Reports of Symposia

2006 ESA Annual Meeting

Ecological Effects of Gulf Coast Hurricanes: Short-Term Impacts and Long-Term Consequences

A symposium organized by Colin Jackson (University of Mississippi), Paul Keddy (Southeastern Louisiana University), and Gary Shaffer (Southeastern Louisiana University), at the 91st ESA Annual Meeting in Memphis, Tennessee, focused on the "Ecological effects of Gulf Coast hurricanes: short-term impacts and long-term consequences."

Hurricane Katrina made landfall in southeastern Louisiana and coastal Mississippi on 29 August 2005, becoming the costliest and one of the deadliest storms in U.S. history. The impacts of Hurricane Katrina on human communities along the Gulf Coast have been well documented. Initially, the storm produced high winds and storm surges that destroyed many of the coastal towns in Mississippi. Surging waters through the Mississippi River-Gulf Outlet and along the south shore of Lake Pontchartrain breached levees and caused flooding of all low-lying areas of New Orleans. Four weeks later, on 24 September 2005, Hurricane Rita made landfall in southwestern Louisiana, and while the second storm's impact on human communities was less than that of Katrina, Hurricane Rita caused appreciable economic damage. Obviously these storms also dramatically affected ecological communities: storm surges of salt water flooded coastal marshes and swamps; winds in excess of 100 mph felled forests; and Lake Pontchartrain itself was stressed as floodwaters were pumped out of New Orleans. A year later it was possible to look back more thoroughly at the ecological consequences of these storms and offer insights into how ecological knowledge might help mitigate damage from future Gulf Coast hurricanes.

This symposium, organized by Colin Jackson (University of Mississippi), Paul Keddy (Southeastern Louisiana University), and Gary Shaffer (Southeastern Louisiana University), focused on the "Ecological effects of Gulf Coast hurricanes: short-term impacts and long-term consequences".

While the Gulf Coast refers to the United States coastline along the Gulf of Mexico from Florida to Texas, the area most impacted by Katrina and Rita was the northern Gulf Coast, which includes the states of Louisiana, Mississippi, and Alabama, and this region was the main focus of the symposium. Hurricane landfall on the northern Gulf Coast is hardly a new occurrence. Hurricanes Betsy (1965) and Camille (1969) caused extensive damage and are still remembered by many in coastal Mississippi and Louisiana. Numerous other hurricanes and tropical storms have moved across the region since then, and the recorded impact of hurricanes in this region goes back to at least 1717. During that year a major hurricane was partially responsible for the shift of the capital of French Louisiana from Mobile, Alabama, to a new city located between the Mississippi River and Lake Pontchartrain: New Orleans.

New Orleans, Louisiana, and the importance of coastal wetlands in hurricane damage mitigation

When New Orleans was founded, the city was built on ground that was above sea level. However, as the city grew, it expanded into reclaimed wetlands, which as John Day (Louisiana State University) describes, have in some places subsided by >5 m. When tidal surges southeast of the city reached 6 m during Hurricane Katrina, levees in the eastern part of New Orleans were overtopped. Combined with the failure of levees that protect the city from Lake Pontchartrain, this resulted in flooding of roughly 80% of the metropolitan area. Louisiana's coastal wetlands provided much of the original protection from tidal surges, but these wetlands are disappearing. Day noted that >25% of the state's coastal wetlands were lost during the 20th century. Much of Louisiana's coastal wetlands loss has been exacerbated by human activities: the construction of shipping channels such as Mississippi River-Gulf Outlet (MRGO) and the laying of pipelines and other infrastructure for the Gulf of Mexico oil industry. Channelization of the Mississippi River so that it no longer connects to its delta plain or moves throughout the landscape is one of the major problems. Day suggested that reconnecting the river to its floodplain, through major freshwater diversion efforts, should be a cornerstone of effective coastal restoration, and is vital if the storm buffering capacity of coastal wetlands is to be recovered. The closure, or at least restriction, of channels such as MRGO is essential. Flow in MRGO reached 2 m/s as this channel funneled surging water towards New Orleans during Katrina. Day stressed that the timing of these restoration actions is critically important. With rising energy costs and an increased likelihood for future major storms and sea-level rise with global climate change, if restoration efforts are not made in the near future, it will be too late to save both Louisiana coastal wetlands and the city of New Orleans.

