5

Chapter Five: Landscape Changes

The hurricanes of 2005 greatly changed the landscape of the Gulf Coast. The following articles document the initial damage assessment from coastal Alabama to Texas; the change of 217 mi^2 of coastal Louisiana to water after Katrina and Rita; estuarine damage to barrier islands of the central Gulf Coast, especially Dauphin Island, Ala., and the Chandeleur Islands, La.; erosion of beaches of western Louisiana after Rita; and the damages and loss of floodplain forest of the Pearl River Basin.

Aerial Rapid Assessment of Hurricane Damages to Northern Gulf Coastal Habitats

By Thomas C. Michot, Christopher J. Wells, and Paul C. Chadwick

Hurricane Katrina made landfall in southeast Louisiana on August 29, 2005, and Hurricane Rita made landfall in southwest Louisiana on September 24, 2005. Scientists from the U.S. Geological Survey (USGS) flew aerial surveys to assess damages to natural resources and to lands owned and managed by the U.S. Department of the Interior and other agencies. Flights were made on eight dates from August 27 through October 4, including one pre-Katrina, three post-Katrina, and four post-Rita surveys. The geographic area surveyed extended from Galveston, Tex., to Gulf Shores, Ala., and from the Gulf of Mexico shoreline inland 5–75 mi (8–121 km). Impacts to barrier island habitats were severe, especially at the Chandeleur Islands, which were reduced in land area by roughly 50 percent. Marsh impacts varied but were greatest in St. Bernard and Cameron Parishes, where much emergent vegetation was scoured or killed. Forested wetlands were impacted heavily, especially in the Pearl River basin and on the cheniers of southwest Louisiana.

Introduction

The USGS National Wetlands Research Center (NWRC) has a history of conducting aerial rapid-response surveys to assess hurricane damages along the coastal areas of the Gulf of Mexico and Caribbean Sea. Posthurricane surveys were conducted from 1985 through 2005 after the following storms: Hurricane Juan (1985), Tropical Storm (TS) Beryl (1988), Hurricane Florence (1988), Hurricane Andrew (1992), Hurricane Erin (1995), Hurricane Opal (1995), Hurricane Danny (1997), TS Frances (1998), Hurricane Georges (1998), Hurricane Mitch (1998), Hurricane Bret (1999), Hurricane Isidore (2002), Hurricane Lili (2002), Hurricane Claudette (2003), TS Bonnie (2004), Hurricane Ivan (2004), TS Arlene (2005), Hurricane Katrina (2005), and Hurricane Rita (2005).

When a storm makes landfall, there is tremendous public pressure on Government agencies to assess and document damages to public and private resources. Our typical response is to launch the USGS aircraft, with trained aircrew and experienced observers, to assess damages and to document impacts. When the aircrew returns to base, data are downloaded and analyzed, and impacts are discussed with a team of scientists and administrators to develop a plan of action. In some cases, no further action is needed. In other instances, detailed short- and long-term studies are proposed or initiated, depending on funding and available resources.

Katrina and Rita dealt a one-two punch to the Louisiana coastline in August and September of 2005 and thus created the need for extensive aerial reconnaissance surveys to assess damages. Impacts were spread geographically over five coastal States (Texas, Louisiana, Mississippi, Alabama, and Florida). Thorough and accurate assessment of impacts required extensive aerial surveys. The objective of this study was to document the spatial extent, severity, and physical characteristics of damages from Katrina and Rita to coastal wetlands, natural resources, and U.S. Department of the Interior (DOI) lands based on preliminary assessments.

Methods

We conducted surveys on eight dates, including one before Katrina, three after Katrina, and four after Rita (fig. 1; table 1). We focused on geographical areas near the path of the eyewall, areas known to be sensitive or important wetland areas, DOI lands and other natural resource areas (refuges, parks, wildlife management areas, and restoration sites), and areas where we had existing studies or prehurricane data. Target sites were coordinated before each flight with NWRC leadership and scientific staff and through liaisons with other agencies.

