Effects of the Deep Horizon Oil Spill on Marsh Fishes in the Mississippi River Delta

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Abstract

A central challenge to assessing effects of major environmental disturbances such as the BP Deepwater Horizon Oil Spill (DHOS) is the lack of quantitative distribution and abundance data from prior to the disturbance. This is especially true for species that are not commercially or recreationally harvested and are therefore not regularly monitored by state and federal resource management agencies. Fortunately, we collected quantitative abundance, habitat use, and distribution data for non-game marsh nekton prior to the DHOS as part of a multi-year evaluation of wetland restoration efforts in the Mississippi River delta. To assess ecological response to the DHOS and other disturbances, we revisited five historically monitored sites in Pass-a-Loutre Wildlife Management Area in July 2012 and sampled marsh fishes and invertebrates in adjacent patches of submerged aquatic vegetation, emergent vegetation, and *Phragmites* using a combination of 1-m^2throw traps and minnow traps. Oil and dispersants from the DHOS probably did not directly settle on these locations, so a nearby impact and associated control site were also sampled. Importantly, many of the common nekton (e.g., blue crabs, brown shrimp, speckled worm eels) found in these marshes spend part or all of their lives in the nearby Gulf of Mexico. Our preliminary results indicate that diversity and abundance of nekton in the Mississippi River delta two years following the DHOS are comparable to historical data.

Introduction

The Mississippi River delta is a diverse and complex coastal wetland ecosystem that has been degraded by multiple anthropogenic activities. The Mississippi River delta supports many recreational and commercially important species of nekton and is one of the leading regions of fisheries production in the United States (Herke 1995, Chesney et al. 2000, McCrea-Strub et al. 2011, Sumaila et al. 2012). Vegetated marshes of the Mississippi River delta provide essential habitat for a variety of organisms, ranging from small nekton to wading and migratory birds (Bildstein et al. 1991), and serve as nurseries for many juvenile species (Herke 1995, Castellanos and Rozas 2001). These marshes also act as a buffer from coastal storms and therefore are help reduce loss of wetlands (Zedler and Kercher 2005).

In addition to providing many ecological services, the Mississippi River delta is also one of the top petroleum producing regions in the United States and the region is economically dependent on production and refining of petrochemicals. Unfortunately, fossil fuel exploration and extraction activities have significant negative ecological impacts on coastal wetlands (Ko and Day 2004). Extraction of subsurface fluids increases subsidence of coastal wetlands (Kolker et al. 2011). Locations contaminated with petrochemicals experience significant decreases in both above- and below-ground biomass of *Spartina alterniflora* (Culbertson et al. 2008). Loss of marsh vegetation is significant, not only because of the role it plays as essential habitat, but also because loss of the roots and rhizomes increases the rate of water intrusion into the inter-terrestrial spaces of the substrate and facilitates erosion and wetland loss. Indirect effects of the petrochemical industry include construction of canals and associated spoil-banks that facilitate salt-water intrusion and accelerate wetland loss (Turner 1990). Increased delivery of sediments and accretion can slow and reverse the effects of subsidence, although the positive affects of sediment delivery are limited by the presence of extensive oil and gas canals (Lane et al. 2006).

The effects of petrochemical exploration and extraction activities on Louisiana's abundant coastal fisheries resources are not well understood. Initial fragmentation of coastal marshes dissected with petrochemical canals and spoil banks results in increased edge habitat and a short-term increase in marsh edge dependent species, but these same species will eventually decline as fragmented marsh transitions into open water (Reed et al. 2012). Direct contamination by petrochemicals can lead to mortality of nekton, but more often results in a wide variety of sublethal effects (e.g., de Soysa et al. 2012, Garcia et al. 2012). Depending on their mobility, nekton are able to move in varying degrees away from contaminated sites and then return (as adults or newly recruited larvae) after contaminants are dispersed and degraded (Roth and Baltz 2009). Fisheries in coastal Louisiana have not declined over the past few decades even though exposed to myriad natural and anthropogenic insults, but an additional large-scale environmental disaster could reduce or eliminate this surprising resiliency (Chesney et al. 2000). The 2010 Deepwater Horizon Oil Spill (DHOS) was the largest marine spill ever and many scientists and many natural resource managers (but not all;) hypothesize that it could be the environmental disaster that ends a long period of stability for fisheries resources in coastal Louisiana (McCrea-Strub et al. 2011, Sumaila et al. 2012; but see DeLaune and Wright 2011 for an opposing view).

