Effects of a hurricane on fish parasites

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Abstract. Hurricanes, also called tropical cyclones, can dramatically affect life along their paths, including a temporary losing or reducing in number of parasites of fishes. Hurricane Katrina in the northern Gulf of Mexico in August 2005 provides many examples involving humans and both terrestrial and aquatic animals and plants. Fishes do not provide much of an indicator of hurricane activity because most species quickly repopulate the area. Fish parasites, however, serve as a good indicator of the overall biodiversity and environmental health. The reasons for the noted absence or reduction of parasites in fishes are many, and specific parasites provide indications of different processes. The powerful winds can produce perturbations of the sediments harboring intermediate hosts. The surge of high salinity water can kill or otherwise affect low salinity intermediate hosts or free-living stages. Both can introduce toxicants into the habitat and also interfere with the timing and processes involved with host-parasite interrelationships. All these have a major influence on fish parasite populations of fishes in coastal Mississippi, especially for those parasites incorporating intermediate hosts in their life cycles. The length of time for a parasite to become re-established can vary considerably, depending on its life cycle as well as the associated biota, habitat, and environmental conditions, and each parasite provides a special indicator of environmental health.

Key words: biocenoclesis, hurricane, monitor, fish, parasites, microbial agents

Introduction

Hurricanes, tropical cyclones, reflect the power produced by the sea and atmosphere.1 When someone hears about a natural disaster, especially one involving the sea, that person usually thinks about how it negatively affects humans. This presentation deals primarily with a hurricane's effects on the parasites of fishes but also mentions some examples involving the effects on human diseases and the presence of terrestrial organisms because all three aspects have features in common. It will focus on Hurricane Katrina in August 2005. Hurricane Katrina spawned in the eastern North Atlantic over the Bahamas on 23 August 2005 as Tropical Depression 12. Based on data from the National Oceanic and Atmospheric Administration (NOAA), the weather condition quickly became Tropical Storm Katrina on 24 August and made a first landfall in South Florida as a category 3 hurricane on the Saffir-Simpson Hurricane Scale. It then entered the Gulf of Mexico, gained strength rapidly, partially because of the passage over the warm water of the Loop Current, and attained category 5 intensity (sustained winds of 285 km/hr with a pressure as low as 895 mbar) at about 360 kilometers, similar to the size of Great Britain. A portion of Hurricane Katrina covered a land mass of about 235,000 square kilometers, and it was equally destructive to the structures there. Following initial landfall, a progression of storm-induced breaches in the New Orleans levee system resulted in catastrophic flooding of about 80% of New Orleans, located about 4.3 meters below sea level. The city received about 3 meters of flood water in some areas (about 34 billion liters on 30 August). Recent advances in early warning technology resulted in fewer than 2,000 human lives lost from Florida to Louisiana, but the stress, diseases, and other factors in combination with pre-existing health conditions caused many more indirect human deaths for the next year or two, especially in Mississippi and Louisiana. The devastation caused by Hurricane Katrina covered a land mass of about 235,000 square kilometers, similar to the size of Great Britain. A portion of this impact to the geography, animals, and people was intensified and the affected area enlarged by the added effects of Hurricane Rita, which struck along the Louisiana-Texas border on 24 September 2005. It was also a category 5 hurricane, and it had sustained winds of 265 km/hr with a pressure as low as 895 mbar with an effect on the coastal marine life in Mississippi as well as further west.

Major human health concerns that gained national notoriety involved potential or actual increases in human diseases transmitted by various mosquitoes and
spiders abundant anywhere a board or other object covered dirt and the brown widow spider not as abundant but still very numerous in leaf litter, trash cans, and hollow spaces in cinder blocks. They also occurred elsewhere in abandoned buildings, under railings and porches, in mailboxes, under flower pots, and in woodpiles. All the widows reached a peak about mid-September 2006, and none was seen by Bullard on 2 March 2007, a couple weeks after fire ants had become abundant. In May 2007, my graduate student Joshua Cook noted that the spiders were less prevalent around his trailer, but a few adults and numerous egg cases were still abundant around many FEMA trailers and woodpiles even after two years post-Katrina. Media shows on gardening still recommended wearing gloves as a preventive measure against the widows. Fire ants, both black and red species, are also introduced and compete with native ants; they were provided an advantage over the native ants by the storm.