We conducted aerial surveys from a single-engine, fixed-winged amphibious aircraft (Cessna 185) owned and operated by the DOI. The aircraft was configured with a voice/Global Positioning System (GPS)/moving map system (Hodges, 1999) that linked the aircraft's GPS, intercom system, and laptop computers so that each voice observation from the pilot or observer was assigned to a specific latitude, longitude, and time. The system also allowed geospatial points, the

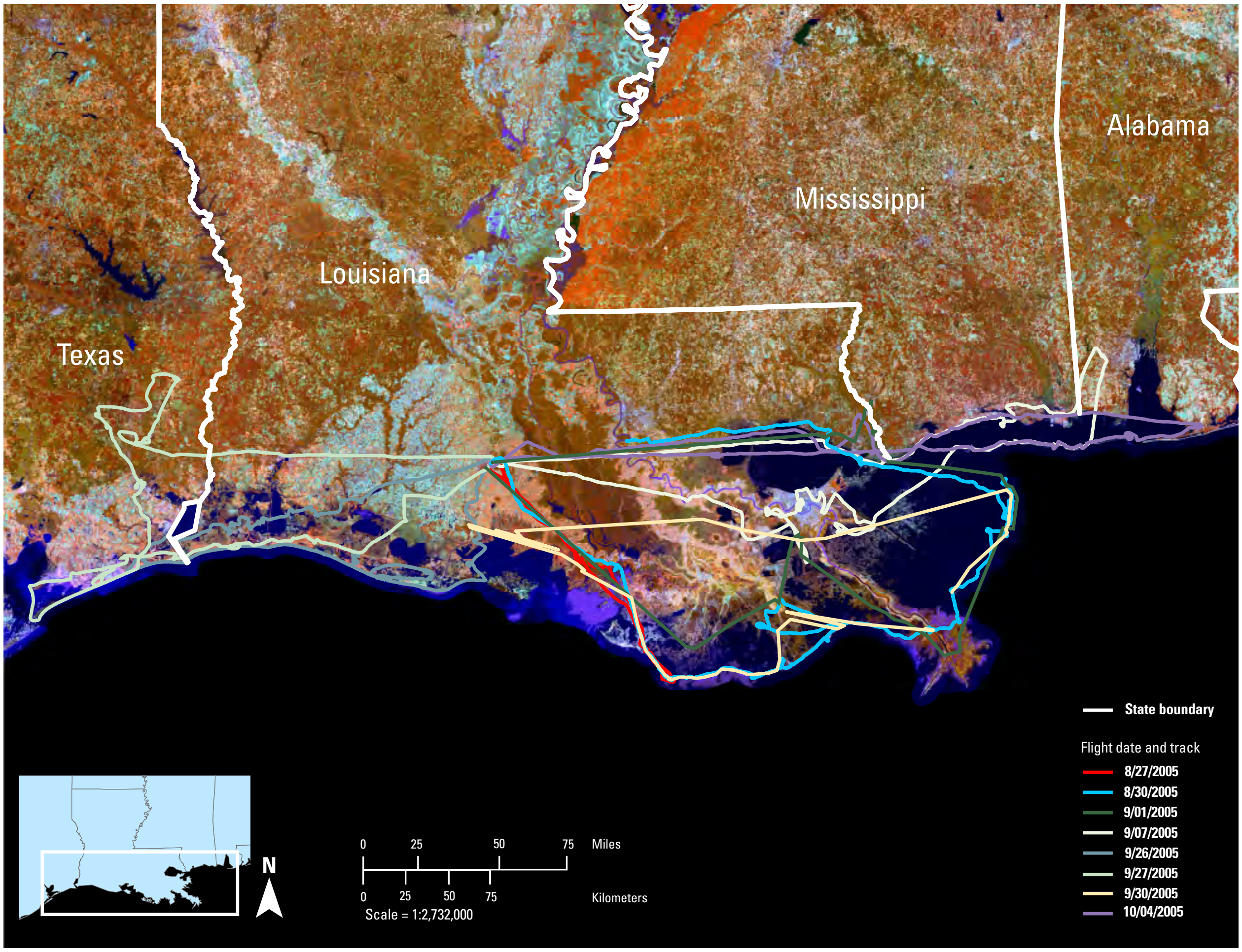

Figure 1. Vicinity map showing areas of impacts from Hurricanes Katrina and Rita, and color-coded flight tracks from eight hurricane reconnaissance surveys during August through October 2005.

Table 1. Dates of hurricanes and reconnaissance flights and areas surveyed for each.

