Katrina: Boon or Bust for Freshwater Fish Communities?

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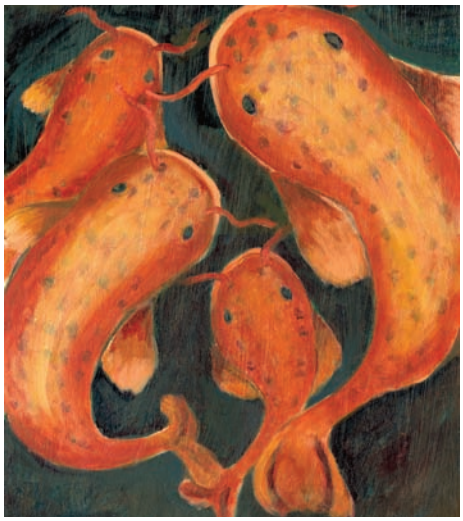
I was fortunate to make my acquaintance with the Mississippi and Louisiana Gulf Coast region several years prior to Hurricane Katrina. There I met dramatic contrasts in the degree of human influence on ecosystems. At one extreme were floating casinos with highway off-ramps built over the water, the bacchanalian Bourbon Street of New Orleans's French Quarter stinking in the May heat, and urbanized rivers that looked like canals. At the other extreme were alligator-infested bayous with Spanish moss dripping spookily from gnarly trees, the quiet isolation of Pilot Town perched along the extreme lower Mississippi River, and the wild beauty of the Pascagoula River with fantastic floodplains full of cypress trees and patrols of ever-graceful Mississippi Kites overhead. With such a diversity of environments, it is no surprise that the impacts of Hurricane Katrina varied dramatically over short distances.

How can we think about a storm as monstrous as Katrina in terms of its position along a continuum of natural to man-made events? Although I admit that humans are part of the natural order, "natural" is typically defined as that which is expected to occur in the relative absence of human influence. With respect to rivers, streams, and hurricanes, three major aspects of Katrina are relevant to this question: the storm itself, its immediate impacts, and its long-term effects.

The Storm

Undeniably, Katrina was the most damaging hurricane to hit the Mississippi Gulf Coast in recent history and, incredibly, the storm remained a hurricane halfway up Mississippi and Alabama. Does that make Katrina unnatural? People argue about the influence of global climate change on storm patterns and intensity, but such argument is more relevant to a discussion of storm incidence and severity over larger spatial and time scales. A single storm like Katrina is possible with or without global climate change, so the storm may be considered "natural."



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The impacts of the storm once it reached land are an entirely different matter. I have not traveled to the Mississippi coast since the storm, but I have seen the news coverage and talked to those who have been there. From these sources, the contrasts are striking: antebellum homes lie flattened, rubble strewn everywhere, yet many live oaks still stand in front yards, albeit looking a bit haggard, as if after a rough night on the town. Not only did many of the live oaks stand up to the winds and the awesome storm surge, they also withstood the debris of houses and casinos that blasted by. As I drove to various study sites farther inland in Mississippi, I noticed time and again that although many trees were down, most forested areas were not nearly as bleak as the landscapes of homes and barns and golf courses. Forests evidently resist hurricanes better than our creations.

Storm Effect on Fish Communities and Riverine Habitats

For the past three years, I have studied fish communities in the Pascagoula River drainage in southeast Mississippi with graduate student Paul Mickle and doctors Brian Kreiser and Jake Schaefer of the University of Southern Mississippi. Monthly, from June to November, we survey fish at ten sites in the drainage: four sites in both the Leaf and Chickasawhay rivers, which join to form the Pascagoula River, and two sites in the Pascagoula River itself. We cancelled our September 2005 sampling trip due to more pressing human needs, insurmountable logistical difficulties, and a second round of very high river flows following Hurricane Rita. When we finally returned to the water the week of October 3, 2005, we spent the first two days sampling in the Leaf and Chickasawhay. I was surprised to find the rivers looking essentially the same as they did in August. The sand bars had rearranged a bit, as would be expected with any high-flow event, but the channels were not choked with wood, nor were all of the trees along

the exposed banks toppled. More importantly, the fish community was essentially unchanged. Our data are not analyzed yet, but we found no real surprises. The young Alabama shad (*Alosa alabamae*), our target species, were few and far between, as usual, but the ones we found were the biggest so far in the study, indicating that the hurricane had a minimal impact on individuals in the upper rivers.

