coast of Louisiana
(*Source: Committee on Environment and Natural Resources*)

Due to record flooding along the Mississippi River, scientists are predicting the largest dead zone ever for the Gulf of Mexico this year. Predictions for the 2011 Gulf hypoxic zone are between 8,500 and 9,421 square miles, an area the size of Lake Erie. In comparison, the average size of the dead zone is 6,000 square miles. If this year’s hypoxic zone does reach predicted levels, it will be the largest dead zone on record since systematic mapping began in 1985 (NOAA, 2011).

4. Wildlife & Endangered Species

Wetlands provide important habitat to countless bird, fish, and native plant species. Virtually all of the wetlands of the MRD have recently been recognized by the National Audubon Society and Birdlife International to harbor populations of global significance to key avian species of concern (http://iba.audubon.org/iba/profileReport.do?siteId=3273). Much of the value of the still-expansive and diverse wetland habitats is that they are a beacon for birds that breed or overwinter there, and also play an increasingly critical role during migration, since so many other Gulf coast wetlands have been lost to agriculture and development.

The MRD wetlands provide habitat for more aquatic and terrestrial species on an aerial basis than any other habitat type, making them among the most ecologically important ecosystems on earth (Comer et al., 2005). In the Gulf, more than one-third of the United States' threatened and endangered species live only in wetlands.

5. Fish and Fisheries

Brackish water and saltwater wetlands, including brackish marshes and salt marshes, provide key nursery habitats for many economically important seafood species that are harvested throughout the northern Gulf, including shrimps and crabs, oysters and clams, Gulf menhaden, and many other coastal fish species, which also provide key prey for many other offshore species. Fish species that depend on estuaries for at least a portion of their life cycle comprise approximately 80% of the fish harvested nationwide (Lellis-Dibble et al, 2008).

About 98% of the commercial fish and shellfish harvested in the Gulf of Mexico are dependent on estuaries for food, protection from predation or reproduction at critical points in their life histories. Some of the important Gulf species that are wetland-dependent include blue crabs, brown and white shrimp, oysters, striped bass, flounder, and menhaden. Commercial and recreational fisheries generate billions of dollars each year for the U.S economy. One-third of the nation's oysters derive from the Louisiana, a $300 million industry in Louisiana alone (*The Wall Street Journal*, June 25-26, 2011). Almost 90% of all recreational landings in Louisiana are estuarine-dependent species (Table 3).

Table 3. Louisiana Recreational Landings by weight, 2003

Louisiana Recreational Landings
(47 taxa; LDWF 2003)

Year	Recreational Landings (x 1000 lbs)	Estuarine-Dependent Landings	Ratio
1999	20,987	17,827	85%
2000	31,978	28,504	89%
2001	26,369	23,339	89%
2002	21,992	18,586	85%

(*Source: Louisiana Department of Wildlife and Fisheries*)

The value of MRD estuaries to the biota, including most of the species targeted by commercial and recreational fisheries, is not indicated solely by counting acres. The estuaries of the MRD are disproportionately important to the entire US GOM in no small measure because of their proximity to the vast flux of carbon and other life-giving materials that are brought to the coast by the Mississippi/Atchafalaya system. Fish and shrimp that enter the estuaries of the MRD as larvae return to the Gulf as adults to be caught as far away as Florida and Texas. Pelagic birds and shorebirds nest adjacent to the outlets of the Mississippi River because that is where the food they need when they are congregated is available in abundance.

Changes in the way the Mississippi and Atchafalaya Rivers are managed, and the way dredged materials are used, could dramatically lower the rate of wetland loss in the Mississippi River Delta, but perhaps more importantly can improve the productivity of the entire northern GOM.

5. Storm Protection

MRD wetlands and barrier islands provide important storm protection to coastal communities and economic infrastructure by reducing surge and lowering wave heights. Further erosion and loss of these protective buffers could have adverse impacts on oil and gas interests of regional and national importance. Coastal wetlands have been described as " 'horizontal levees' that are maintained by nature and far more effective than constructed levees" (Schleifstein, 2008; Costanza, 2008). "The experience of Hurricane Katrina provided a tragic example of the costs of allowing these natural capital assets to degrade" (Schliefstein).

Storm surge is a rapid rise in water level generated by winds and low central pressure from hurricanes and tropical storms. Water piles up higher than mean sea level, and is pushed toward shore by winds. In the open ocean the surge effect is minimal, but as a storm makes landfall, the sea level is locally elevated. The level of surge is controlled by many factors including hurricane wind speed, angle of hurricane approach, storm size and speed, shape and slope of the coast. Louisiana’s shallow slope and the presence of large, shallow, partially enclosed estuarine bays increases vulnerability of coastal communities to flooding.

Winds associated with storms also generate large waves, with some of the most destructive being generated in shallow coastal bays adjacent to New Orleans and other coastal cities. The combination of surge and waves can cause loss of life and severe damage to infrastructure. Land elevations act as physical barriers to storm surge. Barrier islands work to reduce surge and wave energy. Barrier islands close to the mainland work to decrease wave energy in bays, protecting interior wetlands and levees from wave erosion. Wetland vegetation can reduce waves and surge through frictional resistance even when submerged. Wetland attenuation of energy is a function of plant type, density, and spatial coverage. A cypress forest has the potential to reduce surge by mechanically dissipating wave energy through frictional resistance, and also through the separation of wind energy from the water surface due to the dense cypress forest canopy.