Date (2005)	Event	Geographic area
Aug. 27	Pre-Katrina survey	Bay Junop, Raccoon Island, La.
Aug. 29	Katrina landfall	Bastian Bay, Plaquemines Parish, La.
Aug. 30	Post-Katrina survey	Lower Atchafalaya Basin, Terrebonne Parish marsh, Raccoon Island, Mississippi River Delta, Chandeleur Islands, The Rigolets, Lake Pontchartrain northern shoreline, middle Atchafalaya Basin, all in Louisiana
Sept. 1	Post-Katrina survey	Pearl River basin, Chandeleur Islands, Mississippi River Delta, The Pen, Jean Lafitte National Historical Park and Preserve, Bayou Lafourche, Terrebonne Parish marshes, all in Louisiana
Sept. 7	Post-Katrina survey	Mississippi River, Davis Pond, New Orleans, St. Bernard (La.); Gulf Islands National Seashore, Mobile Bay (Ala./Miss. Gulf Coast); Lake Pontchartrain (La.)
Sept. 24	Rita landfall	Johnsons Bayou, Cameron Parish, La.
Sept. 26	Post-Rita survey	Marsh Island, La., to High Island, Tex., and all coastal refuges
Sept. 27	Post-Rita survey	White Lake, La., to Galveston, Tex., coastal refuges, Big Thicket National Preserve, Tex.
Sept. 30	Post-Rita survey	Isles Dernieres, Timbalier Islands, Grand Isle, Mississippi River Delta, Chandeleur Islands, St. Bernard, all in Louisiana
Oct. 4	Post-Rita survey	Lake Pontchartrain (La.), Pearl River (La./Miss.), Mississippi and Alabama barrier islands and coastal refuges

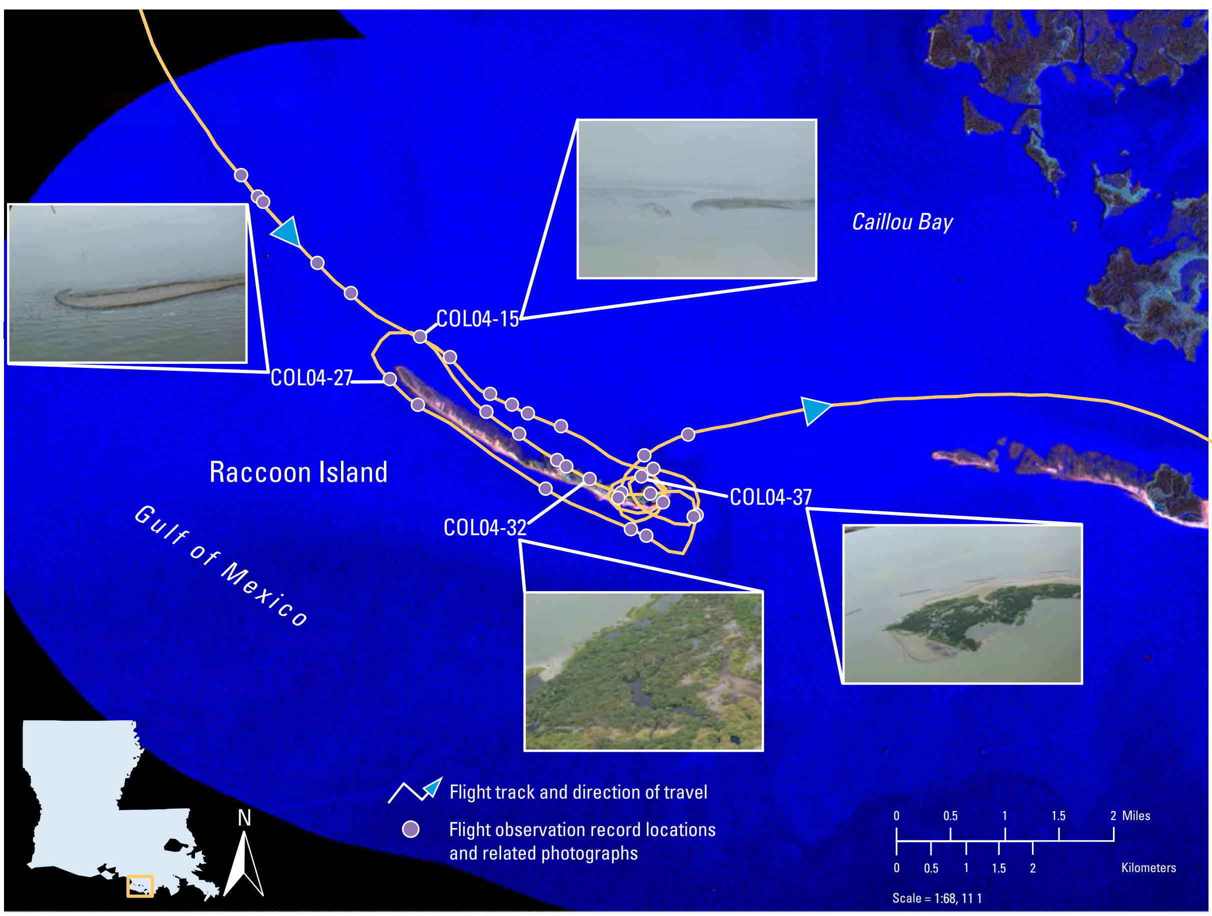

Figure 2. Large-scale map of Raccoon Island, La., showing flight track from reconnaissance survey of August 30, 2005. Purple dots correspond with observations logged into the spatial database (shown in table 3). The numbers that correspond with selected dots (e.g., COL04-15) refer to the file name (COL04) and record number (15) for each observation.