A central challenge to testing this hypothesis is the availability of long-term monitoring data needed to evaluate changes in absolute and relative abundance of nekton in Louisiana's coastal marshes. Ecological studies that monitor and assess the impact of oil and gas related activities are essential for evaluating the effects of disturbances, such as the DHOS, on already dwindling coastal wetlands. Such studies provide crucial information, critical for restoration, and act as a base from which to make conservation decisions. This study makes use of quantitative abundance, habitat use, and distribution data for nekton collected from marshes in the Mississippi River delta prior (199-2004) to the DHOS. To assess the ecological response of nekton to the DHOS, we re-sampled nekton at historical sampling sites in July 2012. Although historical sites may not have been directly contaminated by the DHOS, these marshes support many species that spend part of their lives in the offshore environment of the Gulf of Mexico that was directly affected. Disruption of larval stages offshore in the Gulf of Mexico could lead to recruitment limitation and reduced abundance in marshes that serve as important nursery habitat.

Methods

Study area – Research was carried out in the Pass-a-Loutre Wildlife Management Area (PALWMA) in the Mississippi River delta south of Venice, Louisiana (Fig. 1). This portion of the Mississippi River delta is characterized by distributaries that deliver water and sediment to highly dynamic wetland splays and bays (White 1993, Boyer 1997) that provide valuable aquatic habitat for nekton. Wetland splays in PALWMA are characterized by relatively shallow emergent marsh (primarily *Sagittaria* spp.), whereas adjacent and deeper bays support extensive and mixed species beds of submerged aquatic vegetation (primarily *Potamogeton nodusus*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Heteranthera dubia*, and filamentous algae). Isolated and large contiguous stands of the emergent common reed (*Phragmites australis*) are another important and spatially extensive aquatic habitat available for use by marsh nekton in PALWMA (White et al. 2004). These stands of common reed are a mixture of native and invasive lineages (Hauber et al. 2011).

Sampling methodology–Five historically monitored sites in the Pass-a-Loutre Wildlife Management Area were revisited in July 2012 (Figure 1). Adjacent submerged aquatic vegetation, emergent marsh, and common reed habitats were located at each site. Nekton in emergent marsh and submerged aquatic vegetation were sampled with 1-m^2 throw traps, whereas nekton in stands of common reed and in adjacent beds of submerged aquatic vegetation were sampled with minnow traps. Selecting a sampling method that efficiently samples target organisms is crucial for the success and accuracy of any ecological study (Rozas and Minelo 1997). Throw traps have several attributes that make them ideal for sampling nekton in marshes. One of these attributes is that no habitat alteration is needed prior to sampling (Rozas and Minello 1997). In addition, throw traps provide accurate estimates of abundance that do not vary with changes in plant stem density (Jordan et al. 1997, Rozas and Minello 1997). Unfortunately, throw traps and other active sampling gears are not readily used in tall and dense stands of common reed and therefore minnow traps were used in this habitat. The downside of minnow traps is that they are a passive sampling gear that samples an unknown area of habitat. The sampling efficacy of minnow traps is not well understood, but they should provide comparable estimates of abundance when sampling similar species in adjacent habitats. Minnow traps provide accurate estimates of topminnows in the genus *Fundulus* (Layman and Smith 2001), which are common in marsh habitats of the Mississippi River delta.