I had heard stories of fish kills in the Pascagoula River, but dismissed those as belonging to the collection of overblown rumors that abounded during and after the storm. At our most downstream site in the Pascagoula River, about fifteen miles from the coast as the crow flies, the river looked good. The large sandbar where we sample was bigger than before the storm and covered in white sand. A boathouse lay crumpled near the tree line, but otherwise there was little evidence of a major storm weeks before.

Then we began to sample, first near the sandbar shoreline, then along the steep, opposite bank with its snags and rootwads, and finally in the open water where the fastest current flowed. We caught only ten fish — usually we catch 140 or so. Normally we catch at least twelve species — this time we caught only five. Of these, three species were ones that tolerate fairly sudden changes in salinity and periods of low oxygen. The other two species were single specimens of small minnows usually abundant.

As always, the highlight of sampling this site was a visit with Billy Joe, a retired local, on his houseboat. Besides being the personification of hospitality, Billy Joe knows the river and what goes on there, both in and out of the water. After weathering the storm near the coast, he returned to a slightly damaged, but functional, houseboat. Billy Joe — who doesn't hesitate to pick up a dead animal to retrieve an interesting skull for his porch — had to put Vicks VapoRub® in his nose to tolerate the stench of fish when he returned to the river. He told us that large, bloated catfish lay washed up against the row of houseboats and along the riverbanks and that fish were killed all the way up the Pascagoula River. Others documented at least seven dead Gulf sturgeon (*Acipenser oxyrinchus desotoi*), a fish listed as threatened under the U.S. Endangered Species Act, in the river, which suggests even more may have perished. Newspaper accounts from the *Advocate*, a Baton Rouge newspaper, report that fish kills were widespread in Louisiana, as they were after Hurricane Andrew, which swept through south-central Louisiana in 1992.

The presumed cause of fish death in the Pascagoula River was a combination of salt water and low oxygen. The huge tidal surge forced salt water much further up the river than normal. In addition, the heavy rains likely flushed anoxic (oxygen-deprived) water from floodplain wetlands into the river. Saltwater overlaid with freshwater low in oxygen could have killed most of the fish in the river. Even species that move between fresh and saltwater died, such as Gulf sturgeon, perhaps because they are not physiologically capable of tolerating such a sudden change in salinity. In some rivers beyond the reach of the tidal surge, fish kills also occurred, apparently due only to anoxic water.

Of course, in more urbanized areas, Katrina's impacts were less natural. The pumping of urban flood waters into Lake Pontchartrain on New Orleans's north boundary was anything but natural. And whereas the salinity and low oxygen conditions in most rivers returned to normal fairly quickly after the storm, urban flood waters were pumped into Lake Pontchartrain for at least a month, and contaminants could conceivably remain in sediments for much longer. Bacteria and petroleum hydrocarbon levels were elevated in many samples taken from New Orleans flood waters and sediments, as were other toxic substances, according to the U.S. Environmental Protection Agency. However, water quality effects from urban flood waters do not appear to have been extreme in Lake Pontchartrain and were confined largely to shoreline areas. According to reports in the *Advocate*, fish are returning to the lake, and dolphins were reported in the lake in early October, suggesting its water quality is tolerable.

Long-term Implications for Habitat

The third, and perhaps most interesting, question is: how natural are the long-term impacts and fish community recovery processes? The answer depends not so much on the degree of impact which the hurricane had on ecosystems as on how humans altered ecosystems prior to the storm and how humans respond to post-hurricane conditions.