Table 2. Classification scheme for habitat types and conditions in terms of impacts from Hurricanes Katrina and Rita, 2005.

Habitat type	Condition	Description
Beach/ shoreline	Eroded	Sand and substrate removed, scalloped shoreline
	Displaced beach	Sand pushed back into adjacent marsh
Marsh	Flooded	Water over substrate or vegetation
	Scoured	Vegetation removed from substrate
	Eroded	Substrate or pond shorlines scalloped
	Displaced	An intact piece of marsh vegetation, and its associated substrate, removed from its original position and relocated so that it comes to rest on top of vegetation at an adjacent location
	Buckled	Marsh surface compacted and folded to form ridges, peaks, and valleys
	Inverted	Marsh vegetation and its associated substrate flipped upside down so that the bottom of the substrate is exposed, facing up, and the vegetation is facing down
	Buried	Marsh vegetation covered by sand sediment transported from an adjacent location
Forested wetlands	Snapped	Tree trunk severed above the substrate
	Tipped	Trunk lying at or near horizontal
	Defoliated	Leaves removed
	Uprooted	Tipped with root mass exposed and visible
Barrier islands	Overwashed	Water present (or was present) flowing on top of island, leaving behind evidence such as damaged, scoured, or buried vegetation, sediment deposition, or scoured substrate
	Breached	Channel cut through island, separating what was originally a single piece of land into two or more separate islands
	Eroded	Sand and substrate removed, scalloped
Seagrass beds	Buried	Vegetation covered by sand or sediment transported from the adjacent barrier island
	Scoured	Vegetation and substrate removed so that a depression is formed with a bottom deeper than adjacent substrate
	Detritus	Broken fragments of seagrass leaves or shoots floating on surface of water
Miscellaneous	Wrack deposits	Fragments of broken marsh vegetation (primarily culms of marsh grasses and sedges) deposited on the marsh surface, or floating on water surface, after having been transported by flood waters from another location
	Structural damage	Damage to camps, buildings, piers, roads, bridges, boats, or any other human-made items

flight track of the aircraft, its position, and the location of recent voice observations to be simultaneously displayed on a 1:250,000-scale digital map image in a computer monitor screen mounted on the aircraft's instrument panel in view of the pilot and observer.

The aircraft was flown at an altitude of about 650 ft (200 m) above ground level with airspeed maintained at approximately 110 kn (knots, or nautical miles per hour). The pilot and observer viewed the habitat from a continuous perspective defined by the window frame, float, and wing strut. The viewing area was about 300 ft (100 m) in diameter. Observations were recorded by using the "record" program of the voice/GPS/moving map system (Hodges, 1999). The pilot made voice recordings while the observer shot oblique photographs (i.e., photographs taken at an oblique angle to Earth's surface, as opposed to those taken from the nadir, or vertical, position) and relayed pertinent information to the pilot, who added the observer's comments to the audio file. Impacts to habitats and physical features were placed in general categories (table 2; figs. 2–9). Notes were generated for any observations of birds and other wildlife, specific wildlife habitat, study sites, and known landmarks.

Following each flight, the voice observations were transcribed by using the "transcribe" program of the voice/GPS/moving map system (Hodges, 1999) to digitize the voice observations and link them to GPS locations and time. Once transcribed, the biological, geographical, and temporal information was imported into Excel™ spreadsheet files. We then imported all transcribed data into a geographical information system (GIS) software package (ArcView™ GIS 3.2a) to produce maps showing flight tracks and associated observation points. Observations were displayed on a Landsat Thematic Mapper satellite image of south Louisiana (Braud, 2000). Photographs, track files, and transcriptions of observations were placed on a shared drive on the NWRC computer network and used in subsequent discussions among scientists, managers, and administrators to plan immediate and future actions.

Results and Discussion

The total geographic area covered by all flights extended from Galveston, Tex., to Gulf Shores, Ala., and from the Gulf of Mexico shoreline inland 5–75 mi (8–121 km). Scientists flew 5,003 mi (8,050 km; 64.4 flight hours), recorded 657 observations on hurricane impacts, and took 3,856 high-resolution digital oblique photographs. Each observation and photograph was georeferenced as to spatial coordinates and marked with a time stamp.