Wetlands and barrier islands are the natural storm buffers of Louisiana, protecting the coast from everyday wave effects and smaller storms, making the system more resilient to larger storms. Wetlands also protect levees from wave attack. However, manmade linear elevated barriers, such as levees, increase surge directly in front of the structure. Surge forms in coastal bays and travels preferentially through canals and rivers, but tends to be dissipated by wetlands. The interplay between surge amplifiers which are often linear manmade features or inland water bodies and attenuators, such as barrier islands and wetlands, is an important component of effective coastal planning and management now collectively referred to as “multiple lines of defense.”

Ecosystem-Dependent Interests Across the Gulf

1. Navigation and Shipping

The Port of South Louisiana alone, one of four deep-draft ports located between the mouth of the River and Baton Rouge, stretches 54 miles along the Mississippi River and loads or unloads more tonnage than any other in the western hemisphere. The Port of South Louisiana handled over 246 million short tons of cargo in 2010, brought to its terminals via more than 4,000 oceangoing vessels and 55,000 barges, making it the top-ranked port in the country for export tonnage and total tonnage (Port of South Louisiana website). Three other ports, individually ranked 6th (Port of New Orleans), 14th (Port of Greater Baton Rouge) and 15th (Plaquemines Port Harbor and Terminal District) account for an additional 2,000 ships a year and add another 171 million short tons to the total for the Lower Mississippi port complex, making it collectively the busiest port in the world in terms of tonnage.

Sixty percent of all grain exported from the US is shipped via the Mississippi River through the Port of New Orleans and the Port of South Louisiana (NPS). In addition, a large portion of US oil and gas products are transshipped east and west throughout the US GOM from New Orleans (Mile 0) as far east as Carrabelle, Florida, and west to Brownsville, Texas on barges through the Gulf Intracoastal Waterway (GIWW), the busiest barge canal system in the world (Figure 5). Keeping this national commerce flowing requires a tremendous dredging operation through the U.S. Army Corps of Engineers (USACE) to keep the navigation channels deep enough for vessel safe passage.

Figure 5. Gulf Intracoastal Waterway (GIWW) connects Gulf ports from Florida to the Mexican border to the Mississippi River.

An average of 36 contracts has been bid annually in the Gulf of Mexico USACE Districts over the past decade to move an average of 85,230,082 cubic yards per year from USACE maintained navigation channels. This constitutes 61% on average of all material dredged by USACE contract dredges in the U.S., with an average of 58,207,650 cubic yards moved annually in the New Orleans District (NOD), or 68% of all contract dredging in the Gulf. The cost per cubic yard moved averaged $3.48/cy in Gulf districts, but ranged from $1.77 in NOD to about $12.00/cy in Jacksonville and Mobile Districts.

The lower-unit cost of moving sediment in MR reflects the traditional approach of dumping this material in deep water offshore of the river mouth where it is unavailable to nourish coastal wetlands and barrier islands, as is required in other USACE districts. Clearly, much more restoration benefit could be realized from this material in the Mississippi River Delta if more funds were allocated to even bring the NOD to the Gulf average expenditure on a cubic-yard basis. This does not take into account the dredging done by USACE owned dredges like the hopper dredge Wheeler which works almost exclusively in the bird's foot at the mouth.

In the high-discharge years like 2008 and throughout much of 2010 and 2011, the USACE has had to spend in excess of $100 million annually just to keep the navigation entrance at Southwest Pass open to ships up to a draft of 45 feet. In recent years, it has become impossible at times to maintain the channel to its full width, or in the past two years to full depth, causing safety concerns and restrictions on the volume of cargo each ship can carry. A significant contributor to the cost run up has been the rapidly increasing price of the fuel required for this energy intensive activity. It is now largely understood that an approach that relies solely on dredging to maintain the entrance is not sustainable, and that new approaches, like the use of lateral sediment diversions will be necessary to more economically intercept and extract sediment from the river upstream of the bird's foot where it is needed for restoration.

2. Wildlife, Fisheries and Related Tourism

The tourism economies of all of the Gulf states, in particular their coastal counties, depend not just on clean and healthy beaches and clean Gulf water, but also on recreational fishing, bird watching and enjoyment and/or utilization of the biological resources of the northern GOM. With the dependence of these resources on the vast MRD ecosystem, all of the Gulf coast states and their coastal economies derive significant benefits from the Mississippi River and its Delta.

The biodiversity stemming from the rich ecosystems of the Mississippi River Delta supports a robust outdoor recreation industry all along the Gulf Coast. Love of the outdoors is intertwined with the cultural threads of the region, and it has helped make the Gulf Coast a prime destination for sportsmen and nature lovers from around the world. According to the Department of the Interior’s 2006 survey on hunting, fishing, and wildlife tourism, these activities generated nearly $21 billion in sales for businesses in Alabama, Florida, Louisiana, Mississippi and Texas (see Figure 6). The biggest sources of revenue by far were fishing ($9.49 billion) and wildlife watching ($6.96 billion), with hunting generating $4.3 billion in direct sales and ancillary receipts.