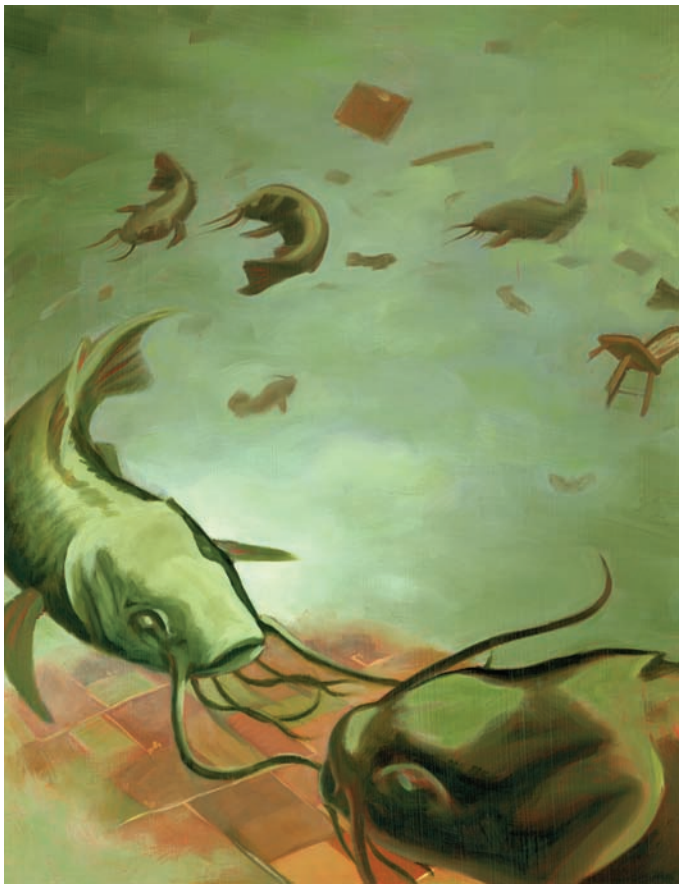
In streams and small rivers of forested areas, the greatest impact to habitat was the addition of copious amounts of organic material. Small material from upland areas, leaves, and fine woody debris (twigs and small branches) will likely create a nutrient pulse in the streams, which could increase stream productivity during the first year. Very large amounts of fine debris, warm water, and low, late summer flows can sometimes cause localized anoxic conditions. However, fish and many other aquatic organisms can often find refuge from such hazards, and fine organic debris is broken down, eaten up, or flushed out of streams fairly quickly.

The long-term impact of the storm will be the addition of rootwads and fallen trees — an integral component of stream and river ecosystems — to streams and smaller rivers. Among its many functions, large dead wood helps retain sediment and organic matter, helps stabilize some stream channels, and creates complex habitats such as pools and side channels. In sand bed streams, large wood provides some of the only stable substrates on which many invertebrates live and forage and numerous fish species lay their eggs, and in which a huge variety of organisms find shelter.

Nevertheless, throughout the history of the United States, untold dollars and Herculean efforts have been spent removing large wood from waterways. Furthermore, when

land is cleared without leaving forested riparian buffer zones, the consequence is a radical reduction in the recruitment of large wood into many rivers. In southern streams, this reduction is exacerbated by the low retention rate of wood compared to northern streams. High decay rates and unstable sand substrates that frequently bury wood in a streambed contribute to low wood levels in many southern streams. Thus, the addition of large amounts of wood from an infrequent event like a hurricane or ice storm can have lasting benefits on aquatic ecosystems.

Some of the trees snapped or toppled by Katrina are in streams now. Others are spanners; they bridge the stream channel above the water level and in time will break and fall into the stream. Some wood will be moved downstream, perhaps lodging in areas that lack riparian forests or accumulating in larger rivers where it will also provide habitat. Whatever its fate, the influx of wood following Katrina will be a positive legacy of the storm in ecological terms, helping to maintain productive, physically complex streams and rivers.



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What is beneficial for a natural ecosystem, however, is not always beneficial to humans — or not perceived to be beneficial by humans. Large wood carried downstream sometimes piles up at culverts and bridges, damming streams and creating floods. This problem can usually be avoided by removing wood from the stream channel within a short distance upstream. But if well-intentioned people continue to believe that woody rivers are messy rivers and that removing wood is a good way to "clean them up," the woody legacy of Katrina will not be realized.