Gary Shaffer (Southeastern Louisiana University) noted that cypress–tupelo swamps are particularly effective at buffering both storm water surges and winds, and if allowed to flourish under favorable conditions, can achieve heights of 10 m in a decade. Analysis of specific habitat loss following Hurricanes Katrina and Rita suggests that swamps dominated by bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) were much less severely impacted than other ecosystem types, such as bottomland hardwood forests or open marsh. In some areas the difference is particularly marked, as in the Pearl River Basin in southeastern Louisiana and southwestern Mississippi. This area was directly in the path of Hurricane Katrina, and while bottomland hardwood forests suffered up to 80% wind throw, cypress–tupelo swamps were left relatively intact. Shaffer agreed with Day that efforts to rebuild the northern Gulf Coast must emphasize the role of coastal wetlands in storm-damage reduction. Bald cypress–tupelo swamps are essential in any coastal wetland restoration strategy, as they appear much more resistant to high winds and storm surges associated with hurricanes than freshwater or brackish marsh. That said, cypress–tupelo swamps are not immune to the effects of hurricanes and tropical storms, and are particularly sensitive to saltwater inundation. A few days exposure to salinity levels in excess of 5 ppt can severely stress these systems, often to the point where they may not recover. This is where freshwater diversion strategies become critical. Shaffer estimated that by diverting water from the Mississippi River, along with increasing other sources of freshwater such as treated wastewater, it would be possible to restore several hundred thousand hectares of coastal cypress–tupelo swamp in Louisiana alone. Much of this area is former cypress swamp that has degenerated into marsh or open water due to a combination of saltwater intrusion and extensive cypress logging in the early 20th century. However, with frequent pulses of freshwater these areas could once again become thriving cypress–tupelo

swamp and serve as a vital line of defense against future hurricane damage.

Long-term consequences of hurricanes and other disturbances on forests along the Gulf Coast

Bill Platt (Louisiana State University) addressed the importance of considering both the physical effects of hurricanes (high winds) and changes arising from storm surges of saltwater on coastal ecosystems. These two factors are enough to disassemble existing coastal ecosystems and promote shifts in species distributions. Platt suggested that in contrast to inland ecosystems, where hurricanes can stimulate regeneration of the existing plant community, major hurricanes such as Katrina and Rita may spur landward regeneration in ecosystems in many coastal areas. Coastal regions show changes in plant communities over small spatial scales, and moving a few meters inland often provides enough of an elevation change to see a succession from submerged communities to coastal saltmarsh to freshwater marsh to forest. Ongoing sea level rise can shift this spatial distribution landward and inhibit the regeneration of coastal communities. In essence, the high winds and saltwater inundation associated with major hurricanes serves as the catalyst that can push coastal ecosystems into new cycles of development, which are reinforced by long-term changes in the environment associated with global climate change and sea level rise. Platt's group has been testing these ideas in the Weeks Bay National Estuarine Research Reserve along the Alabama Gulf Coast. This site is characterized by transitions from low-lying estuarine marsh to upland hardwood forest and was impacted by high winds and extended storm surges associated with both Hurricane Ivan (2004) and Katrina (2005). Initial surveys show that that recovery is occurring through the growth of plant species that were previously lower down in the coastal elevation gradient, and through colonization by disturbance-following species that were not present prior to Hurricane Ivan. A particular concern is the increased appearance of Chinese tallow (*Sapium sebiferum*), a fast-growing exotic species that seems particularly capable of invading hurricane-impacted areas. Platt reported that with increased disturbance from hurricanes and tropical storms it is possible that this invasive species may soon become dominant in Gulf coast forest ecosystems.

While Platt's work addressed the interactions of hurricanes with sea level changes, Heather Passmore, a student of Platt's at LSU, has been examining the interplay between hurricanes and fire. Lightning-induced fires are a frequent, large-scale disturbance in savanna-forest landscapes of the southeastern United States; ecosystems subject to disturbance from both fire and hurricanes can show changes in species composition and community structure that would be different from those expected for each disturbance alone. Passmore has developed a conceptual model of hurricane–fire interactions that predicts a potential for great variation in these interactions across the landscape. Interactions are much more likely to occur in savannas than in forests, but are more unpredictable in ecotones where these systems meet. It is in these ecotones that Passmore experimentally tested the hypothesis that the effects of lightning-season fires on the structure and composition of the plant community would differ depending upon whether hurricanes preceded the fires. Passmore manipulated two of the major impacts of hurricanes on these systems, canopy disturbance, and an increase in organic matter on the forest floor that would serve as fuel for fires by removing canopy trees and increasing fuel loads. Higher fuel loads resulted in hotter fires, which in turn reduced the overall density and species richness of woody plants in manipulated plots. This strongly suggests that hurricane disturbance results in more locally intense fires in these systems, which can reduce overall hardwood density. Passmore notes that this lower plant density could result in decreased competition and encourage the establishment of pines and other fire-resistant species in savanna–forest ecotones. Over longer time periods, these interactions between hurricanes and fire are likely to result in landscape-level changes in savanna–forest ecosystems along the northern Gulf Coast.