Physical differences in the terrestrial habitat as well as direct influence of storm water resulted in a different biotic community; also a gain or loss in some components of the biota helped alter hosts for acquiring parasites. As a human example, in the aftermath of Katrina, a loss of the nine-banded armadillo (Dasypus novemcinctus), the primary vertebrate host for the flagellate Trypanosoma cruzi, and an increase in human dwellings of the reduviid (kissing bug) intermediate host Triatoma sanguisuga prompted a human source for blood-meals. Ten of the 18 tested bugs were positive for T. cruzi by PCR and therefore considered responsible for the cited case of human Chagas disease. Soon after the storm, 22 cases of non-choleragenic Vibrio illness were detected in Louisiana and Mississippi. More disease was anticipated because people along the coastal counties and parishes had no electricity, gas, running water, working toilets, telephone service (not even cell phones), or garbage removal for periods of weeks to months, with many still not having some of these services after almost 2 years.

Alterations in the flora, fauna, and geologic perspective in the terrestrial habitats were quite apparent to people losing their homes and living in trailers, tents, or damaged homes and coming into direct contact with the coastal habitats. All the coasts and barrier beaches exhibited disruption during Hurricane Katrina. The islands provided unique habitats. These deal with perturbations or interactions of the sediments, introduction of toxicants into the ecosystem, and disruption of the seasonal dynamics of the host-parasite relationships. Parasites of fishes provide an exceptional indicator for assessing these perturbations, even when maintained in captivity where they also can be affected, either directly or indirectly.

Perturbations of the sediments

Sediments on shore, near shore, and offshore in specific areas exhibited disruption during Hurricane Katrina. Rethenos turned over and islands eroded. Footprints of the Mississippi barrier islands were reduced by 25%, but the elevations of the islands were reduced to near sea level with vegetation cover reduced by at least 50% (e.g., Carter et al., 2007). The islands provided unique

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habitats to numerous plants and animals as well as a buffering first line of defense against hurricanes and related storm events. In their current condition, they are probably in an estuarine system other function (Barbour, 2006). Clay and sandy sediments were lost from some areas and added to others (Otros and Carter, 2007). Commercial oyster beds in Mississippi Sound became covered by a considerable amount of sediments. A year after Katrina, the harvestable oyster stock was estimated by the Mississippi Department of Marine Resources to be reduced by more than 90%.

One region hard hit by Katrina was offshore from Southwest Pass where the Mississippi River empties into the Gulf of Mexico, a considerable distance south of New Orleans; it was shown by D. Reide Corbet (East Carolina University, Greenville, North Carolina, personal communication) that Katrina's energy was most influential to coastal sediments at an offshore depth of 25-30 meters, where 1 meter of sediments was sourced from the bottom and resuspended, with its corresponding loss of polychaetes, bivalves, and other infauna. Sediments were removed from the delta and added to the continental shelf. Hurricanes Katrina and Rita within one month resuspended, mobilized, and deposited about five times the amount of material normally deposited from the Mississippi River over a one-year period. About 30 cm of deposited sediments settled within a month at a depth of 50 meters off Southwest Pass. Analysis was conducted by looking at pre- and post-hurricane core samples for relative values of 7 beyllum, 234 thorium, and 239 thorium, showing the influence of land input, marine input, and time, respectively. Prior studies on Hurricane Ivan off the Gulf coast of Florida showed an absence of macrofauna and recruitment is delayed until the conditions are again suitable for habitation and growth of the mollusk. Sound as opposed to when it feeds in the bayous, provided within a month at a depth of about 234 cm for at least a year.

Fish parasite populations are altered by this perturbation. Sediments provide an especially good indication of the macrofauna and environmental health. Since all trematodes have a molluscous first intermediate host, the exception of a few infecting blood flukes with polychaete first intermediate hosts, completion of a life cycle can be difficult following any perturbation. When the sediments are perturbed, the first intermediate host may be killed, eliminated, or inhibited from reproducing. The sediments may become altered in such a way that the host can no longer live and recruitment is delayed until the conditions are again conducive for habitation and growth of the mollusk. Even when the host species is re-established, it has to acquire an infection, and the trematode has to undergo annual development to produce infective stages necessary to repopulate the species in the fish host. Depending on the specificity of the digenean specialist and the various hosts in the cycles, repopulation of the digenean can take from several months to several years. The Atlantic croaker, Micropogonias undulatus, uses the estuary as a nursery ground, and its digeneans are followed by the snail-crustacean transmitted monorchiids also started showing up in local fishes. For example, Lasiococcus glebalentris occurred in the striped mullet, Mugil cephalus, and Lecithaster cf. minutum occurred in the Gulf killifish, Fundulus grandis, (from a low salinity clam).