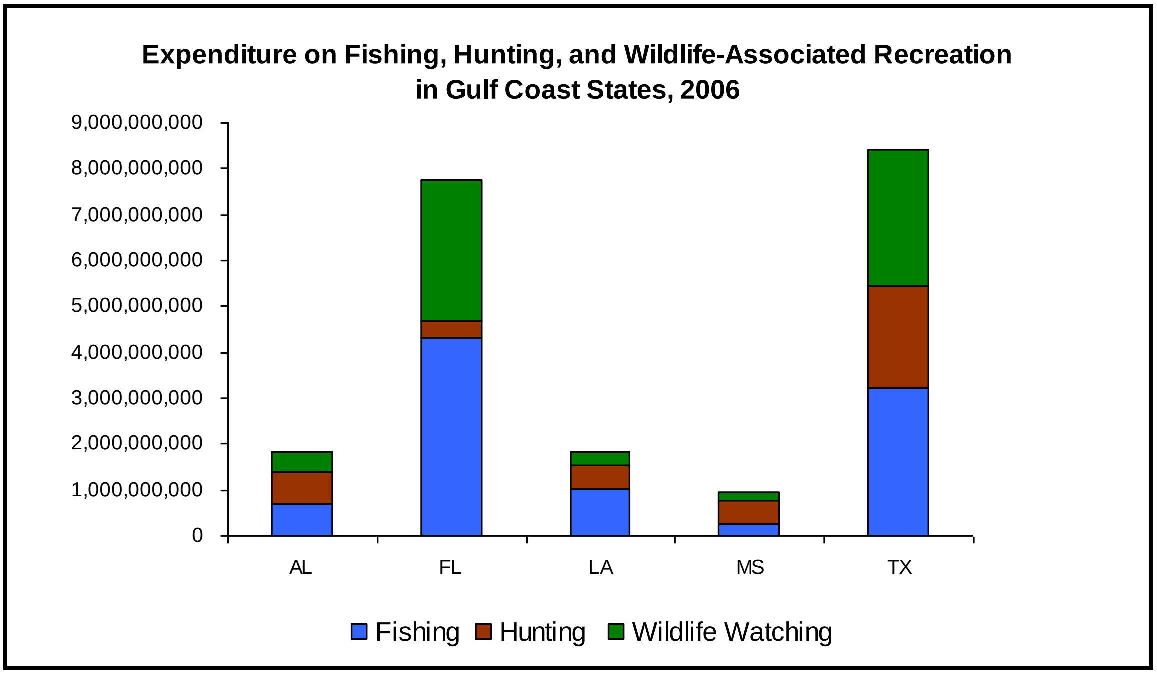

Figure 6. Spending in Gulf Coast States on Outdoor Recreation
(Source: United States Department of the Interior)

While much of this money was spent on businesses far removed from south Louisiana, a significant portion of sales receipts came from companies that directly depend on the Gulf of Mexico and, by extension, the health of the Mississippi River Delta. Based on DOI survey figures and trip data on sea excursions, we estimate that over $861 million worth of 2006 saltwater fishing receipts in the five-state region were derived from game species that spent part of their lifecycle in the estuaries and bays of southern Louisiana. Interestingly enough, the biggest slices of MRD-dependent revenue went to firms based in Florida ($323.4 million (est.)) and Texas ($259.6 million (est.)), while Louisiana firms earned an estimated $240.6 million in 2006 from saltwater sport fishing of delta-dependent species (Table 6).

The Gulf of Mexico leads the nation in commercial estuarine landings with 38% by weight of the national fish harvest, second with 31% by value (Table 5). Perhaps the most telling statistic is that 76% of all commercial landings for the Gulf of Mexico region are from Louisiana ports scattered around the MRD (Table 6). While catch-independent measures are more reliable for estimating fish and shrimp stocks, the fishermen are concentrated around the estuaries of the MRD because this is where their target species are most abundant. This underscores the importance of efforts to protect and restore deltaic estuarine habitats.

Table 4. Regional Contribution to National Commercial Estuarine Landings by Weight and Value, 2000-2004

Region	2000-2004 Commercial Estuarine Landings (weight in lbs)	Percent of National Commercial Estuarine Landings	Region	2000-2004 Commercial Estuarine Landings (value in $)	Percent of National Commercial Estuarine Landings
Gulf of Mexico	7,964,226,642	38%	**North Atlantic**	$3,628,131,288	32%
Alaska	3,758,219,974	18%	**Gulf of Mexicc**	$3,586,776,369	31%
North Atlantic	3,200,386,320	15%	**Alaska**	$1,521,265,608	13%
Chesapeake	2,579,111,548	12%	**Chesapeake**	$885,998,184	8%
Pacific NW	1,537,169,333	7%	**Pacific NW**	$838,634,606	7%
California	935,943,498	4%	**South Atlantic**	$719,410,846	6%
South Atlantic	897,741,014	4%	**California**	$298,298,123	3%
Hawaii	2,279,240	<1%	**Hawaii**	$8,909,821	<1%
Nationwide	20,875,077,569	100%	**Nationwide**	$11,487,424,845	100%

(*Source: Lellis-Dibble, K.A., et al, 2008*)

Table 5. Percent of Gulf of Mexico Commercial Landings Contributed by Louisiana, by Weight and Value for 2000 and 2001

Commercial Landings in the Gulf of Mexico (Current Fishery Statistics Numbers for 2001)				
Region	**2000 Landings (x 1000 lbs)**	**Dollars (x 1000)**	**2001 Landings (x 1000 lbs)**	**Dollars (x 1000)**
Gulf	1,759,993	910,685	1,605,564	798,319
Louisiana	1,344,913	401,095	1,191,460	342,748
% Louisiana	76%	44%	74%	43%

(Source: National Marine Fisheries Service)

Table 6: Estimated Saltwater Fishing Recreational Revenues Dependent on the Mississippi River Delta, 2006

Estimated Value of Delta-dependent Saltwater Fishing Revenue in Gulf Coast States, 2006*	
Florida	323,358,597
Texas	259,591,767
Louisiana	240,560,313
Alabama	26,327,282
Mississippi	11,224,001

**Figures include equipment, food, lodging, transportation, and other costs*

Source: United States Department of the Interior

(*Sources: Environmental Defense Fund, U.S. Department of the Interior*)

Similarly, we estimated that $114.5 million worth of migratory bird hunting revenue was derived from waterfowl that spent part of its life in the Mississippi River Delta. Based on duck hunting trip data and sales receipts, we estimate that Alabama enterprises received more than $3.5 million in revenue from delta-dependent bird hunting parties. These earnings were outpaced by those of hunting companies, equipment sellers, and transport firms from Florida ($4.1 million in delta-dependent bird hunting receipts), Mississippi ($10.9 million), Texas ($46.5 million), and Louisiana ($49.4 million).