Figure 1 shows tracks of all eight flights taken to assess hurricane damages. For any segment along those tracks, a user (using Arc View™) can zoom in to the specific area to identify specific points where observations were recorded and where photographs were taken. An example of this method is displayed in figure 2 and table 3. Figure 2 shows the flight track of the aircraft during a survey of Raccoon Island, La., on August 30, 2005. A red dot on the flight path indicates a location where a voice observation was made. Four such observations are tagged and identified on the figure, each with a number that corresponds to the observation number (e.g., COL04-16) and an oblique photograph displayed on the image. Table 3 lists the 39 voice observations that were stored in file number COL04. In the ArcView™ (GIS) version of this product, each red dot is hot linked so that the user can click on it and pull up a photograph (such as the images shown), a transcript of the observer's comments, and other information, such as latitude/longitude coordinates and time,

Figure 3. Shoreline erosion and beach displacement on Rockefeller Wildlife Refuge, Cameron Parish, La.

Figure 4. Shoreline erosion, beach displacement, and barrier island breaches and overwash, Timbalier Island, La.

for each observation. The numbers that correspond to each dot on figure 2 (e.g., COL04-16) refer to the file name (COL04) and record number (16) for each observation (table 3). For our hurricane reconnaissance flights, we logged hundreds of such observations and thousands of linked photographs for the surveyed area. All of these data are archived at NWRC and are available to users for management and research purposes.

Landscape Impacts

Impacts throughout the study area in general were moderate to severe. The Gulf of Mexico shoreline showed impacts to about 50–75 mi (80–120 km) from the landfall site of each storm. The most prevalent impact that we noted was the movement of sand and other sediments from the beach shoreline into the adjacent vegetation, usually about 30–65 ft (10–20 m) inland (fig. 3). Beach and shoreline erosion (fig. 4) was also noted in numerous areas, and in some stretches of shoreline (e.g., along the Chenier Plain between Freshwater Bayou and Rockefeller Wildlife Refuge), we noted sediment deposition in the shallow nearshore waters (see Barras, this volume, for description of Louisiana's Chenier Plain, Deltaic Plain, and Marginal Deltaic Plain).

Barrier island impacts were most severe at the Chandeleur Islands. Land area on the entire island chain was reduced by about 50 percent (Michot and Wells, 2004; Michot and Wilson, 2004; Barras, this volume). The cumulative impact of Hurricanes Katrina, Rita, Ivan, Lili, Georges and Tropical Storm Isidore over the past 7 years has pushed the total area of exposed lands (subaerial, or above the water surface) to the lowest value that it has ever been in recorded history. The island chain had been cut into hundreds of small islands during previous storms mentioned above; now, because of Katrina, the overwash channels that had formed between those islands have become wider and deeper (fig. 5). In addition, islands on the south end that had become subaqueous (below the water surface) during previous storms have now eroded so that the shoals (shallow underwater areas) exist at greater depths below the water surface. The extensive seagrass beds behind the islands (Michot, 1997) survived but are now greatly reduced because of plants having been uprooted or broken off, buried by overwashed sediments, or subjected to light reduction from increased turbidity (Michot and others, 2003).

Figure 5. Aerial oblique photograph of Chandeleur Islands, La., after Hurricane Katrina, showing barrier island overwashes, breaches, erosion, and seagrass burial.

Figure 6. Sediment deposition in marsh, flooded marsh, scoured marsh, tipped trees, and tree defoliation adjacent to the gulf shoreline in the region known as Chenier Plain, La.

Figure 7. Aerial oblique photograph showing damage to forested wetlands of Pearl River Wildlife Management Area, La., including trees that were snapped, tipped, uprooted, and defoliated.

Live oaks (*Quercus virginiana*) on Grand Isle, La., and other barrier islands, as well as on the cheniers of southwest Louisiana, suffered greatly from defoliation and leaf mortality (Barrow, Chadwick, and others, this volume). This was also true of most tree species in areas within about a 50-mi (80-km) radius of the eye of either hurricane (Katrina or Rita). We also documented extensive movements of sediment on some of the cheniers, including new sediment deposition of 3.3+ ft (1+ m) on Hackberry Ridge (Faulkner, Barrow, Doyle, and others this volume) and similar depositions on the gulf shoreline near Rockefeller Wildlife Refuge (fig. 6). Hardwoods of the Pearl River basin in eastern Louisiana were severely impacted from Katrina (fig. 7). We documented snaps and tips on as many as 85 percent of the trees in some areas of the Pearl River basin (Faulkner, Barrow, Couvillion, and others, this volume). Many trees were snapped about 15 m (50 ft) up on the trunk. All trees were severely defoliated (stripped of leaves).