The initial impacts of Hurricanes Katrina and Rita on coastal forest ecosystems

Stephen Faulkner (USGS National Wetlands Research Center) agreed that hurricanes have major

impacts on the structure and function of coastal forest ecosystems, both in the short and long term. His estimates suggest that $>34 \times 10^6$ m^3 of timber was destroyed or damaged during the combined onslaught of Hurricanes Katrina and Rita, which affected 450,000 ha in Louisiana alone. Confirming what Shaffer had previously observed, Faulkner asserted that plots in the Pearl River Basin that were dominated by bald cypress–tupelo swamp showed much lower mortality than other areas. These observations are similar to those reported for forests surrounding Lake Verret in southern Louisiana, an area that was impacted by Hurricane Andrew in 1992. Faulkner monitored vegetation density and vigor in the Pearl River floodplain at weekly intervals following Katrina and compared the findings to ongoing studies in the same system from 1989 to 2003. Overall, the system now shows below-average vegetation density and health, with the worst areas being the bottomland hardwood forests that were most affected by Katrina. One short-term impact of hurricanes on forest communities is that they generate a large pulse in litterfall. In contrast to the usual litterfall at the end of the growing season, during Katrina this litter consisted of live foliage and likely represented an immense pulse of organic matter to the soil. Hurricanes also promote shifts in forest structure that can change the availability of foraging substrates used by migratory birds, and the impacts of Katrina on Pearl River bottomlands appear to correspond with a shift in migratory bird use from these areas to adjacent upland forests.

Robb Diehl (University of Southern Mississippi) stressed the importance of considering how hurricanes and associated habitat destruction can affect migratory bird populations. Much of the North Atlantic hurricane season coincides with fall bird migration, and major storm systems often develop when bird migration over the Gulf of Mexico is at its peak. Little is known of how hurricanes and major storm systems can affect birds during migratory passage. Diehl raised an important question: Is migratory passage suspended or delayed during major storm events, or is bird migration temporarily shifted to the west to avoid more hazardous routes over the Gulf of Mexico? Such a shift in migratory patterns could allow migrants to potentially take advantage of favorable northern winds to the west of storms, but would result in major shifts in the distribution of birds in coastal landscapes during stopover. Migrants might avoid coastal landscapes immediately preceding and following major storms, which would confirm Faulkner's observations of shifts in migrants from bottomland forests in the Pearl River Basin to the upland forests situated further inland. Diehl has examined radar imagery that shows birds scattered throughout this landscape for over a month after the impact of Katrina, while up until two days before they were still tightly clustered in bottomland forests. The loss of some vegetation types might be so severe that birds may be slow to return to these habitats even after multiple seasons. Indeed, some bird populations may never return, if the impacts of hurricanes are enough to promote long-term changes in plant community structure.

The future of human communities along the Gulf Coast

While human communities along the Gulf Coast have a long history of being impacted by hurricanes, extensive growth of these communities, coupled with changing sea levels and loss of coastal wetlands, have exacerbated these impacts to the level of those seen in the aftermath of Hurricane Katrina. Paul Keddy (Southeastern Louisiana University) believes that two processes are responsible for the current state of both New Orleans and the Gulf Coast in general. First, as human populations in the region have grown, settlements that were originally restricted to higher ground have expanded into areas that were historically floodplains and wetlands, necessitating the construction of levees to protect these settlements. Second, this expansion, coupled with increased industrial development, has degraded these wetlands and accelerated the rates of coastal wetland loss. As other researchers in the symposium emphasized, it is these very wetlands that historically have protected both human settlements and Gulf Coast ecosystems from the floods and winds associated with hurricanes. While Keddy was sympathetic to the plight of human populations along the Gulf Coast (and he himself is a resident of the area impacted by Katrina) he asserted that ultimately some

of these problems arise from irrational decisions made by the citizens of Louisiana and other states.

Keddy noted that at the federal scale, citizens have elected an administration that encourages and supports the exploitation of ecosystems, while simultaneously denying that global climate change and sea level rise are occurring. More regionally, citizens of New Orleans and other areas of Louisiana have made irrational decisions regarding land use. Keddy emphasized that this is by no means a special case, and that history is full of human irrationality that has led to major ecological consequences. The American dust bowl and the collapse of the Canadian cod fishery are prime examples of situations where rational decisions made by the electorate could have averted or at least minimized environmental disasters. Looking back from a historical viewpoint, Keddy observed that those human communities clearly selected development trajectories that would clearly become catastrophic in the long term. The question arises as to what trajectory the development of the northern Gulf Coast will take in the aftermath of Hurricane Katrina: one determined by existing policies and tradition, or a willingness of the populace to adapt to the dynamic nature of coastal ecosystems.