Three throw trap samples were collected haphazardly within each emergent marsh and submerged aquatic vegetation habitat. Throw traps were thrown into a habitat and pressed into the substrate. Water depth and plant canopy height were then measured to the nearest cm. Relative abundance of plant species in the trap was estimated visually and then plants were uprooted, rinsed, and shaken over the trap to dislodge remaining nekton. Plants were placed in a mesh bag, spun to remove excess water, and weighed to the nearest 0.1 kg. A bar seine with 3.0 mm stretch mesh was then passed through the trap until three consecutive clean sweeps were obtained (Jordan et al.1997). Collected nekton were euthanized with MS-222 and preserved in l0% buffered formalin. In the laboratory, nekton were identified to the lowest taxonomic level possible, counted, and measured to the nearest mm standard length (SL) for fishes and total length for large invertebrates. Nekton were also collected from within nearby stands of common reed with minnow traps. Two sets of six un-baited Gee minnow traps (three with 1/4 inch mesh and three with 1/8 inch mesh) were tied to an anchor line 1-m apart from each other and deployed parallel to the edge of the common reed stand. One set was deployed 5 m inside the stand, whereas the other strand was deployed 5 m outside of the stand in submerged aquatic vegetation. Minnow traps were allowed to fish for at least four hours and then nekton were removed and processed as described above.

Our original goal was to use a Before-After-Control-Impact (BACI) study to assess effects of the DHOS on marsh nekton. However, careful inspection and consultation with resource managers at PALWMA indicated that neither oil nor dispersants from the DHOS likely penetrated into our historic sampling sites and we therefore did not have any directly contaminated sites. We instead identified a separate region at the mouth of Pass-a-Loutre that had been heavily contaminated and still had significant amounts of oil adhering to plant stems and buried in sediments. The only vegetated habitat in this region was extensive stands of common reed, so we used minnow traps to sample nekton in common reed at three separate locations within the contaminated region. The contaminated area was far removed from our historic sites, immediately adjacent to the open Gulf of Mexico, and had much higher salinities. We therefore selected similar common reed beds about 2 km away and that had not been directly exposed to oil from the DHOC to serve as controls. Minnow trap sampling was conducted the same as described above, except no traps were fished outside of the stands of common reed.

For this report, we compared the average density of all nekton, average biomass of all nekton, average number of species, and average density of numerically dominant nekton species collected with throw traps from adjacent emergent marsh and submerged aquatic vegetation habitats from the before (1999-2004) and after (July 2012) periods. Full linear models including sampling periods, habitats, and interactions were analyzed, but only results of a planned contrast are reported herein. Further, these contrasts only included samples collected during summer months in the before and after periods in order to avoid confounding seasonal variation with any variation associated with the effect of disturbances that occurred between 2004 and 2012. Importantly, although our focus is on the effects of the DHOC, we recognize that multiple cyclonic disturbances (including Hurricanes Katrina and Rita) occurred during the interim period. Our tests are therefore assessing the resiliency of Mississippi River delta to multiple anthropogenic and natural potential stressors.

Results

Note that these results are preliminary and future analyses will more fully describe observed changes in nekton between sampling periods and between habitats. Future analyses will also include minnow trap data. Overall species richness per trap increased significantly and average biomass of all nekton and average density of all fishes increased marginally post disturbance (Fig. 2). Average density of all invertebrates appeared to increase, but the change was not statistically significant (Fig. 2). Average densities of commercially important species of nekton such as blue crabs, brown shrimp, and white shrimp increased significantly post disturbance (Fig. 3). Other marine dependent-species such as lyre gobies and spiny check sleepers also displayed a significant increase in abundance post disturbance (Fig. 3). In contrast, average density of freshwater invertebrates, such as damselfly larvae and river shrimp, decreased significantly following disturbance (Fig. 3).