3. Oil and Gas Production

The abundant oil and gas resources of the central and western planning areas of the Gulf of Mexico (GOM) are increasingly concentrated off-shore of the Delta, and the on-shore infrastructure of pipelines, refineries, storage tanks and servicing industry such as manufacturing of OCS equipment located not only in Louisiana, but also are important economic drivers in Mississippi, Alabama and Texas.

Louisiana ships substantial amounts of oil and gas and oil and gas product to other Gulf coast states. For example, according to the US Department of Transportation, Louisiana ships to the States of Mississippi and Florida $4.3B and $4.5B, respectively, worth of transportation and airline fuels annually. Insofar as the integrity of the vast Louisiana on-shore and off-shore oil and gas production and its navigation systems benefit from Delta wetlands storm buffering capacity, the entire Gulf coast region depends on and benefits from this energy and transport infrastructure, all of the Gulf coast states depend on the vast expanse of Delta wetlands. The nation as a whole, of course, benefits from the navigation system of the Mississippi River, in particular the agriculture-exporting states of the Missouri and Ohio River basins.

Deep water oil and gas development in the northern Gulf is most intense off of coastal Louisiana because it originates in older MRD deposits, and therefore its most intensive impacts on Gulf coastal resources are evident in the Mississippi deltaic ecosystem of coastal Louisiana. Most U.S. oil production in the Gulf of Mexico comes from offshore of the Mississippi River Delta (Figure 7), and the trend in deep and ultra-deep production is even more concentrated on this BOEMR Central Planning Area (Figures 8 and 9). Depicting the historical well production rates, Figure 10 the critical national importance of the Gulf region's oil and gas infrastructure.

Because of where the oil is produced, the MRD will continue to be faced with a higher threat than other parts of the US GOM. The sea lanes offshore of Louisiana are also heavily transited by bulk oil carrying ships, including the largest supertankers in the world that offload at the Louisiana Offshore Oil Port (LOOP) 16 miles off the coast near Grand Isle. LOOP is the first and only US port capable of servicing ships that can require a water depth in excess of 85 feet, compared to a maximum draft of 45 feet in the Mississippi River. It is the nation’s primary terminal for importation of foreign oil.

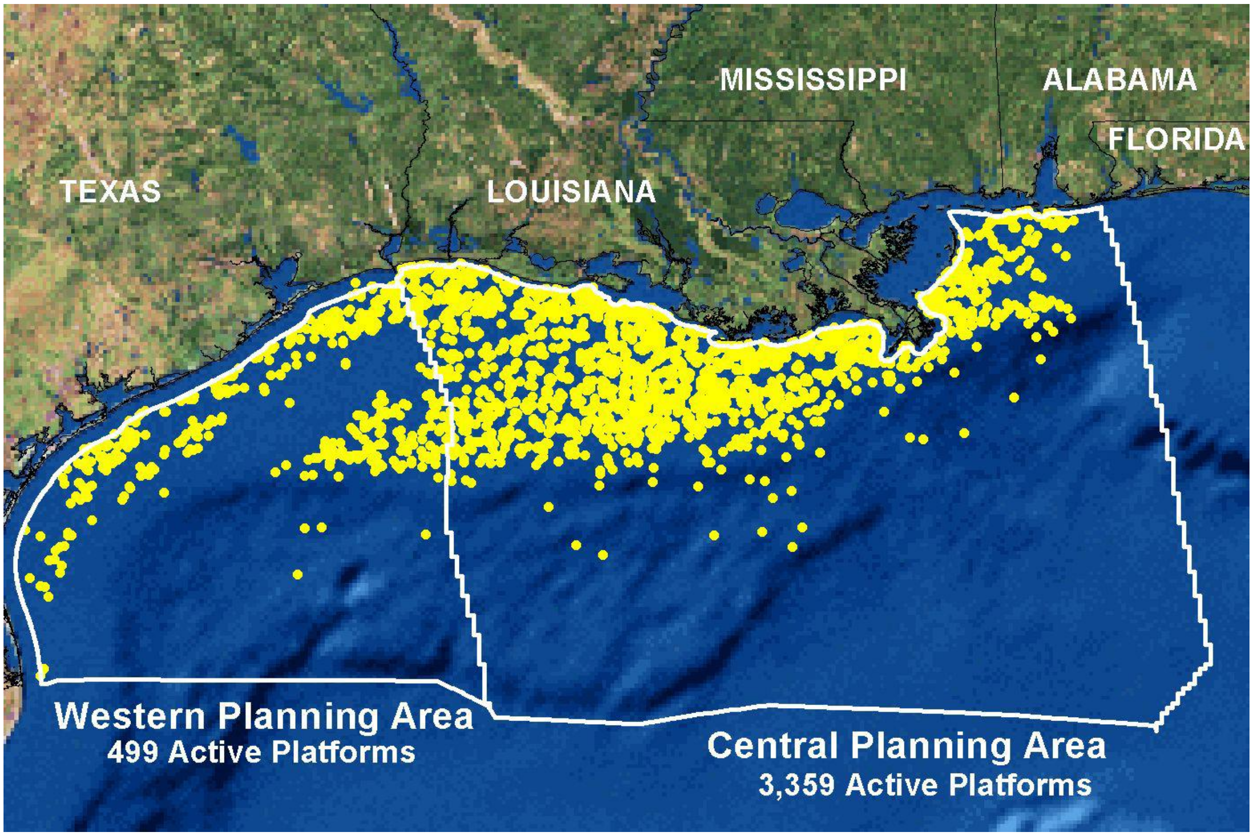

Figure 7. Distribution of Active Oil and Gas Platforms in U.S. Gulf of Mexico in 2004 (*Source: NOAA*)