Impacts to emergent marsh were varied. Hundreds of acres (hectares) of wrack (fragments of dead vegetation) were deposited on top of marshes in the Deltaic Plain and Chenier Plain (figs. 8 and 9), as well as on roads and other structures (fig. 10). Several areas (e.g., near Lake Lery in St. Bernard Parish; Barras, this volume) had undergone severe scouring in which the vegetation (in this case, marshhay cordgrass (*Spartina patens*)) appeared to have been scraped from the substrate such that about 90 percent of the substrate was left unvegetated. As a result of this scouring, hundreds of clumps of marshhay cordgrass were observed floating or submerged in open water areas like Lake Lery.

In Cameron Parish, southwest Louisiana, we observed hundreds of acres (hectares) of marshhay cordgrass marsh that were severely impacted by extensive flooding with high-salinity waters. As a result, when the water finally subsided, the vegetation in many areas appeared gray, matted, and dead, and the marsh had areas that were 30–50 percent devegetated.

Stands of common reed (*Phragmites australis*) throughout the coastal zone, especially in the Mississippi River Delta, were tipped or flattened from the winds or storm surge and had turned brown from the high-salinity waters. In other areas, such as most smooth cordgrass (*Spartina alterniflora*) stands, the marsh vegetation seemed healthy and apparently unaffected. In such cases, we surmised that the storm surge resulted in complete inundation of the salt-tolerant plants, which protected them from the high winds

Figure 8. Aerial oblique photograph showing wrack (stems of dead vegetation) deposits over road and marsh, marsh flooding, and tree defoliation near Pecan Island, La.

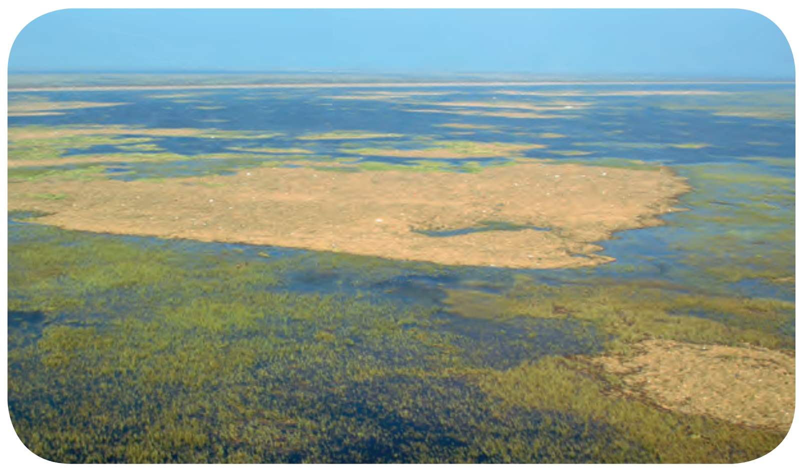

Figure 9. Large wrack deposits and flooded marsh at Sabine National Wildlife Refuge, La.

Figure 10. Structural damage and wrack deposition at the headquarters of Sabine National Wildlife Refuge, La.

Table 3. List of observations from overflight of Raccoon Island, La., on August 30, 2005, 2 days after Hurricane Katrina (see map, fig. 2).

[Hr/Min/Sec, hour, minute, and second when observation was made; Lat/Long, latitude and longitude at time of observation; Obs., observation number in chronological order]