Discussion

Our preliminary results indicate that wetlands in the Mississippi River delta have not suffered long-term declines in the abundance of most species of nekton and suggest that there are no lasting effects of the DHOS or other disturbances on marsh nekton in the Mississippi River delta. This finding of resilience is consistent with the prediction of DeLaune and Wright (2011), who observed that Gulf Coast marshes have a high potential for natural recovery following contamination with oil and dispersants. Coastal fishes in Louisiana appear to be resilient to a broad range of environmental stresses (Chesney et al. 2000) and rapidly re-colonize contaminated sites after exposure to oil (Roth and Baltz 2009). Terrestrial and marine arthropods in salt marshes responded negatively to contamination from the DHOS, but recovered to reference levels within about a year (McCall and Pennings 2012). Diversity, abundance, and recruitment of fishes in seagrass beds in Alabama did not show any short-term changes in response to the DHOS (Fodrie and Heck 2011). The general consensus is that, although oil contamination has demonstrable short-term effects on physiological systems (e.g., de Soysa et al. 2012, Garcia et al. 2012), nekton are able to re-colonize contaminated sites by fleeing and either returning or being replaced by new cohorts of larvae and dispersing juveniles and adults (Roth and Baltz 2009). One important caveat to these findings is that fishes and other types of highly mobile nekton may not be the best indicators of environmental stress in coastal systems (Ellis and Bell 2013).

Oil and dispersants do have strong negative effects on plants that provide essential habitats for marsh nekton, but once again these effects appear to be transient and marsh plants tend to recover at species-specific rates (Li and Mendelssohn 2012, Silliman et al. 2012). Degradation of contaminants and recovery of plants may have taken substantially longer if most of the coastal wetlands were not growing in highly organic soils (Mortazavi et al. 2012). A long-term problem for marsh plants may be that they are contending with multiple environmental stressors such as increasing air and water temperatures, increasing sea levels, subsiding sediments, competition with invasive species, and contamination. Short-term recovery may not translate into long-term resilience as Louisiana's coastline continues to recede at an alarming rate. As described earlier, nekton abundance may increase as coastal marshes enter into the fragmentation stage, but will likely decrease as these marshes transition into open water (Reed et al. 2012). Separating long-term negative effects associated with contamination from the DHOS from other disturbances will present a challenge to environmental scientists (Mendelssohn et al. 2012).

The observed increase in the abundance of several commercially important species of crustaceans may be attributed to several factors. First, the Mississippi River experienced unusually low discharge rates during 2012 due to an extensive and historical drought affecting much of the drainage basin. Low discharge rates resulted in increased salinities over a prolonged period and likely created an osmotic environment more favorable to blue crabs, brown shrimp, and white shrimp and less favorable to damselfly larvae and river shrimp. Regardless, these marine-dependent species recruited larvae from areas that were directly and heavily affected by oil and dispersants associated with the DHOS.

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Figure 1: Study area in the Mississippi River delta. Black dots indicate historical nekton monitoring sites, yellow dots indicate historical sites re-sampled in 2012, and red dots are impact and control common reed sites where additional minnow trap sampling was performed.