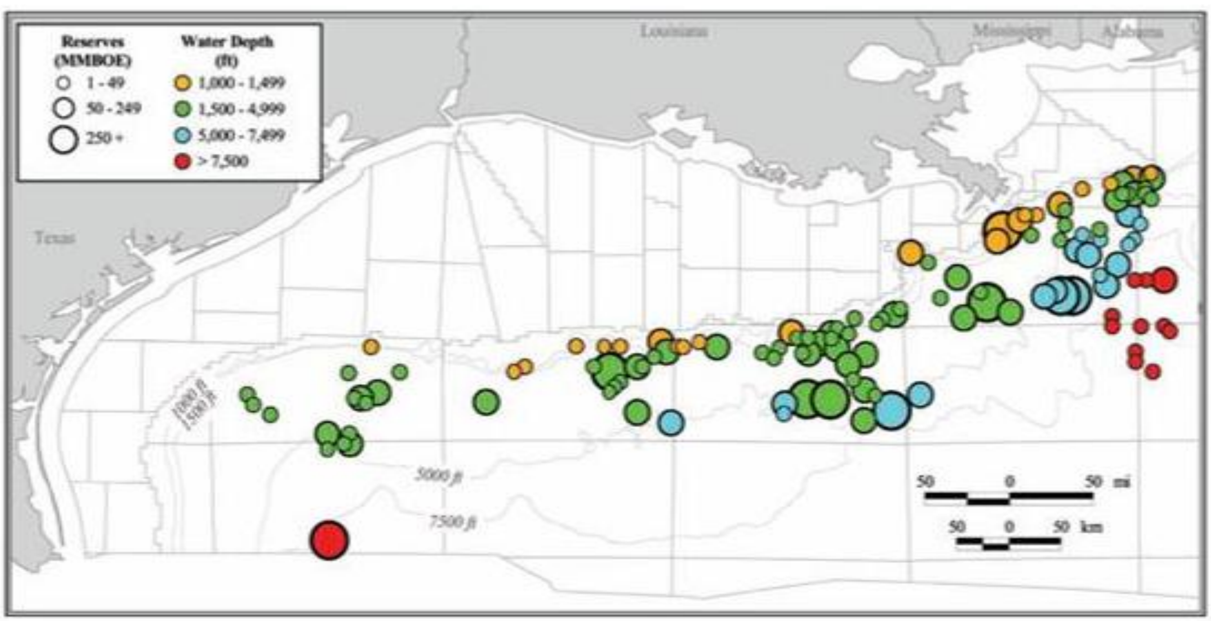

Figure 8. Number and volume of deepwater discoveries (*Source: BOEMRE*)

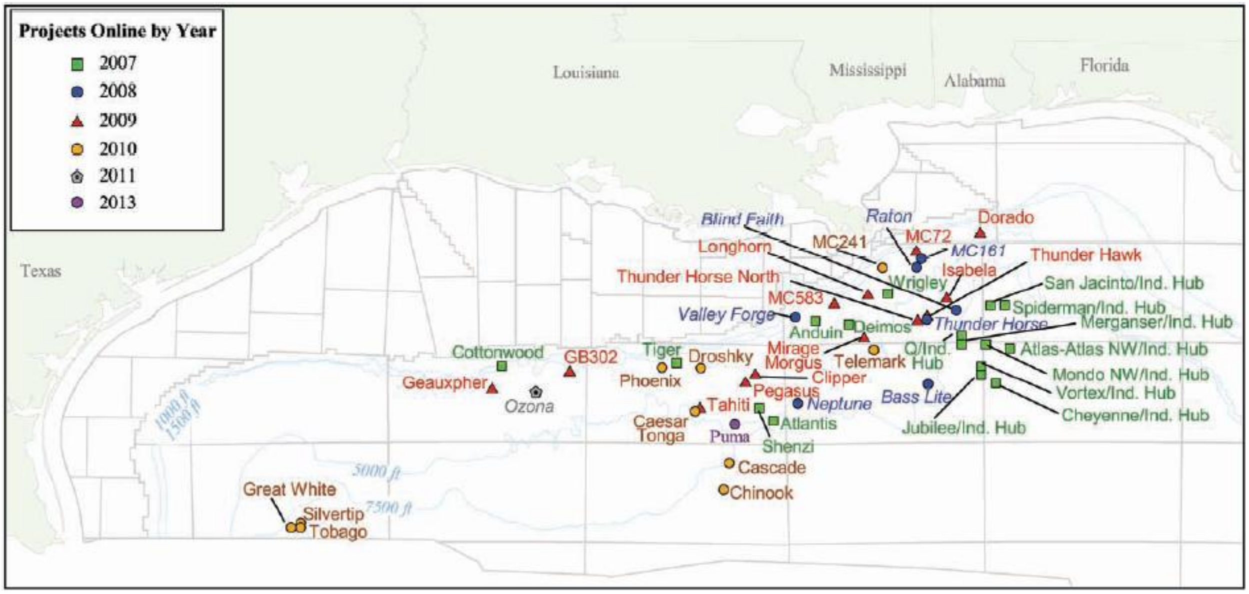

Figure 9. Deepwater projects that began production in 2007 and 2008 and those expected to begin production by yearend 2013 (*Source: BOEMRE*)