Date	Hr/Min/Sec	Lat/Long	File no.	Obs.	Comments
2005/8.30	11.48.01	29.1766/-91.0386	COL04	1	By the gulf; Caillou Bay is very calm right now.
2005/8.30	11.48.46	29.1605/-91.0258	COL04	2	OK, got one dead fish.
2005/8.30	11.48.55	29.1577/-91.0233	COL04	3	Wrack deposit.
2005/8.30	11.48.56	29.1571/-91.0229	COL04	4	There's another dead fish; fairly big, not sure what kind.
2005/8.30	11.49.10	29.1556/-91.0216	COL04	5	About 2 feet long.
2005/8.30	11.49.18	29.1528/-91.0194	COL04	6	Only two individuals so far. I'll continue to mark them.
2005/8.30	11.49.25	29.1470/-91.0145	COL04	7	Lot of big wrack accumulations out here.
2005/8.30	11.49.28	29.1456/-91.0133	COL04	8	Rip tide.
2005/8.30	11.49.38	29.1422/-91.0105	COL04	9	Several dead fish in the rip.
2005/8.30	11.51.42	29.0930/-90.9803	COL04	10	Got Raccoon Island in sight now. Looks to be intact for a good distance, about 2 miles.
2005/8.30	11.51.49	29.0901/-90.9778	COL04	11	On the west end.
2005/8.30	11.51/51	29.0894/-90.9770	COL04	12	Platform about 2 miles west of Raccoon, old platform, it's fine.
2005/8.30	11.52.12	29.0811/-90.9689	COL04	13	We are going to be shooting from about 500 ft.
2005/8.30	11.52.24	29.0770/-90.9639	COL04	14	Raccoon Island west to east 500 feet, north side.
2005/8.30	11.52.48	29.0710/-90.9535	COL04	15	Looks like a lot of birds along the shoreline of the island. Also, a wrack line on the western tip.
2005/8.30	11.53.10	29.0682/-90.9490	COL04	16	There is a very shallow breach a mile east of western tip.
2005/8.30	11.53.17	29.0632/-90.9430	COL04	17	A little island of vegetation here. I remember those from last week.
2005/8.30	11.53.25	29.0617/-90.9397	COL04	18	Island is pretty much intact.
2005/8.30	11.53.30	29.0605/-90.9373	COL04	19	Water is high on the shoreline.
2005/8.30	11.53.41	29.0587/-90.9323	COL04	20	I see pelicans down in the mangroves, a lot of birds.
2005/8.30	11.54.14	29.0528/-90.9184	COL04	21	Eastern tip now, looks fairly intact. Some dead mangroves.
2005/8.30	11.54.41	29.0465/-90.9119	COL04	22	We're shooting the island east to west now, the long way.
2005/8.30	11.55.11	29.0439/-90.9197	COL04	23	Heading back westbound now.
2005/8.30	11.55.17	29.0448/-90.9218	COL04	24	We're shooting up the southern shoreline now, gulf side.

Table 3. List of observations from overflight of Raccoon Island, La., on August 30, 2005, 2 days after Hurricane Katrina (see map, fig. 2). —Continued

[Hr/Min/Sec, hour, minute, and second when observation was made; Lat/Long, latitude and longitude at time of observation; Obs., observation number in chronological order]

Date	Hr/Min/Sec	Lat/Long	File no.	Obs.	Comments
2005/8.30	11.55.49	29.0504/-90.9348	COL04	25	The tombolos seem to have retreated, but use caution because the water is about a foot higher than usual right now.
2005/8.30	11.56.38	29.0619/-90.9540	COL04	26	We're near the shallow overwash now; little channel there.
2005/8.30	11.56/51	29.0654/-90.9582	COL04	27	Now we're rounding the western tip.
2005/8.30	11.57/52	29.0608/-90.9436	COL04	28	More frigatebirds.
2005/8.30	11.58.13	29.0578/-90.9387	COL04	29	Making a low pass west to east now over the island to check it out.
2005/8.30	11.58.17	29.0542/-90.9330	COL04	30	Looks like a lot of fledglings in the water.
2005/8.30	11.58.21	29.0533/-90.9316	COL04	31	And some on the nests, too, maybe…
2005/8.30	11.58.29	29.0516/-90.9281	COL04	32	I thought I saw some nestlings on the nests, but unverified. OK, I do see some, yes. There are some. There are definitely birds on some of the nests.
2005/8.30	11.58.40	29.0497/-90.9233	COL04	33	Some white ones, definitely some white birds and some brown. Still getting their feathers, haven't fledged yet.
2005/8.30	11.58.50	29.0495/-90.9189	COL04	34	And the picture should show that they are here. I thought I saw one or two carcasses.
2005/8.30	11.59.15	29.0463/-90.9124	COL04	35	I thought I saw a few white carcasses, but those are unconfirmed.
2005/8.30	12.00.12	29.0483/-90.9170	COL04	36	OK, one and two, three, yeah, one of them [tombolos] is just about out to the rocks. I think it would probably reach the rocks were the water not so high. The other three look a little deeper.
2005/8.30	12.00.49	29.0518/-90.9202	COL04	37	Tombolo zero, one, two, three, the number three, which is actually the fourth one as far as breakwaters, has the land all the way out to the breakwater except for the very end where it is very shallow. I should say the land is not quite touching the rocks, but maybe it would if the water level was normal.
2005/8.30	12.01.30	29.0490/-90.9238	COL04	38	Looks like a bunch of flightless birds are still on the island.
2005/8.30	12.01.46	29.0546/-90.9197	COL04	39	OK, we got Raccoon pretty good; number 156 was the last frame. Now east to get the rest of the chain.

associated with the storm. We did detect a few areas of fresh marsh that were impacted by buckled marsh (also known as accordion effect, this is marsh whose substrate was compacted and buckled into numerous parallel rows by having been pushed by high winds; see *http://www.nwrc.usgs.gov/hurricane/lilipics.htm* for image), but these areas were not as extensive as for previous storms like Lili and Andrew.