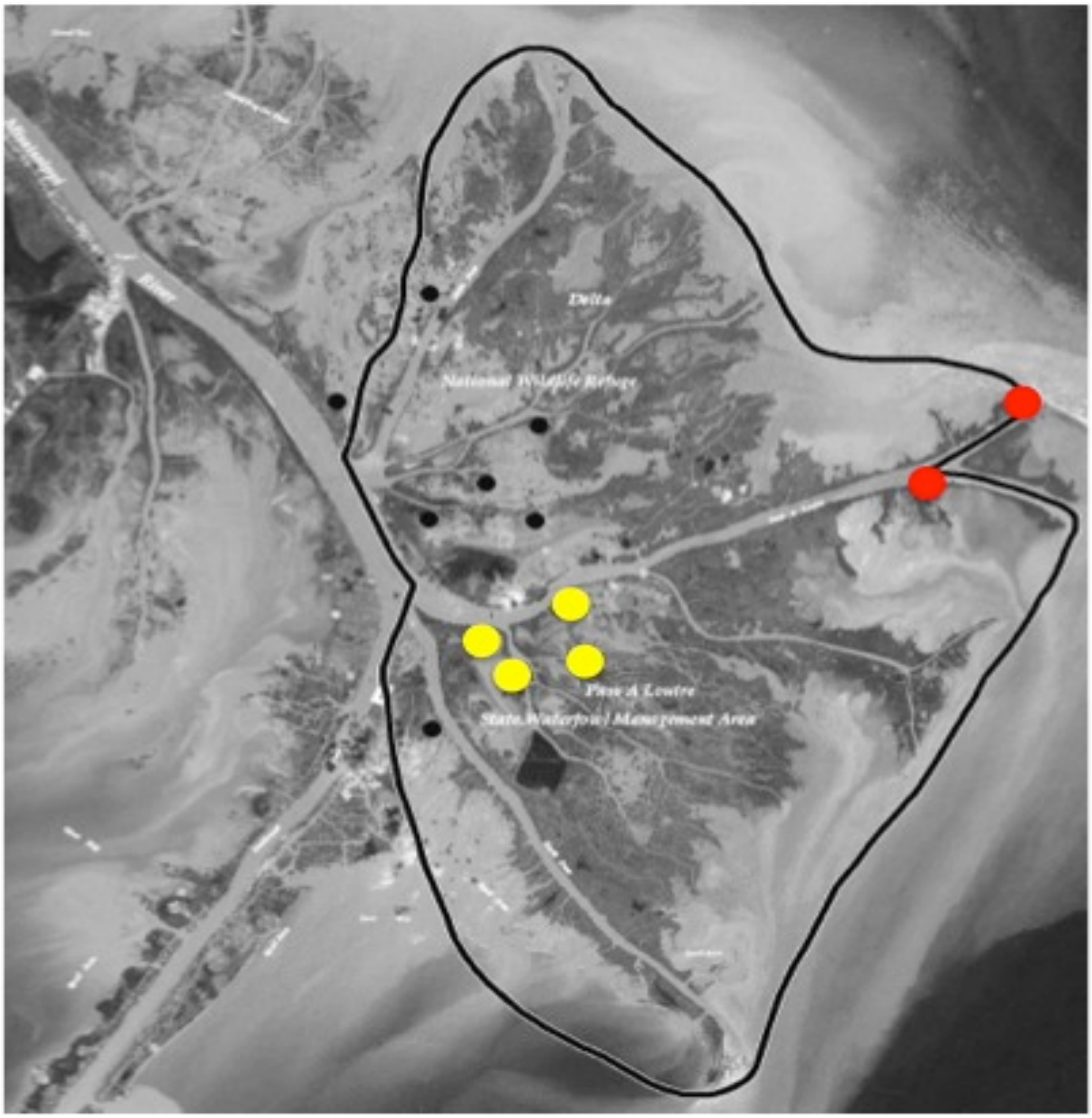

Figure 2: Mean (+ 1 SE) species richness, biomass, total fish density, and total invertebrates density per m^2 before and after the DHOS. Significant ($P<0.05$) increases are denoted by upward red arrows and significant decreases by downward red arrows, whereas marginally significant ($P<0.10$) increases and decreases are denoted by upward and downward yellow arrows, respectively.