Unlike being transmitted by a buried clam, the adult helminth trematode Lecithaster confusa, adult nematode Spirorchus crystallus from the lenticinestes and the juvenile nematode Heterohalichirius sp. from the myxentestes were probably transmitted to the croaker by copepods. Infestations of these three helminths showed up in croaker during March 2006 as did some presumably copepod-transmitted (or by chaetognath) fish parasitic hosts that fed on infected copepods or other infected hosts) tetraphyllidean juvenile cestodes of several popular croaker (about March 2007, other infected hosts) tetraphyllidean juvenile cestodes in the spot in February 2006. None of these occurred in most collections; most individuals of these two fishes as well as most of the many fish species in inshore Mississippi harbored few if any parasites. Also, helminths that do not incorporate intermediate hosts like the monogenean Macravalvismonostomatae microparasites that reproduce in the pre- and post-hurricane core samples for relative values of 7 beyllum, 234 thorium, and 239 thorium, showing the influence of land input, marine input, and time, respectively.

Seatrouts, fishes related to the croaker, include the spotted seatrout (Cynoscion nebulosus), which spends its entire life in Mississippi Sound and adjacent waters and the sand seatrout (Cynoscion arenarius), which lives in the Sound and offshore from it. They commonly harbor numerous similar parasites, including several trematodes (Blaylock and Overstreet, 2003), most of which are probably acquired near the barrier islands. However, they exhibited no trematode and few other parasites except some cestode juveniles until August 2006, when the spotted seatrout constituted most of the samples and acquired the acanthoclid trematode Prosopocotylus intermedium. By January 2007, the seatrout was infected by the bucephalid Bucephalus cynoscion and Prosopocotylus intermedium, which are transmitted by bivalves followed by fish second intermediate hosts; these infections continued to be prevalent and were followed by the small crustacean transmitted Opecoeloides lumbatus in May 2007. In freshwater fishes, species of Phyllobothrium infected the urinary bladder of August 2006, bivalves, and Fundulus sp. These gutgorderid trematodes were
most likely transmitted from spherical clams burled in the muddy sand and common in the fish hosts before Katrina, but none of the trematodes reappeared until April-May 2007 and then they were rare.

Other freshwater and marine parasites also incorpo- rate members of the Infusina in their life cycles. Hosts other than gastropods and bivalve mollusks can host both digeneans and other parasites, and these, not all Infusina, include but are not limited to a range of crustaceans from mysids to decapods (especially cope- pods, isopods, and amphipods), insects, oligochaetes, echinoderms, chonetids, copepods, amphipods, and other fish species.

Introduction of high salinity water into fresh- water or low salinity habitats

The typical tidal fauna in beaches, marshes, bayous, and lower reaches of the rivers in coastal Mississippi is neither consistent in composition from year to year nor from season to season. The dynamics of variation in temperature, salinity, and other conditions result in considerable variation in the prevalence and abundance of most organisms/inhabitants. When the area receives an abundance of rain and the winter and spring weather fronts cause winds to blow toward the south, then the resulting salinity is low, and the low salinity (e.g., 2-6 ppt) populations of gastropods and bivalves are abundant. The coastal salinity preceding Katrina was low, approximating 5 ppt along the coastal marshes. Katrina brought in a surge of high salinity (perhaps 32 ppt) water. An exceptionally warm year and a subse- quent drought for several months kept salinity in the bayous relatively high (e.g., > 15 ppt through December 2005) as well as caused wide-scale mortal- ities of a large portion of the surviving trees as well as fish from oxygen depletion in restricted areas. This fluctuation in salinity probably influenced biodiversity in these areas more than sediments disruption because of large fish present pre-Katrina. The area receives regular tidewater inundation, which when young pre-Katrina were abundant and conspicuous pre-Katrina. The life cycles of the two common species, Culuvella brunoforsf and Biorugatus fascigerus, have been reduced to the fish and low salinity gastropods. There is no second intermediate host; the metacercariae of both encyst on algae or substrata that the mullet eat. Post-Katrina, but none of the trematodes reappeared until July 2006 and then just in specific locations. A few other species have been seen in low numbers that would have indicated a stressed condition.