Impacts of Hurricane Rita: the forgotten storm?

While the ecological consequences of Hurricane Katrina were addressed in detail by a number of participants, the impacts of Hurricane Rita were less clear. The contrast between the two hurricanes is interesting: Katrina came ashore in southeastern Louisiana and coastal Mississippi, while Rita came ashore in southwestern Louisiana close to the Texas border (encouraging the evacuation of much of the city of Houston). Because of the terrible impacts of Katrina on New Orleans, less attention has been paid to the impacts of Rita, which affected a more rural, less developed part of the coast. Much of this coastline consists of the Chenier Coastal Plain, an area characterized by vast stretches of emergent marsh that includes the Sabine National Wildlife Refuge and Rockefeller Wildlife Refuge, some of the most biologically diverse wildlife areas in the US. Immediate impacts from Rita on these areas include the deposition of large amounts of debris from coastal communities and offshore oil rigs, which was washed ashore, and still clogs the bayous and canals of these systems. In Sabine NWR alone, almost 1500 containers of hazardous materials have been identified, potentially containing 350,000 gallons of hazardous liquids and gases. However, these impacts are relatively minor when the effects of long-term flooding and saltwater intrusion associated with Rita are considered.

Andy Nyman (Louisiana State University) has worked on the wetlands that were impacted by Hurricane Rita and has been monitoring the changes in the Rockefeller Refuge. These areas are usually dominated by saltmeadow cordgrass (*Spartina patens*), and, as with the savanna areas studied by Platt and Passmore to the east, are most frequently disturbed by fire. Nyman notes that fires in the area only have modest impacts belowground, so while early successional genera such as bulrushes (*Schoenoplectus*) increase after such as disturbance, within a single growing season the community returns to one dominated by *S. patens,* which regenerates from belowground biomass. Prolonged flooding in the aftermath of Rita appears to have killed both above- and belowground *S. patens* biomass, so that the typical postdisturbance successional trajectory in these systems has been altered. These effects were likely compounded by severe drought conditions for the first half of 2006. Whether these systems return to their former state, or are further impacted by erosion and future tropical storms, remains to be seen.

Ecologists and Gulf Coast hurricanes: what we've done and what we should be doing

The symposium on the impacts of Gulf Coast hurricanes was one of the opening sessions at the ESA meeting, but as the meeting closed, a separate presentation addressed a very fundamental issue that the symposium lacked: Exactly what ecological research has been done on the impacts of hurricanes, and what gaps in our knowledge need to be addressed. Julie Whitbeck (University of New Orleans) reviewed the ecological literature for research on the effects of hurricanes on forest ecosystems. Whitbeck reported that

almost 300 scientific papers on the ecological effects of hurricanes on forests were published from 1978 to 2006, almost half of which are research studies on the impacts of specific storms. More than one-fifth of these studies focused on the impact of Hurricane Hugo (1989), largely because it affected the Luquillo LTER site in Puerto Rico. Whitbeck noted that research on the impacts of hurricanes on the continental United States accounts for just 21% of these studies, and only 7% of the publications addressed the impacts of storms on the Gulf Coast. Whitbeck proposed an agenda for ecological hurricane research that would improve our understanding of how these storms have shaped the organization and ecology of hurricane-impacted systems, explore the impacts of hurricanes at different scales, and predict whether current changes in both landscape use and storm intensity are likely to change the impacts of these storms. Instead of reactive studies to the impacts of specific storms, we need a proactive research plan that encompasses a wide geography of sites (both within the United States and worldwide), long-term studies, standardized experimental designs and methods, and collaboration with meteorologists, social scientists, and geologists, among others. Within this proactive framework, Whitbeck suggested that plans should be in place for opportunistic reactive studies when hurricane disturbance occurs at a site. The impacts of Hurricanes Katrina and Rita are likely to stimulate ecologists in the Gulf coast region to consider these ideas carefully. However, the development of a research agenda to address the ecological impacts of hurricanes along the Gulf Coast, or elsewhere, would also need a parallel funding agenda from federal and state agencies; whether such funding is available remains to be seen.

Colin R. Jackson
Department of Biology
The University of Mississippi
University, MS 38677
E-mail: cjackson@olemiss.edu