Long-term Implications for Fish Communities

In general, fish communities in streams without fish kills are expected to realize benefits from the storm in both the short and long-term. But what are the long-term implications of Katrina where large-scale fish kills occurred? The fish kill in the Pascagoula River resulted from what is known to ecologists as a "pulse disturbance," which means that the cause of the impact was of short duration; habitat and water quality conditions quickly returned to within a normal range. By contrast, a "press disturbance" lasts longer, characterized, for example, by ongoing pollution, lingering toxicity, or degraded habitat. Because basic water quality parameters (temperature, pH, conductivity, and salinity) and habitat in the Pascagoula River returned to normal by October, most fish populations are expected to begin recovering immediately.

Numerous factors govern the recovery of fish populations. These include the number of individuals that survive in the impacted area, the size, proximity, and connectivity of refugia and neighboring populations, the mobility and life history of the species, and the abundance of food. In general, fish communities tend to be very resilient, recovering relatively quickly from disturbances, even those unusually severe or widespread. Recovery typically occurs via a combination of immigration and reproduction; thus, recovery of fish abundance typically precedes recovery of the age and size structure of a population.

Several natural factors can cause a slower recovery of some species, most notably life history (the stages and timing of a species's life cycle). Small-bodied, short-lived species mature rapidly, sometimes during their first year, and often have multiple or extended spawning periods in southern rivers. Large, long-lived fish typically take many years to reach maturity and often have limited spawning periods. A species's tendency to move only short distances can also slow species recovery, but most fish populations contain at least a few "movers" to help refound populations. Finally, a very localized species distribution can slow or preclude recovery after a major disturbance.

Numerous human-caused factors, such as habitat degradation and fishing, can also reduce population sizes. In addition, fewer populations and a loss of connectivity (unobstructed, habitable travel corridors between populations) means that fish from other areas are less likely to buoy or refound populations. Immigrants from neighboring populations are not… *continued on page 23*

continued from page 21... only important demographically, but they also help minimize genetic bottlenecks (the loss of genetic variation due to very small population size) in residual populations. Many or all of the human influences that contributed to fish population declines prior to Katrina operate today and may slow the ability of some populations to rebuild. In urbanized rivers, pre-storm fish communities presumably consisted of species able to tolerate the effects of urbanization, so recovery to a pre-Katrina condition — though not a natural condition — is expected. In fact, many warm-water fishes that occupy degraded habitats are characterized by an ability to colonize affected areas rapidly following disturbance.

Gulf sturgeon, listed as threatened under the U.S. Endangered Species Act and as endangered by the state of Mississippi, is a good example of a species for which recovery will be influenced by both natural and human factors. Sturgeon are large, ancient, bottom-feeding fishes, dating from the late Cretaceous, when the Rocky Mountains were forming and dinosaurs flourished. Gulf sturgeon reach about seven feet long and forty years of age, and once upon a time, they grew larger. The fish is a classic example of a species with an inherently slow recovery rate due to its life history, for they typically mature at age nine for males and twelve for females. Adult females are thought to reproduce only once every three to six years, and bigger, older fish contain more eggs (a.k.a. caviar) than smaller fish. If their population has been severely reduced in number by Katrina, sturgeon populations would be expected to take years to recover in abundance and decades to reach a size and age structure similar to pre-Katrina populations.

Human influences have eliminated some Gulf sturgeon populations and greatly reduced the size of others. Fortunately, conservation efforts have maintained multiple Gulf sturgeon populations along the Gulf Coast, although large populations do not exist as close to the Pascagoula River as they once did. Nonetheless, the sturgeon population in the Pascagoula River will probably recover from Hurricane Katrina in due time — just not quite as quickly as it may have a few hundred years ago.

Hurricane Katrina was a natural event overlaid on a human-modified landscape mosaic, so that the extent to which the impacts were "natural" varied among locations. I have discussed only a few of the ways that human activities, past and future, influence the impacts of Katrina. Many other factors, including loss of wetlands, fish stocking, forestry practices, and land development — all related to how communities are rebuilt and economies restored — will contribute to the ecological legacy of the storm. When all is said and done, I believe that Katrina will not be viewed as a catastrophe for freshwater ecosystems, but rather considered a natural disturbance with many positive long-term impacts on riverine habitats and their fish. ■