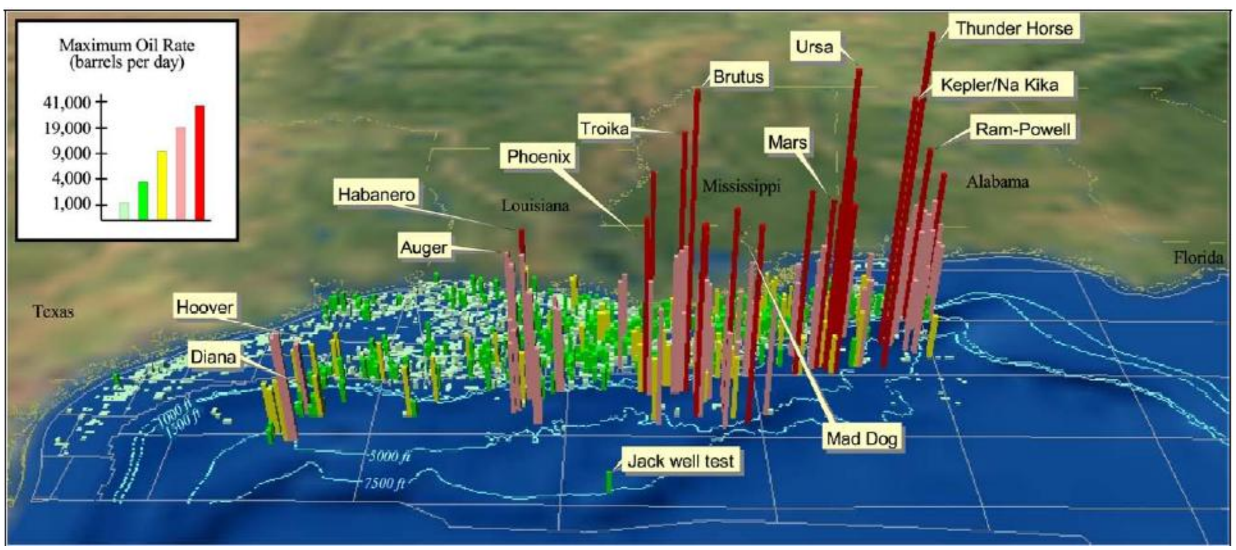

Figure 10. Maximum historic oil well production rates. (*Source: BOEMRE*)

Southeastern Louisiana is the center for a vast network of energy facilities stretching throughout the Gulf Coast. Billions of dollars worth of fuel and petrochemicals are shipped from wells and refineries in and around the Mississippi River Delta to the rest of the United States. Referencing the 2007 Commodity Flow Survey by the Bureau of Transportation Statistics (BTS), we see that the Gulf Coast states are the primary beneficiaries of these products.

- *Gasoline and jet fuel*: Nearly 100% of the aviation fuel and gasoline produced in Louisiana in 2007 was shipped to the five Gulf Coast states. While most of these refined products (80%) were consumed within Louisiana, more than $4.5 billion dollars worth of gasoline and jet fuel was shipped to Florida. Close behind was Mississippi, which received nearly $4.3 billion worth of aviation fuel and gasoline from its neighbor to the southwest. Texas ($1.97 billion) and Alabama ($700 million (est.)) accounted for the balance of gasoline shipments.

- *Fuel oils*: Shipments of diesel and bunker fuel from Louisiana were also primarily for Gulf Coast consumers. Out of the $36.6 billion in fuel oil shipments from the Pelican State in 2007, $2.85 billion was shipped to Mississippi, $1.96 billion was shipped to Texas, $1.15 billion was sent to Florida, and $410 million was shipped to Alabama.

- *Petroleum and natural gas products*: Texas received nearly $7.0 billion worth of kerosene, asphalt, liquefied natural gas, and other products from its eastern neighbor in 2007. Louisiana's other Gulf Coast neighbors also received billions in refined product shipments, with $266 million sent to Mississippi, $243 million sent to Florida and $205 million sent to Alabama.

- *Basic chemicals*: Louisiana is an important producer of dyes, pigments, and basic feedstock chemicals for a huge assortment of industries. The facilities that produce these chemicals are concentrated along the Mississippi River between Baton Rouge and New Orleans. Of the $30.6 billion in basic chemical shipments from Louisiana in 2007, roughly two-thirds was sent to consumers out-of-state. Texas was the largest recipient of ex-state shipments ($3.93 billion), while Mississippi ($462 million) and Florida ($202 million) were also major destinations, though well behind industrial states in the Midwest.

- *Fertilizers and pharmaceuticals:* Agricultural companies and drug makers use billions of dollars worth of Louisiana-produced chemicals on farms and in factories across the country. While shipments of these products are more diffuse, Gulf Coast states like Florida ($365 million) and Texas ($145 million) still receive a significant share of pharmaceuticals and fertilizers manufactured in the Mississippi River Delta.

- *Refined chemical products:* Myriad household goods in American cupboards come from coastal Louisiana. In 2007, this one state produced more than $11.3 billion dollars worth of perfumes, inks, soaps, pesticides, and paints, of which $2.21 billion was shipped to Texas, $282 million was shipped to Alabama and $267 million was shipped to Mississippi.