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hosts for a variety of bird and mammal heterophyids and a couple of echinostomids. Both the fundulid
Gulf killifish in moderate salinity and the poeciliid western mosquitofish, Gambusia affinis, in freshwater or low salinity were monitored to determine when they started to acquire infections. In June 2006, the Gulf kilifish contained a large juvenile trematode (encysted metacercariae) of Phagocola diminuta and Ascomuctyle angrense, two of the several heterophyid trematodes that normally infect it and were previously identified in large individual fish when first examined after the storm. Most heterophyid metacercariae can remain infective in the killifish for over a year. Also in June 2006, Ascomuctyle tenuicolis and Echinochosmus schwartzii occurred in the mosquitofish. By February and March 2007, budephalid metacercariae were also present in juvenile killifish and Ascomuctyle meintoshi occurred in juvenile mosquitofish. In June 2006, juveniles of the poeciliid salmin mollusc, Poecilia latipinna, exhibited Ascomuctyle leighi and Echinochosmus schwartzii, and the sheepshead minnow, Cyniophis vanegratus, had heavy infections of Ascomuctyle pachystoma. As of now, June 2007, I have seen no other heterophyid post-Katrina in these or other cyprinodontiforms. Few other parasites occurred, but the viviparous Gyrodactylus spp. on the skin and Myxobolus funduli (transmitted by an oligochaete) in gills were common in the Gulf killifish.

In August 2006, in Waveland, Mississippi, where there was less buffering from the barrier islands and most structures were totally destroyed, infections of the cockroach Callops prognathica funduli first occurred as light intensities of unsporulated stages in young Gulf killifish. High intensity of infections occurred where there were sporulated stages in fish present before storm. In August 2006, they also showed up in fish from the east in Hahokin Bayou, a low salinity individual where the live was over 90% involved with unsporulated stages. This parasite uses a grass shrimp as the intermediate host. Few other parasites occurred, but the viviparous Gyrodactylus spp. on the skin and Myxobolus funduli (transmitted by an oligochaete) in gills were common in the Gulf killifish.

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A hurricane such as Katrina also has high winds that produce turbulent mixing in the water column of both volatile and persistent organic and inorganic compounds introduced through spills and through the atmosphere in a poorly understood dynamic (e.g., Juraslo et al. 2007). When one considers the additional rapid dispersion resulting from the surge, there is little way to assess it, especially when no person is in a physical position to determine the immediate concentrations of toxicants or the face and effects contributed by the toxicants. Nevertheless, one can still assume that an enormous quantity of all sorts of persistent pollutants was released from the sediments and much more than that amount of persistent and non-persistent pollutants were introduced. Lack of a published reference data base for fish tissue quality in near-coastal areas of the Gulf of Mexico restricts an assessment of the environmental significance of point source contaminants or general consumption. Lewis et al. (2002), however, has provided levels of inorganic and organic contaminant concentrations in edible tissue of fish collected from eight coastal areas in the northern Gulf of Mexico receiving wastewater discharges and from two reference locations. Some indeterminate amount of the decreased biodiversity of fish parasites results from the effects of the toxicants on the various hosts. The parasites in a sample of 30 histologically sectioned specimen of the western mosquitofish, Gambusia affinis, taken from Back Bay from 12 months post-Katrina were evaluated from a monitoring station continuously contaminated with three heavy metals and various other organic compounds. Some infections were similar to that reported pre-Katrina (Overstreet, 1997) and later, more strongly affected by possible additional compounds, perhaps because ofmixing of the contaminated water and sediments. The high salinity surge water from Katrina appeared to flush out and remove the heavy metal and perhaps affect the freshness of intermediate hosts, at least temporarily, from the habitats. Only one harmful parasite was seen, a metacercarian in the liver of one individual, neither of which was present in earlier samples and both of which were acquired from feeding on crustaceans. Two individuals contained a diplomonad monacaccara that was not seen previously. 80% of the fish showed no parasite in two examined slides per fish compared with 7% of similar pre-Katrina samples. Disruption of seasonal dynamics of host-parasite interactions Infectious stages of parasites typically co-occur seasonally with their susceptible hosts. For example, the haplorid trematodes Culiciguia beauforti and Dicrogaster similigranu discussed above from Mugil cephalus first reappeared in July 2006. No infected fish was seen in most areas until March 2007 but finally absent again until at least June 2007. High prevalence and mean intensity of infections typically occur in the spring, summer, and autumn months. Apparently, infected snails have not become re-established along the coast in the two years following the storm. Perhaps not enough snails were present or infected in the general area, only snails from few specific locations were infected in 2006. Snail populations had not reached their normal levels (we have not seen the snails in some typical locations), or there is some other inconsistency. We experienced low salinity waters in the bayous of 5-8 ppt in January-March of 2006 and 2007, but the snails hosting the above and other trematodes have not returned and some of the higher salinity (e.g., 15 ppt) snail species have become established at low salinities, at least temporarily, and are apparently replacing the low salinity species (Hoard et al., 2002). This shift definitely influences the snail populations. Some parasitic stages live in their intermediate or final hosts for several years. This serves as a good means to maintain a parasite population even though environmental condition might temporarily interrupt the life cycle. In the case where a hurricane eliminates a species rather than reduces it, the cycle could be broken for several years, especially when seasonal salinity and temperature conditions do not mesh synchronous-ly with the parasite stage. Oligochaetae host some myxosporans and nemouridae. Many nubifidids live for a few years and production of infective myxosporan stages is seasonal and, as such, few infections have reappeared. The metacercarian Eustrongyloides grunavi occurs abundantly in fish intermediate and parasitic hosts in specific low salinity localities in Mississippi. The Gulf killifish has been an exceptional host, and some large fish with large worms were seen for about a year after the storm. It has not been seen in any fish that could represent a post-Katrina infection. Captive conditions can stress fish In most cases, facilities which housed fish, whether they were commercial ponds, public displays, research facilities, or personal aquaria, lost all or most of the captive stock. In many cases, the storm washed away both the facilities and inhabitants and in others it flooded them. In all cases, the power was lost and
the remaining fish, if any, died from oxygen depletion over the several-week period. In most places electric-ity was not restored for weeks, and all generators were ruined or inoperable. Perhaps following the storm, restored facilities were more vulnerable. Spotted sciaenids in our Gulf Coast Research Laboratory research culture facility all died during the storm, but the restored fish did acquire an infection of Amyloodinium ocellatum several weeks after being re-established. Whereas this outbreak could not be attributed directly to the hurricane, A. ocellatum in wild fish appeared to be especially prevalent locally (Reg Blaylock, personal communication), making contamination of the systems easy.