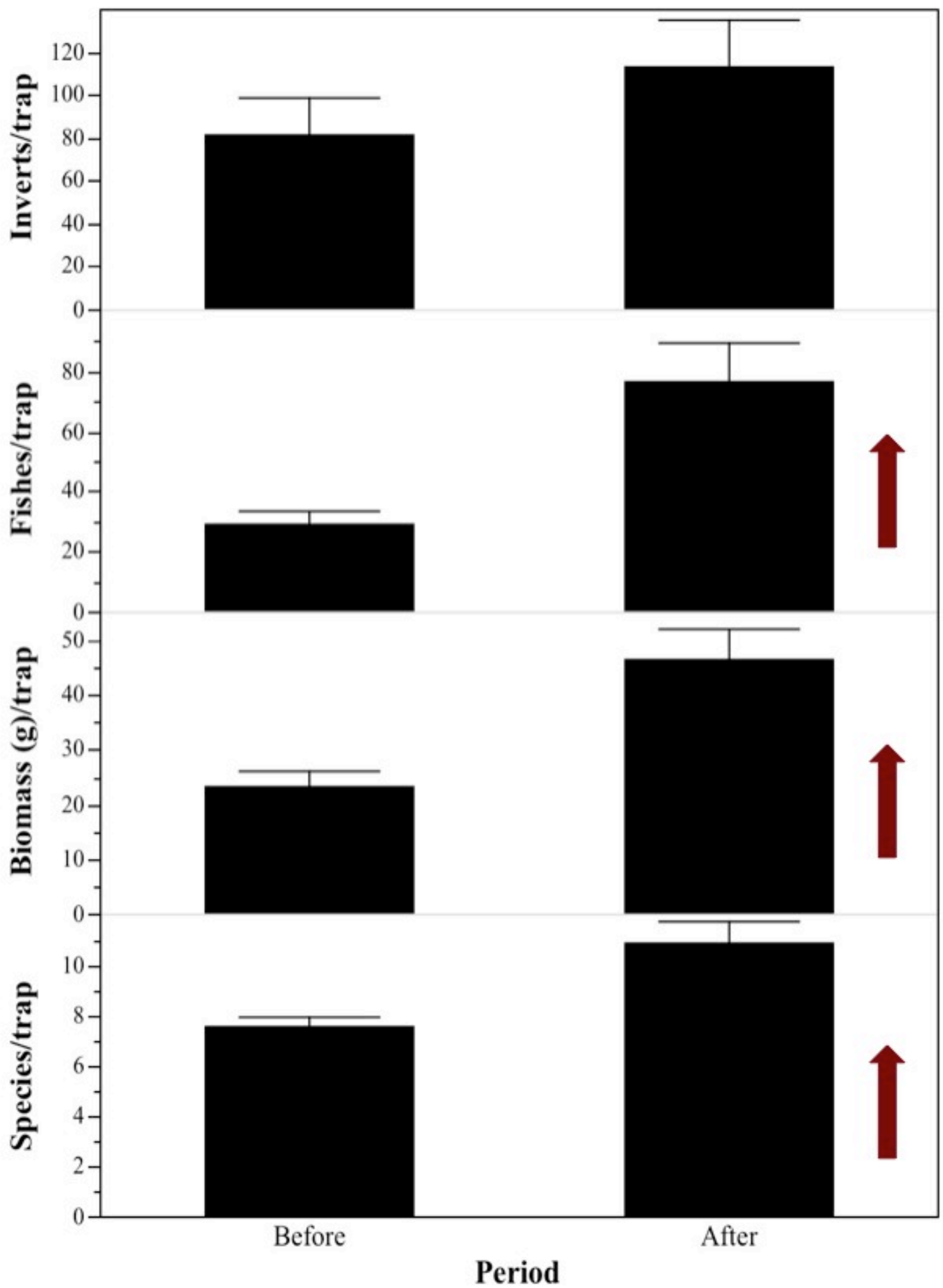

Figure 3: Mean (+1 SE) densities per m^2 numerically important species of nekton during past and present summer sampling periods. The most recent and post DHOS summer sampling period is highlighted by a red box. Dark bars represent nekton abundance in emergent marsh habitat, whereas grey bars represent nekton abundance in submerged aquatic vegetation habitats. Arrows denote significance as described in Fig. 2.