- *Plastics and rubber*: Out of $13.7 billion in plastics and rubber shipments from Louisiana, almost $7.2 billion were sent to destinations on the Gulf Coast, with $2.46 billion going to Texas, $584 million going to Mississippi, $313 million going to Alabama and $163 million going to Florida.

Urgent Need to Restore the MRD Ecosystem

1. Extent and Vulnerability of Coastal Wetlands

The northern Gulf of Mexico has 41% of the national inventory of coastal wetlands, but some 60% of these are concentrated in the MRD (Turner 1997). MRD coastal wetlands are among the most threatened in the world, however, accounting for over 80% of the nation's total coastal wetland loss (Field, D.W. 1991, Turner 1997, Dahl 2000). The most recent assessment by the US Geological Survey indicates a loss of 1,515 square miles since 1932 in the MRD, with another 368 in the Chenier Plain of southwest Louisiana (Couvillion et al., 2011). It is apparent that the loss is not distributed uniformly over the MRD (Figure 11). Almost half of the marshes that once made up the bird's foot delta at the mouth of the main stem of the MSR are now gone, while those around the Atchafalaya River mouth have been much more stable, and the twin deltas of the Atchafalaya have grown rapidly although they are getting less than 30 percent of the MSR discharge. The net loss in the MRD over this 79 year period amounts to 26 percent of the 5,763 square miles of wetlands once present in the MRD. The only good news is that the rate of land loss appears to be dropping from 70 square miles a year in the 1970s to 12 square miles per year since the mid-1980s (Couvillion et al., 2011).

This loss is due in large part to the construction of levees along the Mississippi River and dredging of more than 15,000 miles of canals for navigation and energy development. These man-made modifications have disrupted natural flooding cycles and prevented deposition of sediments that once sustained the wetlands of the Mississippi River Delta. Without a new round of human intervention to reconnect the Mississippi River to its delta and to restore estuarine hydrology, it is projected that Louisiana's coastal wetlands, along with their amazing biological productivity, will be gone in less than 200 years.

The MRD is the most dynamic and changeable landscape in North America, because it is subject to subsidence or sinking rates that are also unequalled anywhere else. So wetland loss has always been a natural part of the deltaic cycle in the MRD, as the MSR has periodically shifted courses in a major way every 1,000 years or so. Once the primary locus of deposition shifts away from one lobe as the river begins to build a new one elsewhere across the deltaic plain, wetlands associated with the abandoned lobe begin to break up and disappear as they sink below sea level. This geologic history is evident in land loss maps that have been compiled since the advent of high-resolution aerial photography in the 1930s. Today, only the wetlands in the vicinity of the outlets of the Atchafalaya are stable and sustainable, while everywhere else, particularly adjacent to the leveed MSR mainstem, MRD wetlands are experiencing a catastrophic collapse (Figure 11).

Shoreline retreat and barrier island fragmentation are aspects of the delta cycle, particularly as it has been accelerated by modern management, but the more pervasive impact is that of interior breakup of wetlands and rapid formation of large bays and lagoons that reduce the integrity of the coast and make it more vulnerable to deep inland penetration of oil, whether released offshore or in the interior. As was made apparent during the BP disaster, effective cleanup of oil is today essentially limited to sandy strandlines and beaches, and is not possible for muddy marsh shorelines.