In contrast with fishes, most specimens of the bot-tleneck dolphin (Tursiops truncatus) were placed in swimming pools distant from the beach immediately pre-Katrina and not crowded, like fish are in both pro-duction and display facilities. The dolphin remaining in a destroyed local oceanarium swam out to sea but came back after the storm to feed. These dolphins were so well-nourished that they remained healthy and could be cultured. Species richness was greatest, seven, from blowhole isolates, with four from lesions and fil-teps and all, and none from the blood (Kennedy et al., 2006). Most parasites of captive dolphins, such as ciliate protozoa (Dalgleish et al., 2006), apparently do not harm their hosts. Once the dolphins were transferred to less-confined spaces in the Bahamas, their infections apparently cleared.

General aspects

Hurricanes Katrina caused an apparent lack of many parasite species for a long period, at least two years as of this report. A loss of intermediate hosts resulted from lost habitat or altered ecological conditions halted new infections of parasites. However, when a fish undergoes local migratory activity, it can acquire some parasites, producing a lower intensity of infection than typical. The freshwater cestode Bothriocephalus acheilognathi constitutes the only post-Katrina introduction to Gulf waters. Overstreet et al. (2003) report that this parasite becomes restricted to the area of investigation. The cestode maintains the parasite population. Also, when an intermediate host occupies a multitude of habitats or geographic localities, those from one habitat or location can maintain the parasite population. Habitat alterations can support atypical hosts for a specific geographic locality, resulting in different or unexpected parasites.

To properly assess changes in parasite populations after a hurricane, which by definition is a rare event, fish recolonized after the storm, typically young-of-the-year individuals, should be examined for the parasites. Since some parasites, whether adult or juvenile, can survive for several years in a host, attention has to be directed toward the life histories of the parasites used as indicators. Also, migratory fishes entering a perturbed area usually do not show an absence or low number of parasites, unless the host acquires the parasite in the perturbed area and the cycle is restricted to that area of investigation.

Re-establishment of parasites that disappear after a hurricane seems to take one, two, and perhaps a few more years, depending on the species and situation, as indicated by the "short-term-loss" examples provided. When specific substratum that is unique for a specific parasite becomes disturbed, that parasite might be a "long-term-loss" and may require many years to become re-established. Such a long-term loss might also occur when one of the necessary hosts in the parasite cycle is replaced or its population drastically reduced.

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References


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