We believe that the ecological implications of the damages noted here will be severe. The barrier islands, cheniers, emergent marsh, and coastal forests serve as important habitat to numerous species of migratory landbirds, waterfowl, wading birds, and shorebirds, as well as to numerous species of fishes and shellfish that are recreationally and commercially important. Loss of subaerial land on the islands and cheniers, and subsequent secondary impacts to adjacent seagrass beds and water bottoms, reduces nesting, foraging, nursery, and roosting habitat for those species. Damage to vegetation structure reduces available nesting and roosting sites for hundreds of species of birds and other wildlife. Conversion of emergent marsh to open water will exacerbate an already critical land-loss situation in coastal Louisiana. Recovery of impacted sites will depend on numerous factors, including storm frequency in the immediate future, local hydrological and climatological conditions, and human factors such as coastal restoration efforts.

Conclusions

We used extensive aerial surveys to document and rapidly assess impacts of Katrina and Rita to high-priority natural resources. Our methodology worked well to maximize spatial data collection in a short time and to get the information to scientists, managers, and the general public quickly enough for them to use in making critical management decisions. Products resulting from this study were made available through NWRC and were publicized on the center's Web site. Information generated from this study was essential for scientists and managers to plan actions for the immediate future, as well as for the long term, and even a year after Katrina and Rita, the information is still being used extensively by the USGS, other agencies, and the public media.

Acknowledgments

We thank numerous individuals for assisting us in this effort. In addition to the authors, participants in hurricane reconnaissance flights included Fred Roetker (U.S. Fish and Wildlife Service), Larry Handley (USGS), Martha Segura (National Park Service), and Ron Boustany (U.S. Department of Agriculture, Natural Resources Conservation Service). Melissa Collins, Dustin Aguillard, Jason Dugas, Scott Wilson, David Guilbeau, and Ann Gaygan (all of whom are USGS employees, contractors, or interns) assisted with transcriptions of observation records, data manipulations, and data management. Gregory Smith, Gerald Grau, Jimmy Johnston, Carroll Cordes, and Gaye Farris (all of whom are USGS employees) provided administrative support during and after flights. We thank Don Cahoon, Fred Roetker, and Jarita Davis for helpful reviews of and comments on the manuscript.

References

Braud, D.W., 2000, Louisiana GIS CD—a digital map of the State—Version 2.0: Baton Rouge, Louisiana State University, Department of Geography and Anthropology.

Hodges, J., 1999, Voice/GPS/moving map software [unpublished software]: Juneau, Alaska, U.S. Fish and Wildlife Service.

Michot, T.C., 1997, Carrying capacity of seagrass beds predicted for redheads wintering in Chandeleur Sound, Louisiana, USA, *in* Goss-Custard, J., Rufino, R., and Luis, A., eds., Effect of habitat loss and change on waterbirds: Institute of Terrestrial Ecology Symposium no. 30, Wetlands International Publication No. 42 p. 93–102.

Michot, T.C., Burch, J.N., Arrivillaga, A., Rafferty, P.S., Doyle T.W., and Kemmerer, S., 2003, Effects of Hurricane Mitch on seagrass beds and associated shallow reef communities along the Caribbean coast of Honduras and Guatemala: U.S. Geological Survey Open-File Report 03-181, 65 p.

Michot, T.C., and Wells, C.J., 2004, 2004 prehurricane survey of barrier islands (Louisiana, Mississippi, Alabama): Lafayette, La., U.S. Geological Survey, National Wetlands Research Center, *http://www.nwrc.usgs.gov/hurricane/prehurricane-survey-2004.htm*

Michot, T.C., and Wilson, S., 2004, Post-Hurricane Ivan survey of Chandeleur Islands, Louisiana: Lafayette, La., U.S. Geological Survey, National Wetlands Research Center, *http://www.nwrc.usgs.gov/hurricane/postivanphotos.htm*

Contact Information

Thomas C. Michot, Research Wildlife Biologist (*tommy_michot@usgs.gov*); Christopher J. Wells, Geographer (*chris_wells@usgs.gov*); and Paul C. Chadwick, General Biologist (*paul_chadwick@usgs.gov*)

U.S. Department of the Interior

U.S. Geological Survey

National Wetlands Research Center

700 Cajundome Blvd.

Lafayette, LA 70506