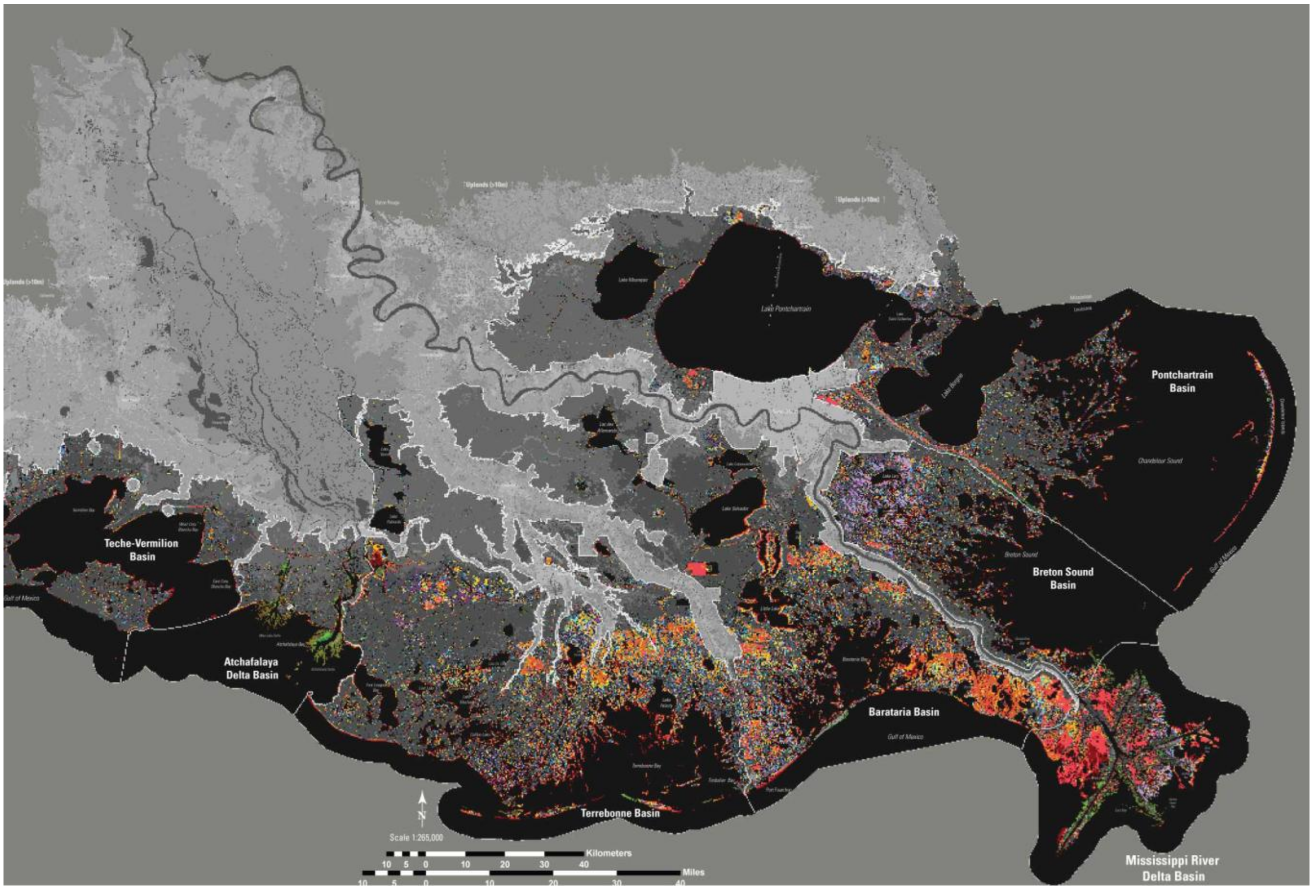

Figure 11. Yellow, orange, red and purple show land lost in the Mississippi River Delta between 1932 and 2010, while green shows land built. The net change amounts to a 26% loss of the coastal wetlands shown in darker grey (1,515 square miles). *(Source: Couvillion, 2011)*

2. Compounded Adverse Impacts from the 2010 BP Oil Blowout

It was once thought that oil released 50 miles or more offshore had little potential to impact coastal estuaries. Yet coastal Louisiana experienced by far the most intense ecosystem impacts from the Deep Water Horizon blowout 60 miles from the nearest land. We have learned far more about the unpredictability of the shifting wind-driven circulation that drove oil onto 600 miles of the northern Gulf coast. While relatively high discharges from the MR and the opening of available river diversion structures at Caernarvon and Davis Pond limited penetration of oil into MRD wetlands, the offshore islands that are so important to sea birds were disproportionally impacted. Because of the sheer length of its shoreline with open estuaries, exposed wetlands and fragile barrier islands, the MRD coast is much more difficult to clean up and will experience more lasting damage and residual effects than other parts of the Gulf coast.

3. Priority MRD Restoration Opportunity

Outside of the Mississippi River Delta, the major cause of Gulf coastal wetland loss has been draining and filling for residential, commercial and industrial development and dredging associated with such filling operations. It would be difficult to restore these wetlands without wholesale relocation of this development. While filling for such purposes has been a factor in wetland loss in the MRD, the major causes of wetland loss are the results of MSR flood control and maintenance of the navigation system that prevents the introduction of sediment into its wetland basins; and the intensive dredging of oil and gas pipeline and equipment navigation canals that have altered hydrology and salinity within the wetlands themselves. The causes of Delta wetland loss point to practical restoration strategies, such as reintroduction of river sediment into the wetlands by means of sediment and freshwater diversions and more ecologically sound transport and placement of sediment dredged from the river or offshore.

Clearly if the goal of Gulf restoration is to recover habitat, it makes sense to look in particular at those parts of the Gulf coast that are losing habitat most rapidly yet have a high potential for restoration that improves the functioning and longevity of deteriorating estuaries. Louisiana, which has a long history of natural wetland loss and regeneration, still has 40 percent of the coastal wetlands in the continental United States and 60 percent of those along the U.S. Gulf Coast.

Given the historical and continuing degradation of the MRD, an urgent opportunity now exists to protect the entire Gulf by restoring the natural processes and land-building capacity of the MRD. The potential for protection and restoration of the Delta is substantial in view of the massive sediment resources of the Mississippi River. Because of the scale of influence, preserving and restoring the Mississippi River Delta are keys to recovery of the entire Gulf ecosystem. With the prospect of BP Clean Water Act penalties in the billions of dollars potentially available for Gulf Coast recovery and restoration, there is an urgent need to focus initially on restoring the Mississippi River and Delta as the keystone of a healthy Gulf-wide ecosystem and the myriad economic interests that depend upon it.

CONCLUSION

The Deepwater Horizon disaster brought to national attention both the amazing productivity and critical vulnerability of America's Gulf Coast. While subject to catastrophic environmental mismanagement and abuse, the Gulf continues to sustain viable fisheries and vast congregations of fish, birds and other wildlife that can no longer be seen elsewhere. What has been less clear is that the ecosystem of the entire U.S. Gulf of Mexico is heavily dependent on the engine of that abundance, namely the Mississippi River and its river-built deltaic estuaries. We have used a few measures to demonstrate the scales at which processes found only in the Mississippi River Delta influence the Gulf as a whole. We have also pointed out the disproportionate and ongoing exposure of the Delta to threats posed by economic activities like navigation and energy development that benefit the Nation as a whole. We suggest that any long-range plan to restore the Gulf in the wake of the most recent tragedy must rely heavily on the natural leveraging that is possible only if we also tap into the healing potential afforded by the Mississippi River. Accordingly, we recommend that the deltaic estuaries built and nourished by the Mississippi and Atchafalaya Rivers be singled out for special attention.

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